A MYCLE SCHNEIDER CONSULTING PROJECT
Paris, London, Washington, D.C., July 2014

THE WORLD NUCLEAR INDUSTRY STATUS REPORT 2014

BY Mycle Schneider
Antony Froggatt

WITH Yurika Ayukawa
Shaun Burnie
Raffaele Piria
Steve Thomas
Julie Hazemann

FOREWORD Tatsujiro Suzuki

V4

HEINRICH BÖLL STIFTUNG
The Green Political Foundation

SCHWEIZERISCHE ENERGIE-STIFTUNG
FONDATION SUISSE DE L'ENERGIE
SES

Fred & Alice Stanback

The World Nuclear Industry Status Report 2014

By

Mycle Schneider
Independent Consultant, Paris, France
Project Coordinator and Lead Author

Antony Froggatt
Independent Consultant, London, U.K.
Lead Author

With

Yurika Ayukawa
Professor for Environment & Energy Policy, Chiba University of Commerce, Japan
Contributing Author

Shaun Burnie
Independent Consultant, Hamburg, Germany
Contributing Author

Raffaele Piria
Independent Consultant, Berlin, Germany
Contributing Author

Steve Thomas
Professor for Energy Policy, Greenwich University, U.K.
Contributing Author

Julie Hazemann
Director of EnerWebWatch, Paris, France
Documentary Research, Modeling and Graphic Design

Foreword by Tatsujiro Suzuki
Former Vice-Chairman of the Japan Atomic Energy Commission

Paris, London, Washington, D.C., July 2014

A MYCLE SCHNEIDER CONSULTING PROJECT

Cover page created by Noëlle Papay

Acknowledgments

The project coordinator wishes to thank his colleague and main co-author Antony Froggatt for his continuous solid contribution to this project. A big thanks to contributing authors Steve Thomas, Yurika Ayukawa, Raffaele Piria and Shaun Burnie for their creative special contributions to this report and their patience with me. The project would not be possible without Julie Hazemann's countless hours of work on the core database and the graphic illustrations. Thank you.

A special thank you to Tatsujiro Suzuki for his thoughtful foreword.

Many other people have contributed pieces of work to make this project possible and bring it to the current standard. These include in particular Fraunhofer's ISE that has contributed a number of enlightening graphic illustrations on the German electricity system and Nuclear Engineering International that provided the nuclear load factor statistics.

The report has greatly benefitted from partial or full proof-reading, editing suggestions and comments by Amory B. Lovins, Walt Patterson, M.V. Ramana, Doug Koplow, Paul Jobin, Sabine von Stockar. I'm grateful to my daughter Nina Schneider who served as an effective all-round verifier.

Thank you all.

The authors wish to thank in particular Fred & Alice Stanback, Amory B. Lovins, Rocky Mountain Institute, Rebecca Harms, the Greens-EFA Group in the European Parliament, Rebecca Bertram, Heinrich Böll Foundation U.S., Sabine von Stockar, the Swiss Renewable Energy Foundation, Hermann Hatzfeldt, Hatzfeldt Foundation, for their generous continued support for this project.

A big thank you to Philippe Rivière for his reliable work on the website and his generous assistance at any time of the day as well as to Noëlle Papay who has created the well-thought special cover page 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.

Lead Authors' Contacts

Mycle Schneider
45, allée des deux cèdres
91210 Draveil (Paris)
France
Phone: +33-1-69 83 23 79
Email: mycle@orange.fr

Antony Froggatt
53a Nevill Road
London N16 8SW
United Kingdom
Ph: +44-79 68 80 52 99
E: a.froggatt@btinternet.com

The World Nuclear Industry Status Report 2014

Table of Contents

Foreword

By **Tatsujiro Suzuki***

"What will be the impact of the Fukushima nuclear accident on the global nuclear industry?" This is the question that I have been asked many times since March 11, 2011. The answer is, of course, "no one really knows." But, it is an unavoidable question that needs to be explored, even though we cannot predict the future. More than three years later, we hear both positive and negative views on the future of nuclear industry. But, I believe those voices are mostly based on their "wishful thinking" and not necessarily the result of detailed analysis of the current situation. Without deeper understanding of what happened in the past and of what is happening now, a wise decision for the future action cannot be made.

The World Nuclear Industry Status Report (WNISR) 2014 is a perfect reference for that purpose. There are other authoritative references on the global nuclear energy situation, such as the ones by the International Atomic Energy Agency (IAEA) and the World Nuclear Association (WNA) etc., or some dark projections are made by citizen organizations against nuclear energy. All reports are useful, of course, but it is critically important to understand the past and current situations *without bias* for a healthy public policy debate. Unfortunately, not only policy makers but also the general public are confused by arguments and ideologies imposed by both pro-and anti-nuclear organizations. This is not healthy. Now we have *The World Nuclear Industry Status Report 2014,* which is, I believe, at least one of such "reliable, unbiased, and trusted" information sources.

One important innovation that *The World Nuclear Industry Status Report* made this year is to establish a new category, called "Long Term Outage (LTO)." Its definition is very clear and empirical: "A nuclear power reactor is considered in LTO if it has not generated any power in the entire previous calendar year and in the first semester of the current calendar year." I believe this simple new category can bring new insights into the nuclear energy policy debate as it can reflect the actual situation more accurately than previously discussed. Thanks to the new category of LTO, now we realize that the impact of the Fukushima Daiichi nuclear accident has been already significant. This is also important as it excludes any "biased" observation on the status of the global nuclear industry. I congratulate the authors of *The World Nuclear Industry Status Report 2014* for creating such a simple, but very significant, innovative category of reactor status.

Another important contribution that *The World Nuclear Industry Status Report 2014* makes is to illustrate the clear trend of the declining share of nuclear energy in the world's power production. It says: "*The nuclear share in the world's power generation declined steadily from a historic peak of 17.6 percent in 1996 to 10.8 percent in 2013*." In fact, the WNISR in previous years already highlighted this trend, and I learned a lot from the impressive, detailed assessment of "new construction vs shutdown" statistics. Although experts familiar with the nuclear industry are aware that such trends could be confirmed—as the average age of existing nuclear plants get older in the last decade—the expectation of and media reporting about a "Nuclear Renaissance" obscured such concerns. In fact, this may be the biggest difference between the impacts of the Fukushima accident and the impacts of previous most serious nuclear accidents, i.e. Three Mile Island (TMI) and Chernobyl. In case of the latter two accidents, which happened in 1979 and 1986 respectively, the average age of nuclear reactors in the world was relatively low, and thus nuclear power generation continued to increase due to improved capacity factors even without many new construction projects. But, now as the average age of nuclear reactors are getting higher (now 28.5 years), more than 200 reactors may face shutdown in the coming two decades. Thus, if new construction pace does not match the pace of shutdown, it is clear that the nuclear share will decline rapidly. Even some IAEA and OECD/IEA projections suggest similar trends (a declining nuclear share), but *The World Nuclear Industry Status Report 2014* demonstrates this tendency most clearly and all energy/environmental experts should be aware of this fact, regardless of their position on nuclear energy.

Finally, let me conclude this Foreword by sending out my personal message. Even over three years after the accident, people who were forced to evacuate from their homeland have not recovered their life back. Their anger, frustration, anxiety and fear of radiation risk have not disappeared. I myself, as a nuclear energy expert and as one of the government officials then, would like to express sincere apologies and sympathy with those people. By talking with evacuated citizens face-to-face, I learned that logical explanation of radiological risk is not enough. The most important factor in human relationship is "trust", which is lost completely after the Fukushima nuclear accident. In order to recover trust, policy must be designed not only based on "logic" but also on "humanity", i.e. sharing the feeling with the victims of the accident and other citizens who are concerned about future accident risks of nuclear power plants. Without the attitude of sharing the hard feelings of the victims of the accident, it is difficult to recover public trust. The future fate of the nuclear industry can depend on how much we will learn from this accident and how much we recover public trust. In this sense, it is important to share accurate information with complete transparency.

I sincerely believe that *The World Nuclear Industry Status Report 2014* can be a good reference for anyone who is interested in nuclear energy and understand the reality of the global nuclear industry more accurately without bias. The report will definitely contribute to improve transparency of the policy debate over nuclear energy.

---

*Tatsujiro Suzuki is Vice Director and a Professor of the Research Center for Nuclear Weapons Abolition (RECNA), Nagasaki University, Japan. Until the end of March 2014, he was Vice Chairman of the Japan Atomic Energy Commission (JAEC).

Executive Summary and Conclusions

The *World Nuclear Industry Status Report 2014* 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. A 20-page chapter on nuclear economics looks at the rapidly changing market conditions for nuclear power plants, whether operating, under construction, or in the planning stage. Reactor vendor strategies and the "Hinkley Point C Deal" are analyzed in particular. The performance on financial markets of major utilities is documented.

The WNISR2013 featured for the first time a Fukushima Status Report that triggered widespread media and analyst attention. The 2014 edition entirely updates that Fukushima chapter.

The Nuclear Power vs. Renewable Energy chapter that provides comparative data on investment, capacity, and generation has been greatly extended by a section on system issues. How does nuclear power perform in systems with high renewable energy share? Is this the end of traditional base-load/peak-load concepts?

Finally, the 45-page Annex 1 provides a country-by-country overview of all 31 countries operating nuclear power plants, with extended Focus sections on China, Japan, and the United States.

Operation and Construction Data (1 July 2014)[1]

Operation. There are 31 countries operating nuclear power plants in the world.[2] A total of 388 reactors have a combined installed capacity of 333 GW[3]. Only two Japanese units (Ohi-3 and -4) have generated power in 2013 and WNISR classifies 43 reactors[4] as being in Long-Term Outage (LTO).[5] Besides the Japanese reactors, one Indian and one South Korean reactor meet the LTO criteria. Ten reactors at Fukushima Daiichi and Daini are considered closed permanently, and are therefore not included in the count of operating nuclear power plants. As of the middle of July 2014, it appears likely that at the most two reactors (Sendai-1 and -2 in Kyushu Prefecture) will restart before the end of the year.

The nuclear industry is in decline: The 388 operating reactors are 50 fewer than the peak in 2002, while the total installed capacity peaked in 2010 at 367 GW before declining to the current level, which is comparable to levels last seen two decades ago. Annual nuclear electricity generation reached a maximum of 2,660 TWh in 2006 and dropped to 2,359 TWh in 2013, which represents however a stabilization (+0.6 percent) after two consecutive years of significant decline (-4 percent in 2011, -7 percent in 2012), corresponding to a level previously seen in 1999.

The nuclear share of the world's power generation declined steadily from a historic peak of 17.6 percent in 1996[6] to 10.8 percent in 2013[7]. Nuclear power's share of global commercial primary energy production declined from the 2012 low of 4.5 percent, a level last seen in 1984[8], to a new low of 4.4 percent.[9]

---

[1] See Annex 7 for a country-by-country overview of reactors in operation and under construction as well as the nuclear share in electricity generation and primary energy.

[2] Unless otherwise noted, the figures indicated are as of 1 July 2014.

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

[4] Including the Monju reactor, shut down since 1995, listed under "Long Term Shutdown" in the IAEA-PRIS database.

[5] WNISR considers that a unit enters the LTO period—once it is meeting the criteria of zero power production in the previous calendar year and in the first half of the current calendar year—from the day it is disconnected from the grid. WNISR counts the startup of a reactor from the day of grid connection and the shutdown from grid disconnection. This is the first year that WNISR has adopted the LTO category trying to provide an alternative for an increasingly misleading representation of the industrial reality in world nuclear statistics provided by other sources. Besides the Japanese reactors, one Indian and one South Korean reactor meet the LTO criteria.

[6] Readjustment from the figure of 17 percent in 1993 in previous editions of the WNISR. See Figure 1 and related footnote.

[7] WNISR2013 indicated a 10.4 percent share for year 2012. However, the adjusted figure for that year is 10.9 percent. In other words, the nuclear share remained stable (-0.1 percentage points).

[8] According to BP, "Statistical Review of World Energy", June 2014.

[9] Ibidem.

As in 2012, the "big five" nuclear generating countries—by rank, the United States, France, Russia, South Korea and China—generated 68 percent of the world's nuclear electricity in 2013. And, as in 2012, only one country, the Czech Republic, reached its record nuclear contribution to the national electricity mix in 2013.

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 increase and by mid-2014 stood at 28.5 years. Over 170 units (44 percent of the total) have operated for 30 years or more; of those units, including 39 that have run for over 40 years.

Construction. As one year earlier, fourteen countries are currently building nuclear power plants. With Belarus, a new country was added to the countries engaged in nuclear projects, while Taiwan has halted construction work at two units. As of July 2014, 67 reactors were under construction (one more than in July 2013) with a total capacity of 64 GW. The average building time of the units under construction stands at 7 years. However:

- Eight reactors have been listed as "under construction" for more than 20 years, another for 12 years.
- At least 49 have encountered construction delays, most of them significant (several months to several years). For the first time, major delays—several months to over two years—have been admitted on three quarters (21/28) of the construction projects in China.
- For the remaining 18 reactor units, either construction began within the past five years or the reactors have not yet reached projected start-up dates, making it difficult or impossible to assess whether they are on schedule or not.
- Two-thirds (43) of the units under construction are located in three countries: China, India and Russia.

The average construction time of the last 37 units that started up in nine countries since 2004 was 10 years with a large range from 3.8 to 36.3 years.

Twenty-eight years after the Chernobyl disaster, none of the next generation or so-called Generation III or III+ has entered service with construction projects in Finland and France many years behind schedule.

Reactor Status and Nuclear Programs

- **Startups and Shutdowns.** In 2013, four reactors started up (3 in China, 1 in India), while one was shut down (in the U.S.).[10] In the first half of 2014, two started up (1 each in China and Argentina) and none were closed.
- **Newcomer Program Delays.** Delays have occurred in the development of the nuclear programs for most of the more advanced potential newcomer countries, including Bangladesh, Jordan, Lithuania, Poland, Saudi Arabia, Turkey, and Vietnam.

Construction & New Build Issues

- **Construction Starts.** In 2013, construction began on 10 reactors, including 4 units on two sites in the US, a first in 35 years. In the first half of 2014, a second unit got underway in Belarus and work started on a small 25-MW pilot plant in Argentina.
- **Construction Halt.** In Taiwan, construction on two units (Lungmen-1 and -2), which had been under construction for the past 15 years has been halted.
- **Certification Delays.** The certification of new reactor designs encounters continuous obstacles. In the U.S., the Nuclear Regulatory Commission (NRC) first delayed to 2015 the certification of the Franco-German-designed EP[11]and now no longer projects any completion date for the review. The NRC rejected the license application for the South Korean APR1400 due to lack of information in key areas. Only the Westinghouse AP1000 has received full generic design approval in the U.S. There is no projected completion date for the renewal of the certification for the two versions of the ABWR (GE-Hitachi and Toshiba).
- **Construction Start Delays.** Various countries' construction starts were delayed, including in Vietnam, previously considered to feature one of the most advanced potential newcomer projects.

---

[10] Shutdown is defined as definitively taken off the grid. The shutdown date is the last day when the reactor generated electricity.

[11] European Pressurized Water Reactor (in Europe) or Evolutionary Pressurized Water Reactor (in the U.S. and elsewhere).

- **Project Delays and Cancellations.** Over the past few years, numerous nuclear projects have been indefinitely delayed or cancelled. The most recent is the call for tender for two new units at the Czech Temelin site that was simply withdrawn in April 2014, officially due to low electricity prices and a lack of government guarantees.

Economics and Finances

- **Capital Cost Increases.** Construction costs are a key determinant of the final nuclear electricity generating costs and many projects are significantly over budget. Investment cost estimates have increased in the past decade or so from US$1,000 to around US$8,000 per installed kilowatt. The latter, record figure is for the two EPRs at Hinkley Point in the U.K. Construction cost estimates increased in virtually all countries, including China, Finland, France, and the United Arab Emirates. In the U.S., the builder of two units at the VC Summer site in South Carolina has asked for the seventh price increase since 2009 to meet rising costs. The analogous Vogtle project in Georgia has reported modest cost increases but the project's independent construction monitor has expressed concern these may be understated.
- **State Aid.** The U.K. model of Contract for Difference (CFD), a kind of feed-in tariff agreement for nuclear electricity that is aimed at providing a subsidy scheme for new-build, is likely to violate current EU competition rules. In February 2014, the EU Commission opened a formal enquiry considering "at this stage that the notified measures involves State Aid", the result of which, as of July 2014, had not been announced but it is likely that significant modifications will need to be made to the financial model of the project for it to proceed.
- **Operating Cost Increases.** In some countries (including France, Germany, the U.S. and Sweden), historically low inflation-adjusted operating costs—especially for major repairs—have escalated so rapidly that the average reactor's operating cost is barely below, or even exceeds, the normal band of wholesale power prices. The largest nuclear operator in the world, the French state-controlled utility EDF experienced an income deficit of about €1.5 billion (US$2 billion) in 2012, because tariffs did not cover the running costs. According to the French Court of Accounts, the cost of generating nuclear power increased by 21 percent between 2010 and 2013, from 49.6 €/MWh to 59.8 €/MWh (US$67.8–81.7/MWh) , an increase of 16 percent in real terms). In Germany, operator E.ON decided to close one of its reactors seven months earlier than required by law because of projected income does not cover the costs. In Sweden, income from electricity sales for at least three reactors was below production costs in two of the past four years. In the U.S., utilities decided to retire at least five reactors that no longer cover operating costs, including two with operating licenses valid beyond 2030. One study identifies up to 38 U.S. units threatened by the same fate. In Belgium, operator Electrabel (GDF-Suez) lost its legal case against a nuclear fuel tax and wonders whether future operation of its seven plants is still worthwhile.
- **Life Extension.** The extension of operating periods beyond original design basis is handled differently from country to country. While in the U.S. about three quarters of the reactors have already received licenses extensions for up to a total lifetime of 60 years, in France, only 10-year extensions are granted and the safety authorities made it clear that there is no guarantee that all units will pass the 40-year in-depth examinations. According to one assessment, the costs for upgrading the plants for operating beyond 40 years could vary between €1 billion and €4 billion (US$1.4–5.5 billion) *per reactor*. Furthermore, the proposals for lifetime extensions appear in conflict with the French government's target to reduce the nuclear share from the current three quarters to half by 2025.
- **Post-Fukushima Costs.** Additional costs arising from upgrading and backfitting measures following the lessons of the Fukushima crisis remain uncertain and vary widely according to the requirements of the safety authorities in various countries. At least in some countries, including Japan and France, they will significantly affect the economic competitiveness of nuclear power.
- **Income and Debt.** In 2013, for the first time in its 60-year history, German utility RWE filed a loss of €2.8 billion (US$3.8 billion) after writing down the value of its conventional power plants by close to €5 billion (US$6.8 billion). Debt level remains very high amongst the European nuclear utilities. The two largest French groups (EDF and GDF-Suez) and the two largest German utilities (E.ON and RWE) share about equally a total of more than €127 billion (US$173 billion) in debt.
- **Credit Rating.** Over the past year, few changes were observed in the credit ratings of 11 assessed nuclear utilities: GDF-Suez was downgraded by credit-rating agency Standard

and Poor's from A to BBB+, while for Finish utility and EPR builder TVO, the outlook changed to negative. Moody's perceived Czech utility CEZ's decision to abandon a new-build project as "credit positive" and considers nuclear construction projects generally as "credit negative".

- **Share Value.** Since 2008, Europe's top ten utilities lost half of their €1 trillion (US$1.4 trillion) share value. A regional comparison shows Asian utilities have recovered little with their average share value still almost half of the 2008 value, European utilities still 30 percent down, while U.S. utilities are almost 30 percent *above* the level of five years ago even though total U.S. electricity use has been drifting down since 2007.

Fukushima Status Report

This assessment includes analyses of on-site and off-site challenges that have arisen from the 3/11 disaster and remain significant three years after the beginning of the disaster.

• **On-site Challenges.** In a highly positive development, since November 2013 and as of the middle of July 2014, over three quarters of the spent fuel had been transferred from the pool in the badly damaged unit 4 to a common pool. The operation is to be completed by the end of 2014. This significantly reduces the radioactive inventory exposed to possible further degradation (draining of the pool, spent fuel fire), especially in the event of additional severe earthquakes or weather events.

The main parameters, however, remain largely unchanged from the previous year. Radiation readings inside the reactor buildings of units 1–3 continue to make direct human intervention almost impossible. Massive amounts of water, about 360 tons per day, are still pumped into the destroyed reactors to cool the molten fuel. This water, as well as a similar quantity of groundwater, seeps into the basements of the reactor buildings, some of it is decontaminated to some degree and then re-injected. The amount of radioactive water that cannot be re-used is constantly increasing and, as of 15 July 2014, exceeds 500,000 tons in precarious storage including about 90,000 tons sitting in the power plant basements. Tank storage capacity is to be increased to 800,000 tons by the end of March 2015. Numerous leaks have been reported, including the discovery in August 2013 of a 300-ton leak from a tank of highly radioactive water[12], rated Level 3 on the International Nuclear Event Scale (INES), and a 100-ton leak from another tank with even higher activity levels.[13] It turned out that hundreds of 1,000-m^3 storage tanks had not even been equipped with volume gauges. Several hundred tanks that were simply bolted together will be replaced by welded containers. Sophisticated water decontamination systems remain plagued with technical failures and have yet to operate continuously for any significant length of time. A much advertised US$0.5 billion underground ice-wall, designed to avoid water influx into the reactor basements and to be completed by March 2015, has an uncertain future. A short test section failed to freeze as anticipated. In the meantime, TEPCO has reached an agreement with local fishermens' unions, allowing for a groundwater bypass to be activated in April 2014, to allow discharge into the sea. It is expected that the measure could reduce the water intrusion into the basements by a one quarter or some 100 m^3 per day.

Around 32,000 workers, 28,000 of whom are subcontractors, have worked at the Fukushima site since 3/11 (not including firemen, policemen, military). By May 2014, the daily average of on-site workers was 4,200, up 40 percent from a year earlier. Recruitment is becoming increasingly difficult.

In December 2013, TEPCO formally announced the shutdown of Fukushima Daiichi (I) Units 5 and 6. The four reactors at Fukushima Daini (II), 15 km from the Daiichi site inside the exclusion zone remain officially "operational", but operating them appears entirely unrealistic.

• **Off-site Challenges.** Officially, as of March 2014, more than 130,000 people in Fukushima Prefecture are still evacuated. About 100,000 people are from designated evacuation zones. Many more people have voluntarily left. Another 137,000 people is still living in temporary housing spread out over seven or more prefectures. About 1,700 deaths have been officially recognized as linked to mental causes or lack of medical care triggered by the nuclear disaster and ensuing evacuation. Suicide rates are on the rise.

In April 2014, a few hundred residents were allowed for the first time to return to a previously evacuated region. However, it is estimated that only about one-fourth of the residents returned. Others commute from evacuation residences outside the area. A government-commissioned study, hidden from the public for six months, concluded that radiation exposure, while remaining below the

[12] 80 million Bq per liter of Beta radiation emitting radionuclides (strontium, tritium…) and 100,000 Bq/l of Cesium-137.

[13] 230 million Bq/l of Beta emitters and 9,300 Bq/l of Cesium-137.

post-emergency level of 20 mSv per year, could exceed the pre-disaster limit of 1 mSv per year in the areas cleared for resident to return.

A total of 101 municipalities in eight prefectures were designated as a "Scheduled Contamination Survey Zone", where annual doses between 1 mSv and 20 mSv are predicted and local authorities are responsible for decontamination work. In addition, the central government is in charge of decontamination efforts in 11 municipalities in Fukushima Prefecture covering 235 km^2, where annual doses exceed 20 mSv. Decontamination efforts are far behind schedule, mainly because of technical difficulties, lack of waste storage facilities and shortage of manpower. Disputes over cost coverage between the Ministry of Environment, which is officially responsible, and TEPCO, the Fukushima operator, lead to additional delays. The three-year decontamination budget for 2011-2013 totaled ¥1.3 trillion (US$13 billion), but just a third has been spent and of that TEPCO reimbursed less than 20 percent. A complex variety of companies and subcontractors is at work, often under obscure circumstances. Press agency *Reuters* has identified 733 companies working under Ministry of Environment contract with 56 subcontractors, some of which are reported to specifically recruit homeless people for work in contaminated areas. The Yakuza, the Japanese mafia, also has reportedly entered the system.

As of 11 July 2014, more than 2.2 million compensation claims had been filed by individuals, corporations, trade unions, and local governments, of which TEPCO has paid ¥4 trillion (US$40 billion) in total settling around 2 million claims. Numerous law suits against TEPCO are underway, including one filed by a group of U.S. sailors, exposed to radiation in emergency U.S. Navy operations right after 3/11. In March 2014, over 4,000 citizens from 39 countries filed a collective (class action) lawsuit against nuclear manufacturers, including Hitachi, Toshiba and General Electric to pay compensation to the victims of the Fukushima nuclear disaster.

Nuclear Power vs. Renewable Energy Deployment

The year 2013 brought a number of new developments that widened the gap between nuclear power and renewable energy costs and market trends.

- **Investment.** Global investment in renewable energy totaled US$214 billion in 2013, decreasing for the second year in a row, down from a record US$300 billion in 2011, but still four times the 2004 amount. The decrease, however, was four-fifth due to lower costs and only one-fifth due to lower sales As in 2012, with US$54.2 billion spent, China has been the largest investor. Some of the past large investors showed sharp declines in expenditures over the previous year, like Italy (-76 percent), Germany (-57 percent) and the U.S. (-23 percent). On the other side, some countries increased investments significantly with Japan (+75 percent) advancing to the third position, the U.K. (+46 percent) taking rank four, and newcomer Australia entering the Top Ten for the first time. Also, decreasing amounts pay for more installed capacity as system costs continue to decrease. Regional analysis reveals that over the past decade Europe spent 40 percent of the US$1.6 trillion total investment, while China alone holds a 20 percent share. According to a new assessment by the OECD's International Energy Agency, during 2000-13 global investment in power plants was split between renewables (57 percent), fossil fuels (40 percent) and nuclear power (3 percent).
- **Installed Capacity.** Globally, since 2000, the annual growth rates for wind power have averaged 25 percent and for solar photovoltaics 43 percent. This has resulted in 2013 alone in 32 GW of wind and 37 GW of solar being added. Nuclear generating capacity declined by 19 GW compared to the 2000 level.[14] In the European Union, in the same time frame, wind increased by 105 GW outpacing natural gas plants with 103 GW and solar with 80 GW, while nuclear decreased by 13 GW. In 2013, wind and solar added 11 GW each to the European grids, while all fossil fuels decreased and nuclear remained stable. By the end of 2013, China had a total of 91 GW of operating wind power capacity. China's 18 GW of installed solar capacity for the first time exceeded operating nuclear capacity. China added a new world record of at least 12 GW of solar in just one year (vs. 3 GW of nuclear), overtaking Germany's previous 7.6 GW record and exceeding cumulative U.S. additions since it invented photovoltaics in the 1950s. China now aims at 40 GW solar and will probably exceed the 100 GW wind power target for 2015.
- **Electricity Generation.** In 2013, Spain generated more power from wind than from any other source, outpacing nuclear for the first time. It is also the first time that wind has become the largest electricity generating source over an entire year in any country. Spain has thus joined the list of nuclear countries that produce more electricity from new renewables—excluding large hydro-power—than from nuclear power that includes Brazil, China, Germany, India and Japan.

[14] Even considering the LTO reactors as "operational", nuclear would only have increased capacity by 17.5 GW.

In Italy, solar photovoltaics provided 8 percent of the national electricity production—ten times its contribution in 2010 and two and half times higher than the maximum annual contribution ever made by nuclear power, before the country abandoned its use.

Compared to 1997, when the Kyoto Protocol on climate change was signed, in 2013, there has been an additional of 616 TWh per year of wind power produced in 2013, 124 TWh of solar photovoltaics outpacing nuclear with just 114 TWh. In 2013, growth rates for generation from wind power above 20 percent were seen in North America, Europe and Eurasia and Asia Pacific, with the two largest markets, the U.S. (19 percent) and China (38 percent). In the world of photovoltaics, North America saw a more than doubling of power generation, Asia Pacific a 75 percent increase.

- **Increasing System Incompatibilities.** The traditional concept of baseload electricity generation might become obsolete with increasing renewable energy penetration in national grid systems. Several countries now experience periods of very low or even negative electricity prices on the spot market. Electricity generators literally pay to produce because shutdown and restart would cost them even more. As illustrated with empirical examples from Germany, nuclear plants turn out the least flexible to react to unfavorable economic conditions and keep operating for hundreds of hours at spot prices below their average marginal operating costs.
- **Increased Renewables Generation Entailing Lower Power Prices**

In 2013, the German system generated 152 TWh from renewables, 56 percent more than from nuclear plants. In just the two past years, the number of hours with negative prices more than quadrupled, from 15 to 64. The hours with prices below €15/MWh (US$20.5/MWh) increased from 161 to 727 (8 percent of the time). From 2011 to the first quarter of 2014, average baseload prices decreased by an astonishing 40 percent. Consequently, in 2013, Germany exported a record 34 TWh *net* to neighboring countries, while nuclear France—otherwise also a net power exporter—remains a net power *importer* from Germany. This is quite the opposite of what had been forecasted following the German nuclear phase-out decision, but accurately reflects Germany's more competitive wholesale power prices.

Introduction

The draft Energy Bill that Minister Ségolène Royal presented to the French Council of Ministers on 18 June 2014 contains an article that stipulates: "If a basic nuclear facility ceases to operate for a period of over two years, its outage is considered final (…)".[15] If this criterion were to apply today in Japan then all but four nuclear reactors would be considered shut down for good. The implications would be substantial, including the requirement for full-scale new licensing procedures prior to any restart authorization request.

The world's nuclear statistics are seriously distorted by an anomaly whose cause is not technical but political. Three years after the Fukushima events started unfolding on 11 March 2011, all of the government, industry and international institutional organizations—whether the Japanese or any other government, the Japan Atomic Industrial Forum (JAIF), the international industry's representation World Nuclear Association (WNA) or the International Atomic Energy Agency (IAEA)—continue, without exception, to misrepresent the real and very concrete effects of the disaster on the Japanese nuclear program. In every single statistical document on the issue, with the exception of the six units at Fukushima Daiichi, the entire Japanese reactor fleet of 48 units is considered "in operation" or "operational".

The IAEA in its online Power Reactor Information System (PRIS) classifies 48 Japanese reactors as "in operation"—11 percent of what the IAEA considers the world nuclear fleet—despite the fact that none of them have generated power since September 2013, only two produced electricity in 2013 and just ten in 2012. In other words, 38 units, four fifths of Japan's fleet, have not "operated" in at least two and a half years. The *average* outage of these Japanese "operational" units is over three years, as this report documents. In fact, three units at the Kashiwazaki-kariwa site have not generated power for the past *seven* years, since a large earthquake stopped all seven of operator TEPCO's units at that site in July 2007. When the 3/11 events hit Fukushima, TEPCO was still in post-earthquake recovery in Niigata Prefecture on the other side of Honshu Island.

To find a more appropriate way to deal with this situation, the *World Nuclear Industry Status Report 2014* inaugurates a new category called Long-Term Outage (LTO). The definition is simple and purely empirical: A nuclear power reactor is considered to be in LTO, if it has not generated any power in the entire previous calendar year and in the six months of the current calendar year. This classification decision leads to some significant retroactive adjustments in nuclear statistics, as many reactors—mainly in Japan but also one in South Korea and one in India—have generated no power for several years.

Taking into account reactors in LTO, the number of operational reactors in the world drops by 39 (9 percent) from 427 in July 2013 to 388 in July 2014, and brings the world nuclear statistics into closer alignment with reality.

WNISR considers that none of the 10 Fukushima reactors will ever restart and therefore categorizes them as shut down. The two reactors at Ohi in Kansai Prefecture, which produced power in 2013, would be deemed as operational, but all other 42 units are in the LTO category. This edition's Japan Focus contains a thorough analysis of the status of the reactors and their specific situation as to potential restart. The current national government is keen to restart as many reactors as possible, but most of the public and many Prefectural Governors and municipalities (whose consent is required) are not; a recent judicial decision reflects public unease; and such a fundamental conflict, entangled with other political issues, is without clear precedent in recent Japanese history, which therefore offers little guidance.

This edition contains more changes and innovations. Beyond the entirely restructured Economics of Nuclear Power chapter, we have added a section on system issues to the updated Nuclear vs. Renewables chapter. We have also started to rebuild our own database, reactor-by-reactor, and adapted some a-posteriori adjustments to the statistics. The integration of revised data from other international data sources remains a difficult challenge.

Considering the significance of the Japanese nuclear program in this edition, the WNISR team is particularly grateful to Tatsujiro Suzuki, former Vice-Chairman of the Japan Atomic Energy Commission (JAEC), to having kindly contributed the Foreword.

---

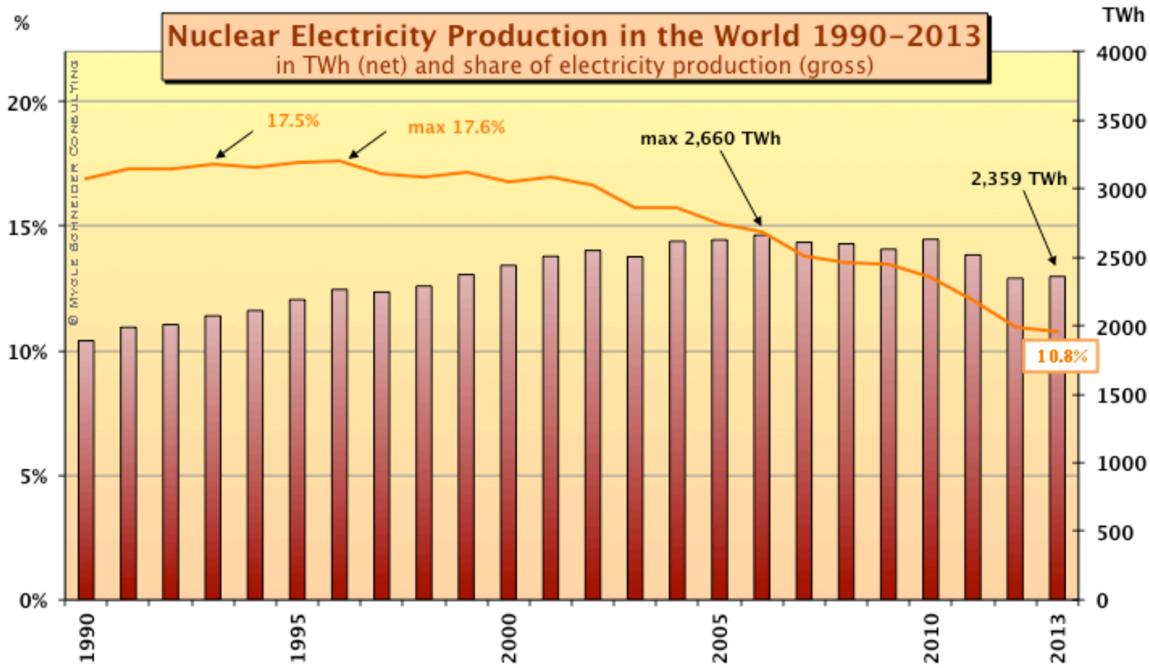
[15] Ministère de l'écologie, du développement durable et de l'énergie, "Projet de loi de programmation pour la transition énergétique", présenté en Conseil des Ministres, 18 June 2014; see *Art*. L. 593-24. The French original reads: "Si une installation nucléaire de base cesse de fonctionner pendant une durée continue supérieure à deux ans, son arrêt est réputé définitif (…)."

General Overview Worldwide

> *Extreme weather events pose a major threat to all power plants but particularly to nuclear plants, where they could disrupt the functioning of critical equipment and processes that are indispensable to safe operation including reactor vessels, cooling equipment, control instruments and back-up generators.*
>
> World Energy Council
> June 2014[16]

As of the middle of 2014, 31 countries were operating nuclear fission reactors for energy purposes. Nuclear power plants generated 2,359 net terawatt-hours (TWh or billion kilowatt-hours) of electricity in 2013[17], a minor increase (+0.5 percent) after two years of significant decline, but still less than in 1999 and 11.3 percent below the historic peak nuclear generation in 2006. (See Figure 1.)

Figure 1: Nuclear Electricity Generation in the World



Source : IAEA-PRIS, BP, MSC, 2014

Nuclear energy's share of global commercial electricity generation also remained almost stable (–0.2 percent) in 2013 compared to the previous year, but declined from a peak of 17.6 percent in 1996 to 10.8 percent (see note[18]).

---

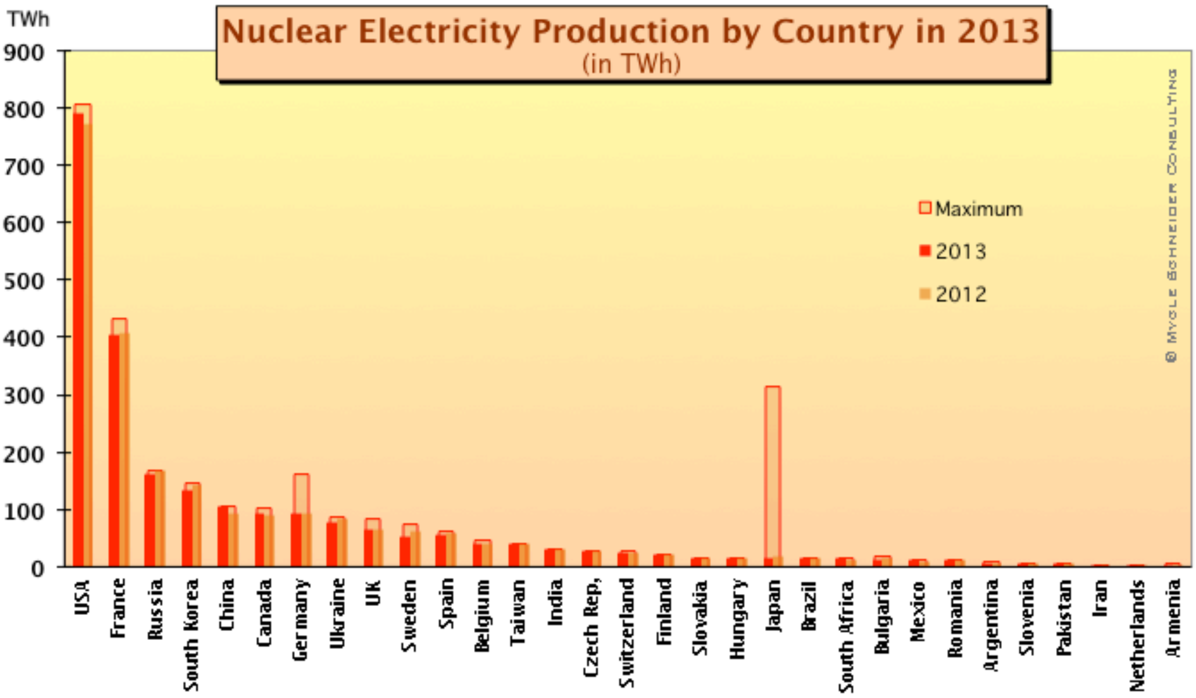
[16] World Energy Council, "Climate Change: Implications for the Energy Sector", University of Cambridge, June 2014, see http://www.worldenergy.org/wp-content/uploads/2014/06/Climate-Change-Implications-for-the-Energy-Sector-Summary-from-IPCC-AR5-2014-Full-report.pdf, accessed 11 July 2014.

[17] 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 if not otherwise noted.

[18] With the WNISR2014, we have decided to modify the calculation basis for the nuclear share. In previous years, we have used the IAEA's nuclear generation figures and the BP's world electricity generation figures in order to calculate the nuclear share. The main reason for that choice was that we use the IAEA nuclear generation figures throughout the report and intended to provide homogeneous figures. However, the IAEA figures are net of auto-consumption, while the BP figures are gross. Therefore we consider it is more consistent to derive the *share* of nuclear generation (gross) entirely from the BP statistics on gross electricity generation (nuclear vs. total). Unfortunately, there is not a better statistical basis for world net power generation. The WNISR2013 stated: "The maximum contribution of nuclear power to commercial electricity generation worldwide was reached in 1993 with 17 percent (see figure 1). It has dropped to 10.4 percent in 2012, a level last seen in the 1980s." With the same calculation basis, the 2013 figure would drop to 10.2 percent. The differences in the results between both calculation methods remain very limited, below 1 percent.

Nuclear generation declined in 13 countries, while in 16 countries it increased and remained stable in two[19]. Six countries[20] generated their historic maximum in 2013. (See Figure 2.)

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



Sources: IAEA-PRIS, MSC, 2014

As in the previous year, the "big five" nuclear generating countries—by rank, the United States, France, Russia, South Korea and China—generated 68 percent of all nuclear electricity in the world. China increased its nuclear power generation for the fifteenth year in a row and overtook Germany as the fifth largest producer in 2013. The three countries that have phased out nuclear power (Italy, Kazakhstan, Lithuania), and Armenia, generated their historic maximum of nuclear electricity in the 1980s. Several other countries' nuclear power generation peaked in the 1990s, among them Belgium, Canada, Japan, and the U.K. A further six countries' nuclear generation peaked between 2001 and 2005: Bulgaria, France, Germany, South Africa, Spain, and Sweden. Besides China, the Czech Republic, Finland (although by a very small margin), India (with a still modest generation of 30 TWh), Iran (its Busheer plant entered commercial operation in the third quarter of 2013) and Mexico (that had undergone major uprating) achieved their greatest nuclear production in 2013.

Even where countries are increasing their nuclear electricity production, this is in most cases not keeping pace with overall increases in electricity demand leading to a reduced and generally declining nuclear share (see Figure 3). Except for Iran, which started up its first nuclear plant only in 2011, only one country in the world, the Czech Republic, had its nuclear share peak in 2013. In fact, all other countries, except for Russia (which peaked in 2012)[21]—reached their maximum share of nuclear power prior to 2010. While two countries peaked in 2008 (China) or 2009 (Romania), the other 26 countries saw their largest nuclear share by 2005. In total, nuclear power played its largest role in ten countries during the 1980s[22], in 12 countries in the 1990s and 13 countries in the 2000s.

Increases in nuclear generation are mostly a result of higher productivity and uprating[23] at existing plants rather than due to new reactors. According to the latest assessment by *Nuclear Engineering International*[24], which assesses about 400 of the world's nuclear reactors, the global annual load

However, by 0.1 percent difference, the historical maximum moves from 1993 to 1996. This is likely below the statistical uncertainty.

[19] Less than 1 percent variation from the previous year.

[20] China, Czech Republic, Finland, India, Iran, Mexico.

[21] Data modified retroactively on IAEA-PRIS.

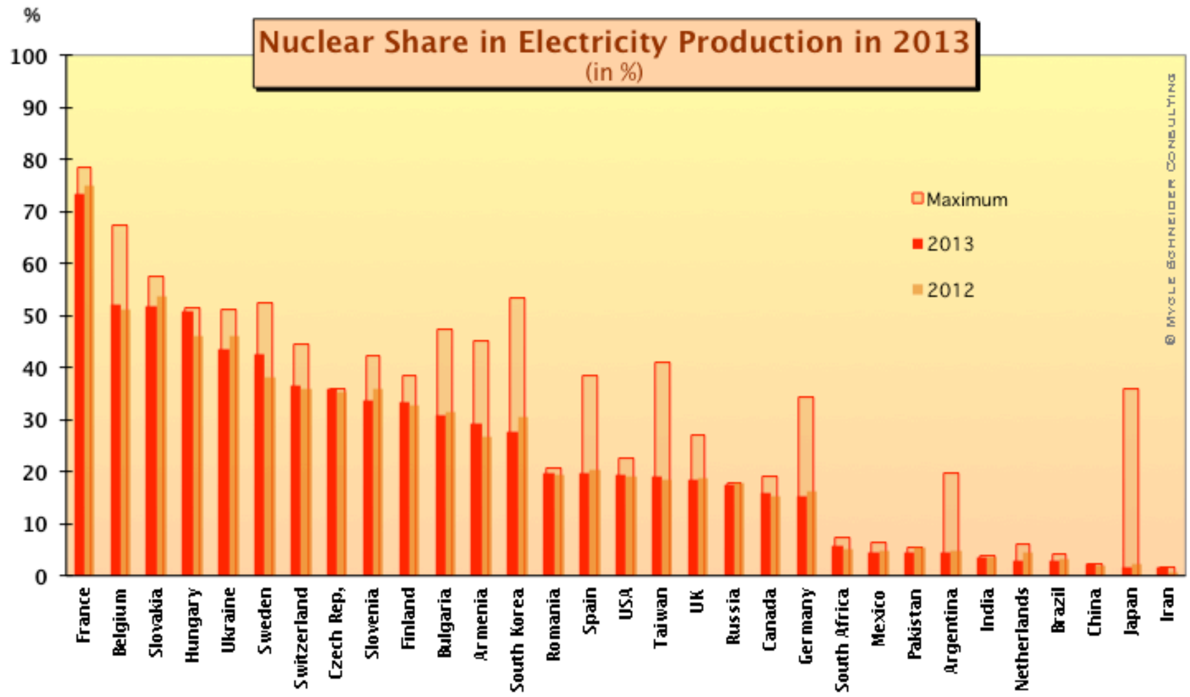
[22] Armenia, Hungary, India, Germany, Italy, Netherlands, South Africa, South Korea, Spain, Taiwan.

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

[24] Will Dalrymple, Editor of Nuclear Engineering International magazine, personal communication, email 27 June 2014.

factor[25] of nuclear power plants remained stable at 70 percent (+0.2 percent), down from 77 percent in 2011. Excluding Japan, the average load factor decreased slightly (-0.5 percent) to just under 80 percent.

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



Sources: IAEA-PRIS, MSC, 2014

Romania and Finland achieved the highest annual load factors in 2013 with 94.2 and 93.8 percent respectively.[26] The two countries also lead the Top Ten of the lifetime load factors with 90.8 and 87.3 percent. However, Romania and Finland only operate two and four reactors. Amongst the larger nuclear programs, the most remarkable changes in load factor performance are reported from Canada (+7.6 percent), the U.S. (+4.6 percent) on the positive side and from South Korea (-8.6 percent) and Ukraine (-6.3 percent) on the negative side. Canada brought three units (Bruce-1 and -2, Point Lepreau) that had experienced multi-year outages back into commercial operation in 2013. In the U.S., remarkably low outage times helped increase availability, a performance that could be repeated in 2014, as the outage level is below that of 2013 for the first half of the year.[27] South Korea had to deal with the ongoing aftermath of a major scandal of forged quality control documents that kept three reactors down for most of the year (see country profile in Annex 1). The main origin of the decreasing load factor in Ukraine was major upgrading work on South-Ukraine-1 that kept the reactor down for 240 days but led to a proposed lifetime extension of ten years.

Overview of Operation, Power Generation, Age Distribution

Since the first nuclear reactor was connected to the Soviet power grid at Obninsk on 27 June 1954, 60 years ago, there have been two major waves of grid connections (see Figure 4). The first wave peaked in 1974, with 26 reactor startups in that year. The second wave reached a historic maximum in 1984 and 1985, just before the Chernobyl accident, reaching 33 grid connections in each year. By the end of the 1980s, the uninterrupted net increase of operating units had ceased, and in 1990 for the first time the number of reactor shutdowns outweighed the number of startups. The 1991-2000 decade showed far more startups than shutdowns (52/30), while in the decade 2001-2010, as many units

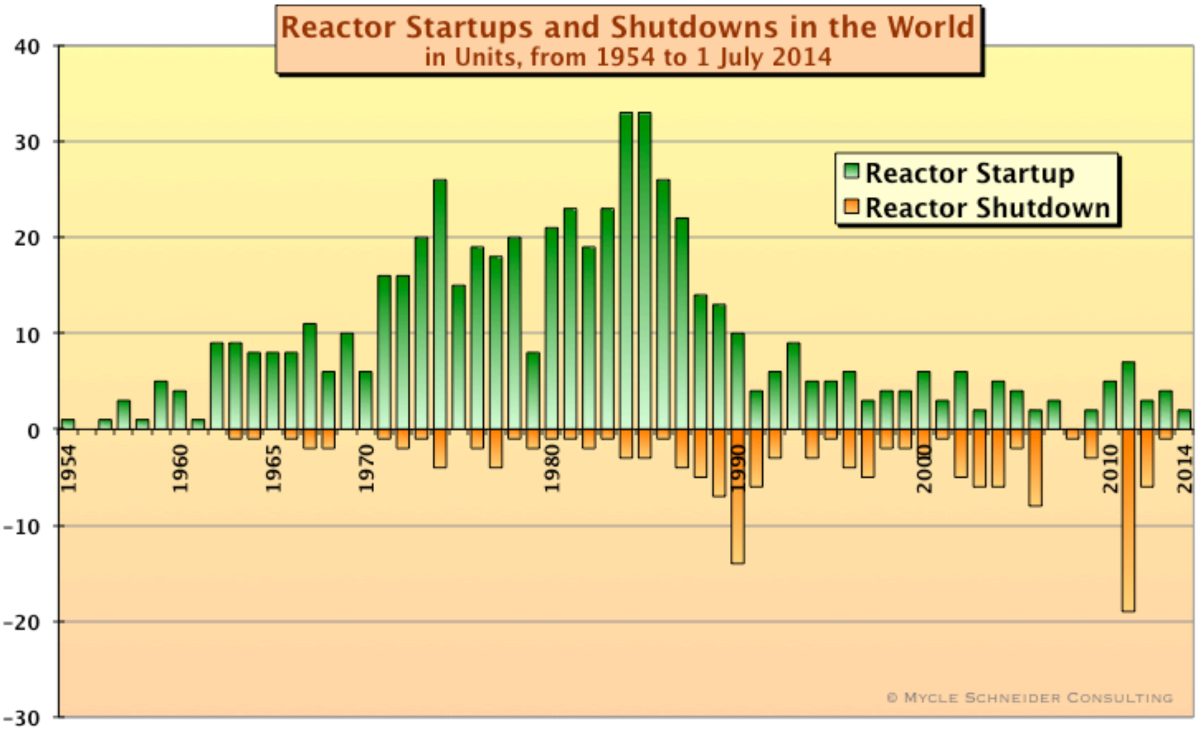
[25] Nuclear Engineering International load factor definition: "Annual load factors are calculated by dividing the gross generation of a reactor in a one-year period by the gross capacity of the reactor (sometimes called output), as originally designed, multiplied by the number of hours in the calendar year. The figures are expressed as percentages. Where a plant is uprated, the revised capacity is used from the date of the uprating."

[26] Unless noted otherwise, all load factor figures are from Nuclear Engineering International, "Load Factors to end December 2013", May 2014 (print version), see also http://www.neimagazine.com/news/newsload-factor-tables-17, accessed 11 July 2014.

[27] U.S.EIA, "Status of U.S. Nuclear Outages", see http://www.eia.gov/beta/outages, accessed 25 June 2014.

started up as were shut down (32/32). In other words, 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 the middle of 2014, the startup of 16 reactors did not match the shutdown of 26 units over the same period—partly as a result of events in Fukushima. In 2013, four reactors started up (three in China, one in India) and one was shut down. In the first half of 2014, one reactor started up each in Argentina and in China, while none were shut down. Overall, since 2001, it is in Asia that 39 units (81 percent) out of 48 units were connected to the world's power grids.

Figure 4: Nuclear Power Reactor Grid Connections and Shutdowns, 1954–2014



Source: IAEA-PRIS, MSC, 2014

The International Atomic Energy Agency (IAEA) in its online database Power Reactors Information System (PRIS) still accounts for 48 units in Japan in its total number of 435 reactors "in operation",[28] while no nuclear electricity has been generated in Japan since September 2013 and it is now expected that the first units could restart operations in September 2014 "at the earliest".[29] Only two reactors (Ohi-3 and -4) have operated in 2013 and ten in 2012. The particular 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 to continue considering the entire reactor fleet in the country as "in operation" or "operational" is misleading.

The IAEA actually does have a reactor-status category called "Long-term Shutdown" or LTS.[30] 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 we have illustrated in the WNISR 2013, one could argue that all but two Japanese reactors fit the category. And 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.[31]

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 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:

---

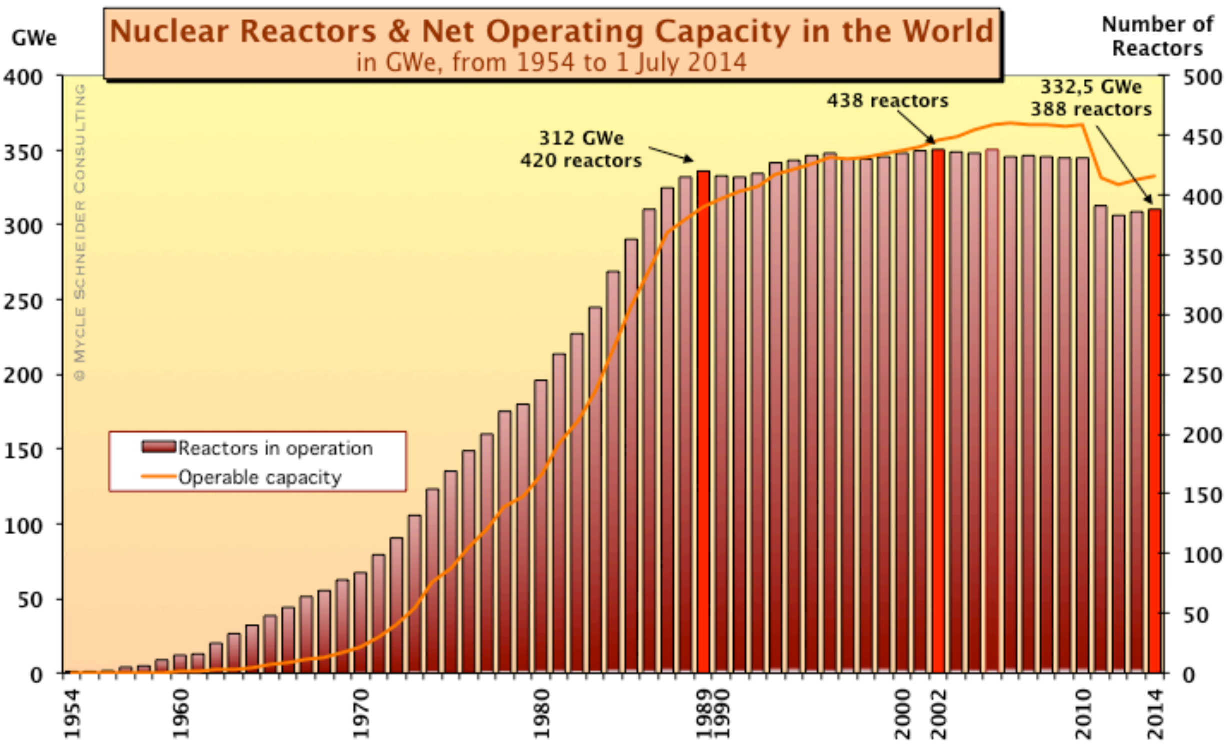
[28] IAEA, "Power Reactor Information System", see http://www.iaea.org/pris/, accessed 27 June 2014.
[29] Asahi Shimbun, "Japan to experience nuclear-free summer", 25 June 2014,
see http://ajw.asahi.com/article/0311disaster/fukushima/AJ201406250047, accessed 27 June 2014.
[30] See IAEA Glossary www.iaea.org/pris/Glossary.aspx, accessed 27 June 2014.
[31] See detailed accounts on www.WorldNuclearReport.org.

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.

Applying this definition to the world nuclear reactor fleet leads to considering 43 Japanese units in LTO, as WNISR considers all ten Fukushima reactors shut down permanently (while 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[32], because it was shut down after a sodium fire in 1995 and has never generated power since. But it meets WNISR's new LTO criterion. Besides the Japanese reactors, the Indian reactor Rajasthan-1, off-line since 2004, and the South-Korean unit Wolsong-1, shut down since 2012, fall into the LTO category. The total number of nuclear reactors in LTO are therefore 45; all but one (Monju) are considered by the IAEA as "in operation".

As of 1 July 2014, a total of 388 nuclear reactors are considered operating in 31 countries, down 39 units (-9.1 percent) from the situation one year ago, mainly due to the revised categorization and the situation in Japan. The current world reactor fleet has a total nominal electric net capacity of 333 gigawatts (GW or thousand megawatts), down from 364 GW (-8.5 percent) one year earlier. (See Figure 5.)

Figure 5. World Nuclear Reactor Fleet, 1954–2014



Sources: IAEA-PRIS, MSC, 2014

The total world installed nuclear capacity decreased during six years since the beginning of the commercial application of nuclear fission, five of them during the past seven years—in 2003, 2007–09, and 2011–12. Overall, the net installed capacity has continued to increase far beyond the net increase of numbers of operating reactors. This is a result of the combined effects of larger units replacing smaller ones and, mainly, technical alterations at existing plants, a process known as uprating. In the United States, the Nuclear Regulatory Commission (NRC) has approved 154 uprates since 1977. These included, in 2013 and the first half of 2014, seven minor uprates between 1.6 and 1.7 percent, except for one (Monticello) with 12.9 percent. The cumulative approved uprates in the United States total 7 GW[33] most of which have already been implemented (for a detailed overview see Annex 3). A similar trend of uprates and lifetime extensions of existing reactors can be seen in Europe. The main incentive for lifetime extensions is their considerable economic advantage over new-build. Upgrading but extending

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

[33] Nuclear Regulatory Commission (NRC), "Approved Applications for Power Uprates", updated 21 February 2014, see www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/approved-applications.html, accessed 27 June 2014.

the operating lives of older reactors usually also lower safety margins than replacement with more modern designs.

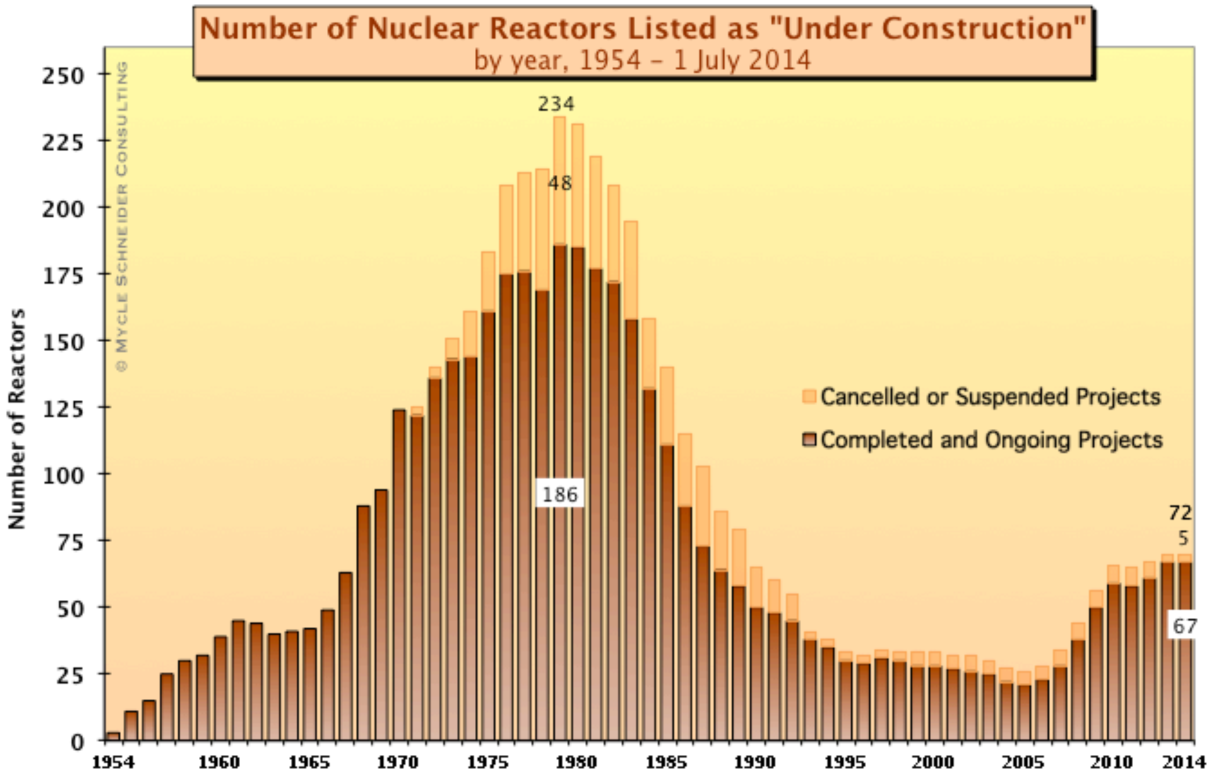
It appears, however, that the incentives and opportunities for power uprates are reducing as in 2012 the number of units with pending applications in the U.S. dropped from 20 in the previous year to 14, declining to eight by the middle of 2014, of which six are "on hold" and the total capacity increase that would occur should they be implemented be limited to 0.8 GW—in other words, insignificant on a U.S. scale.[34]

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 June 2014 (see Figure 2). Close to half of the world's nuclear countries are located in the European Union (EU), and in 2013 they accounted for 36 percent of the world's nuclear production, of which France generated about half (48.7 percent).

Overview of Current New Build

Just as one year ago, currently there are 14 countries building nuclear power plants. Japan halted work at two units following the 3/11 events, Ohma and Shimane-3, which had been under construction since 2007 and 2010 respectively. Officially, construction resumed at Ohma on 1 October 2012 and Shimane-3 has remained "under construction", according to the Japan Atomic Industrial Forum (JAIF)[35] and IAEA statistics. However, in view of the current situation in Japan, it is very unlikely that these plants will be completed (see also Japan Focus) as it will be hard enough for the industry to get its stranded plants restarted.

Figure 6. Number of Nuclear Reactors under Construction



Source: IAEA-PRIS, MSC 2014

As of the middle of July 2014, 67 reactors are considered here as under construction, one more than WNISR reported a year ago; four fifths of all new-build (56) are in Asia and Eastern Europe, of which half (28) are in China alone. Almost two thirds (43) of the units under construction are located in just three countries: China, India and Russia. Ten projects started construction in 2013, in the U.S. (4),

[34] NRC, "Pending Applications for Power Uprates", updated 30 April 2012, see www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/pending-applications.html, accessed 27 June 2014.

[35] JAIF, "Nuclear Power Plants in Japan", 22 May 2013.

China (3), Belarus (1), South Korea (1) and United Arab Emirates (1). In the first half of 2014, only two projects got underway: a second building site opened up in Belarus and the construction of an experimental 25 MWe reactor (CAREM) was launched in Argentina.

The current number of active building sites is the highest since 1987 and is still relatively small compared to a peak of 234 units in building progress—totaling more than 200 GW—in 1979. However, many of those projects (48) were never finished (see Figure 6.) The year 2004, with 26 units under construction, marked a record low since the beginning of the nuclear age in the 1950s.

Table 1. Nuclear Reactors "Under Construction" (as of 1 July 2014)[36]

Country	Units	MWe (net)	Construction Start	Grid Connection
China	28	27,756	2008-2013	2014-2018
Russia	9	7,273	1983-2019	2014-2019
India	6	3,907	2002-2011	2014-2016
South Korea	5	6,320	2008-2013	2014-2018
USA	5	5,633	1972-2013	2015-2019
Belarus	2	2,218	2013-2014	2019-2020
Pakistan	2	630	2011	2016-2017
Slovakia	2	880	1985	2014-2015
UAE	2	2,690	2012-2013	2017-2018
Ukraine	2	1,900	1986-1987	2015-2016
Argentina	1	25	2014	2018
Brazil	1	1,245	2010	2016
Finland	1	1,600	2005	2016
France	1	1,600	2007	2016
Total	67	63,677	1972-2014	2014-2020

Sources : IAEA-PRIS, MSC, 2014

The total capacity of units now under construction in the world remained stable at about 63.7 GW (+0.2 GW), with an average unit size of 947 MW (see Table 1 and Annex 8 for details). A closer look at currently listed projects illustrates the level of uncertainty and problems associated many of these projects, especially given that most constructors assume a five-year construction period:

- Eight reactors have been listed as "under construction" for more than 20 years. The U.S. Watts Bar-2 project in Tennessee holds the record, as construction started in December 1972, but was subsequently frozen. It failed to meet the latest projected startup date in 2012 and is now scheduled to be connected to the grid in late 2015. Other long-term construction projects include three Russian units, two Mochovce units in Slovakia, and two Khmelnitski units in Ukraine. One Russian unit, the fast breeder reactor BN-800, went critical in June 2014 and is expected to start generating power in mid-2014.
- One reactor, the Indian Kudankulam-2 unit, has been listed as "under-construction" for 12 years. Due to massive opposition, work on two Taiwanese units at Lungmen was stopped in April 2014 after about 15 years of construction.
- At least 49 of the units listed as "under construction" have encountered construction delays, most of them significant (several months to several years). For the first time, major delays have been officially admitted relating to projects in China.[37] Indeed, 21 of the 28 units under construction in China are experiencing delays between several months and over two years.
- All of the 18 remaining units under construction in the world were started within the past three years or have not reached projected start-up dates yet. This makes it difficult to assess whether or not they are on schedule.

The lead time for nuclear plants includes not only construction times but also lengthy licensing procedures in most countries, complex financing negotiations, and site preparation. Past experience shows that simply having an order for a reactor, or even having a nuclear plant at an advanced stage of

[36] For further details see Annex 8.
[37] Shan Sun, "Challenges during construction of new NPPS", IAEA Technical Meeting, 6 February 2014, see www.iaea.org/nuclearenergy/nuclearpower/Downloadable/Meetings/2014/2014-02-04-02-07-TM-INIG/Presentations/37_S7_China_Sun.pdf, accessed 28 June 2014; see also Nuclear Intelligence Weekly (NIW), "China: Sanmen—Two Year Delay Pushes Costs Higher", 14 March 2014.

construction, is no guarantee for grid connection and power production. The French Atomic Energy Commission (CEA) statistics on "cancelled orders" through 2002 indicate 253 cancelled orders in 31 countries, many of them at an advanced construction stage (see also Figure 6). The United States alone accounted for 138 of these cancellations.[38] Many U.S. utilities incurred significant financial harm because of cancelled reactor-building projects.

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-2014 stands at 28.5 years.[39] Some nuclear utilities envisage average reactor lifetimes of beyond 40 years and even up to 60 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 2014, 72 of the 100 operating U.S. units have received an extension, with another 19 applications are under NRC review.[40] However, these applications are currently on hold pending completion of a review of the management of commercial nuclear reactor spent fuel, with no license extension decision to be granted until completion of this process.[41]

However, even license renewal does not guarantee longer operating life and none of the 32 units that have been shut down in the U.S. had reached 40 years on the grid. In other words, at least a quarter of the reactors built in the U.S. never reached their initial design lifetime. On the other hand, of the 100 currently operating plants, 24 units have operated for more than 40 years. In other words, one third of the units with license renewals have already entered the life extension period.

Many other countries, have no specific time limits on operating licenses. In France, where the country's first operating PWR started up in 1977, reactors must undergo in-depth inspection and testing every decade. The French Nuclear Safety Authority (ASN) evaluates each reactor before allowing a unit to operate for more than 30 years. The French utility Électricité de France (EDF) has clearly stated that, for economic reasons, it plans to prioritize lifetime extension beyond 40 years over large-scale new-build. Having assessed EDF's lifetime extension outline, ASN stated:

> ASN requested additional studies and underlined the fact that if operation of the existing reactors were to be extended beyond 40 years, they would be operating alongside other reactors around the world of more recent design and compliant with significantly strengthened safety requirements. Through its requests, ASN thus restated that the reactor operating life extension desired by EDF was in no way a foregone conclusion. Over and above the question of management of aging, it is also dependent on an ambitious safety reassessment aiming to achieve a level as close as possible to that of a new reactor.[42]

In fact, only a few French plants have so far received a permit to extend their operational life from 30 to 40 years, but even then only under the condition of significant upgrading. The draft Energy Bill presented by Minister Ségolène Royal in June 2014 caps the installed nuclear operating capacity at the current level. This would mean that prior to the startup of the EPR under construction in Flamanville, an equivalent nuclear generating capacity has to be shut down. Incidentally, this would be close to the capacity of the country's oldest reactors at Fessenheim that President François Hollande vowed to close down by the end of 2016, the current planned startup date for Flamanville-3. The draft Energy Bill also confirms the target to reduce the nuclear share in power generation from 75 to 50 percent by 2025. If ASN gave the go-ahead for all of the oldest units to operate for 40 years, 22 of the 58 French operating reactors will still reach that age by 2020. In fact, in order to reach the 50-percent goal by 2025 and significantly increase the renewable energy share, at constant power consumption, over 20 units will need to be closed by 2025. According to an independent assessment[43], lifetime extension beyond 40 years will probably be very expensive (between €1 billion and €4 billion (US$1.4–5.5 billion) per reactor, depending on the safety level to be achieved). Because of the different costs

[38] CEA, "Elecnuc – Nuclear Power Plants in the World", 2002.

[39] 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.

[40] U.S. Nuclear Regulatory Commission (NRC), "Status of License Renewal Applications and Industry Activities", see www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 2 June 2014.

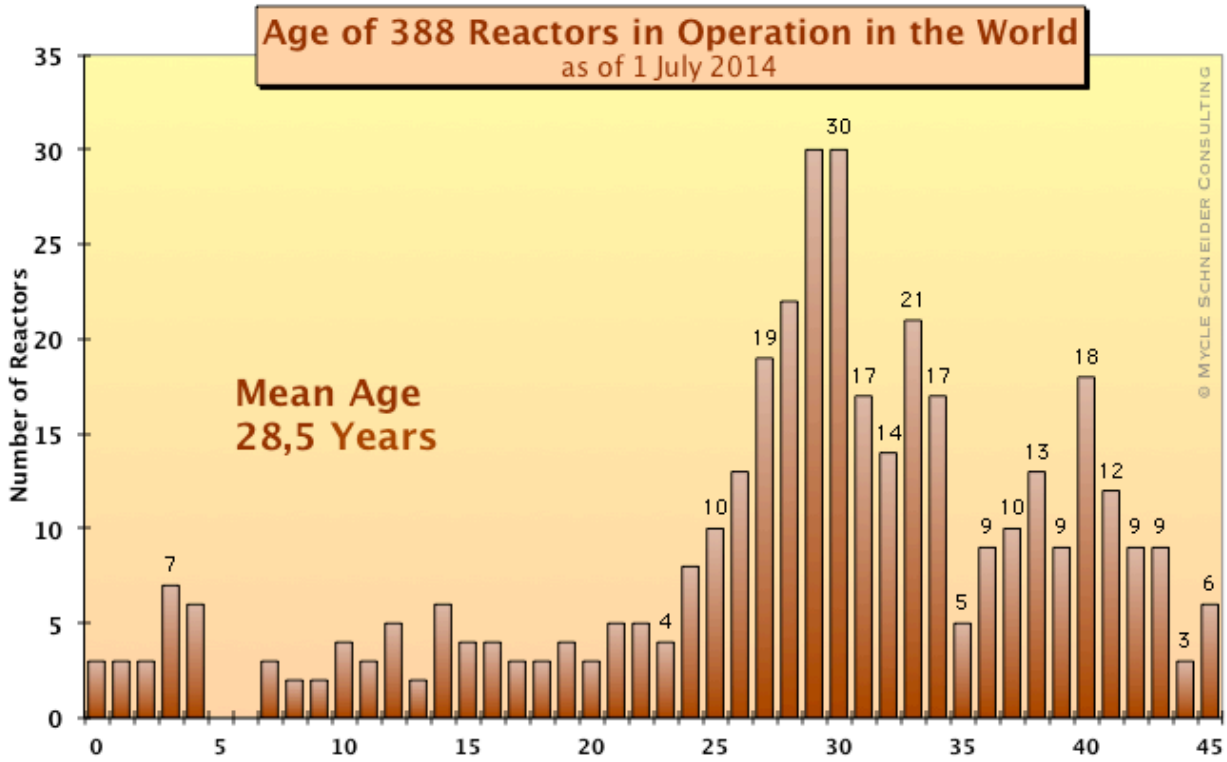
[41] U.S.NRC, "Waste Confidence", updated 29 May 2014, see http://www.nrc.gov/waste/spent-fuel-storage/wcd.html, accessed 10 July 2014.

[42] ASN, "ASN report abstracts—on the state of nuclear safety and radiation protection in France in 2013", 2014.

[43] Yves Marignac, "L'échéance des 40 ans pour le parc nucléaire français : Processus de décision, options de renforcement et coûts associés à une éventuelle prolongation d'exploitation au-delà de 40 ans des réacteurs d'EDF", WISE-Paris, commissioned by Greenpeace France, February 2014, 169 p., see http://www.greenpeace.org/france/PageFiles/266521/greenpeace-rapport-echeance-40-ans.pdf, accessed 7 June 2014.

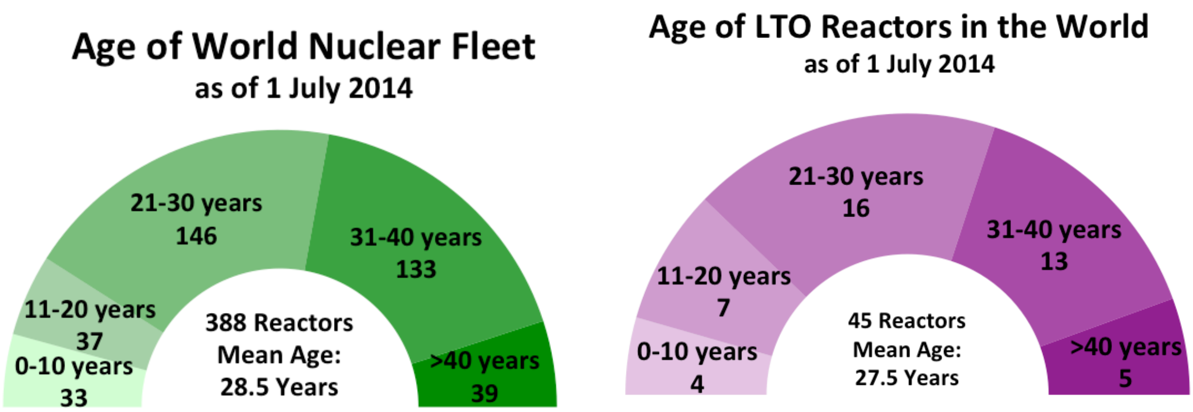
associated with lifetime extensions at different reactors and other considerations (geographical distribution, overall target to reduce the nuclear share, etc.) EDF will likely attempt to extend lifetimes of some units while others might be closed prior to reaching the 40-year age limit. (See also the section on Lifetime Extension in the Economics chapter).

Figure 7a. Age Distribution of Operating Nuclear Reactors



Sources: IAEA-PRIS, MSC, 2014

Figures 7b: Age Distribution of 388 Operating and 45 LTO Reactors in the World (by Decade)

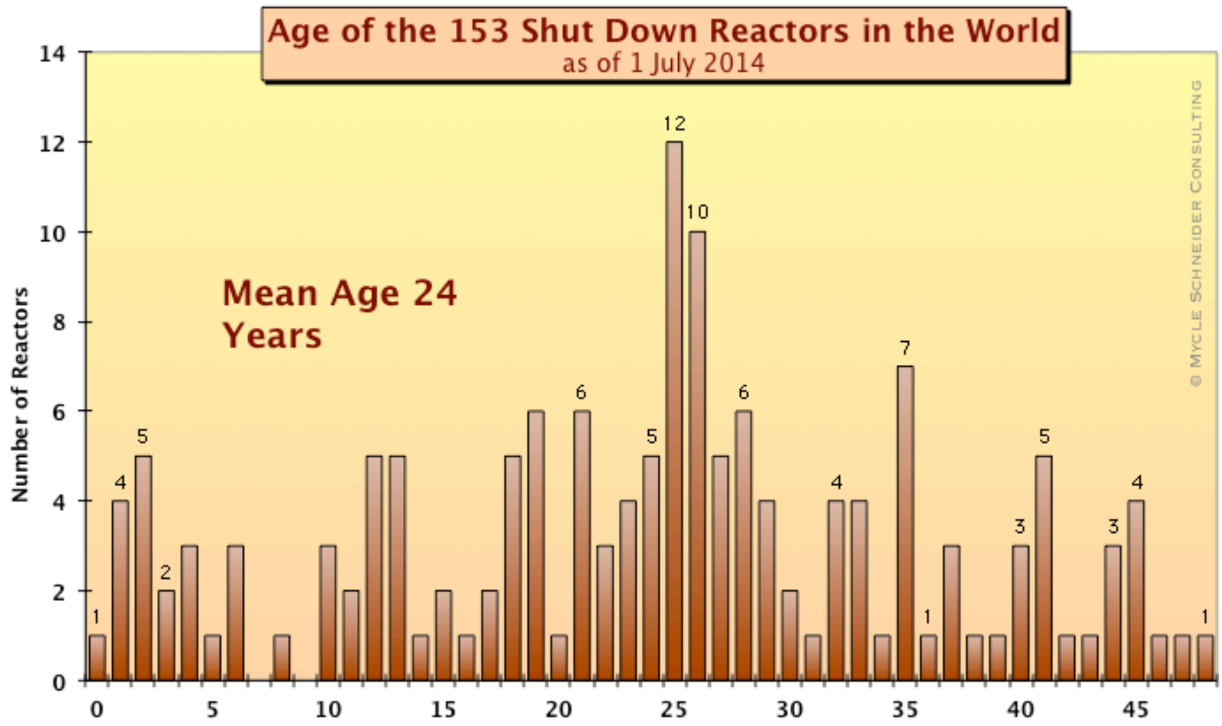


Sources: IAEA-PRIS, MSC, 2014

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 Figures 7 and 8). As of mid-2014, 39 of the world's operating reactors have exceeded the 40-year mark (eight more than one year ago).[44] As the age pyramid illustrates, that number could rapidly increase over the next few years. A total of 172 units have already reached age 30 or more. In fact, none of the 120 reactors started up in the past 25 years (since 1989) has been permanently shut down yet.

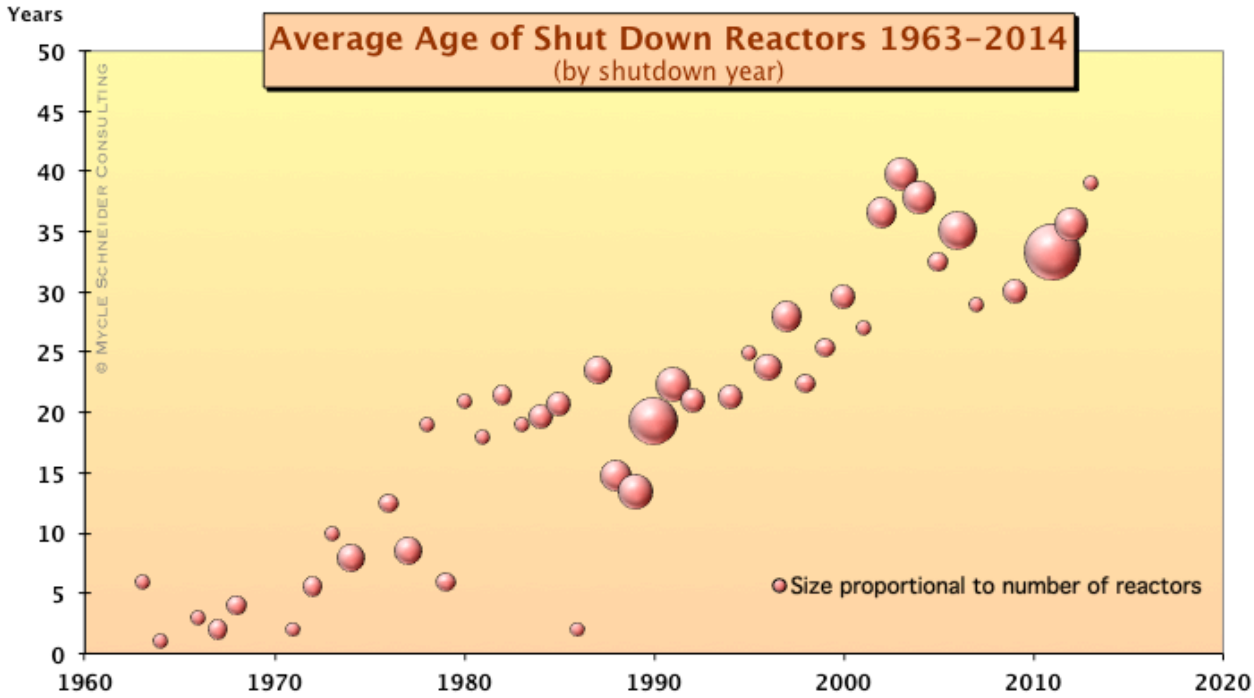
[44] WNISR considers the age starting with grid connection, and figures are rounded by half-years.

Figure 8a. Age Distribution of 153 Shut Down Nuclear Reactors



Sources: IAEA-PRIS, MSC, 2013

Figure 8b. Average Age Profile of Shut Down Nuclear Reactors



Sources: IAEA-PRIS, MSC, 2014

The age structure of the 153 units already shut down confirms the picture. In total, 45 of these units operated for 30 years or more and of those, 20 reactors operated for 40 years or more (see Figure 8a). The majority of these were Magnox reactors located in the U.K. As they were designed to produce weapons-grade plutonium, these were all small reactors (50–490 MW) that had operated with very low burn-up fuel and very low power density (watts of heat per liter of core volume).

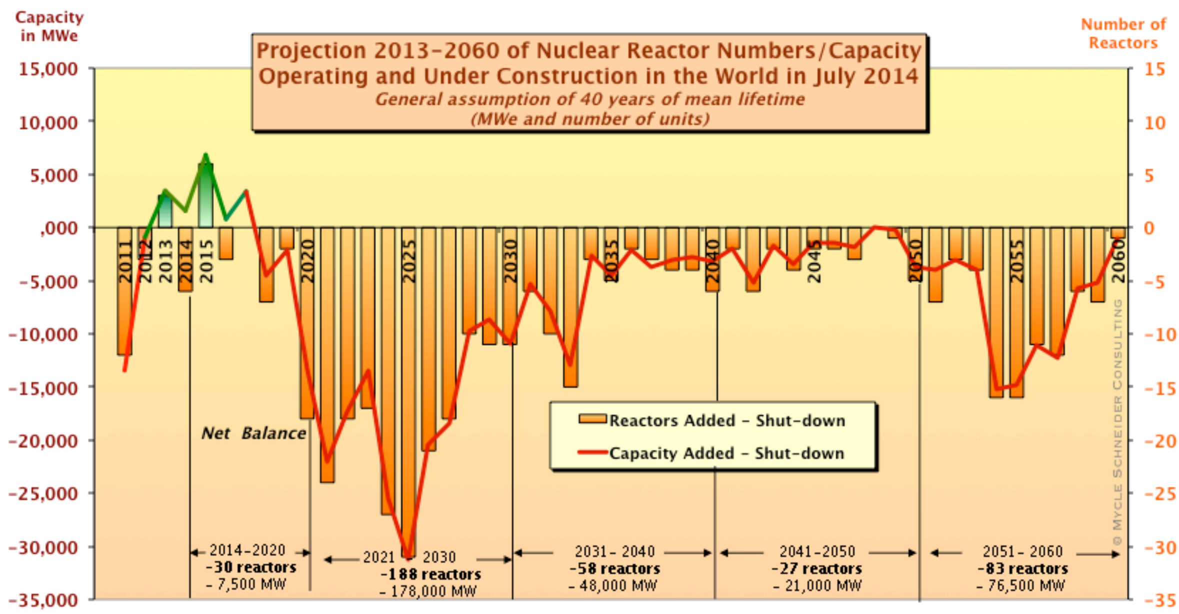
Therefore there are significant differences from the large 900 MW or 1,300 MW commercial reactors whose high burn-up fuel and high power density generate significantly more stress on materials and equipment. Many units of the first generation have operated for only a few years. Considering that the average age of the 153 units that have already shut down is about 24 years, plans to extend the operational lifetime of large numbers of units to 40 years and beyond seems rather optimistic. The operating time prior to shutdown has clearly increased continuously, as illustrated in Figure 8b. But while the average age at shutdown got close to, it never passed the 40-year line. In 2003, six units averaged 39.8 years, and one reactor closed in 2013 (Kewaunee in the U.S.) operated for 39 years.

As a result of the Fukushima nuclear disaster, questions have been raised about the wisdom of operating older reactors. The Fukushima-I units (1 to 4) were connected to the grid between 1971 and 1974. The license for unit 1 was extended for another 10 years in February 2011. 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.

Other countries continue to implement or prepare for lifetime extensions. We have therefore created two lifetime projections. In a first scenario (40-Year Lifetime Projection, see Figure 9), we have assumed a general lifetime of 40 years for worldwide operating reactors (not including reactors in LTO, as they are not considered operating), with a few adjustments, while we take into account already-authorized lifetime extensions in a second scenario (PLEX Projection, see Figure 10).

The lifetime projections allow for an evaluation of the number of plants that would have to come on line over the next decades to offset closures and simply maintain the same number of operating plants. Even with 67 units under construction—as of 1 July 2014, all of which are considered online by 2020—installed nuclear capacity would drop by 7.5 GW. In total 30 additional reactors would have to be finished and started up prior to 2020 in order to maintain the status quo of the number of operating units. This corresponds to about five grid connections per year, with an additional 188 units (178 GW) over the following 10-year period—one every 19 days. This compares to 37 grid connections over the past 10-year period with an average construction time of ten years.

Figure 9. The 40-Year Lifetime Projection (not including LTOs)

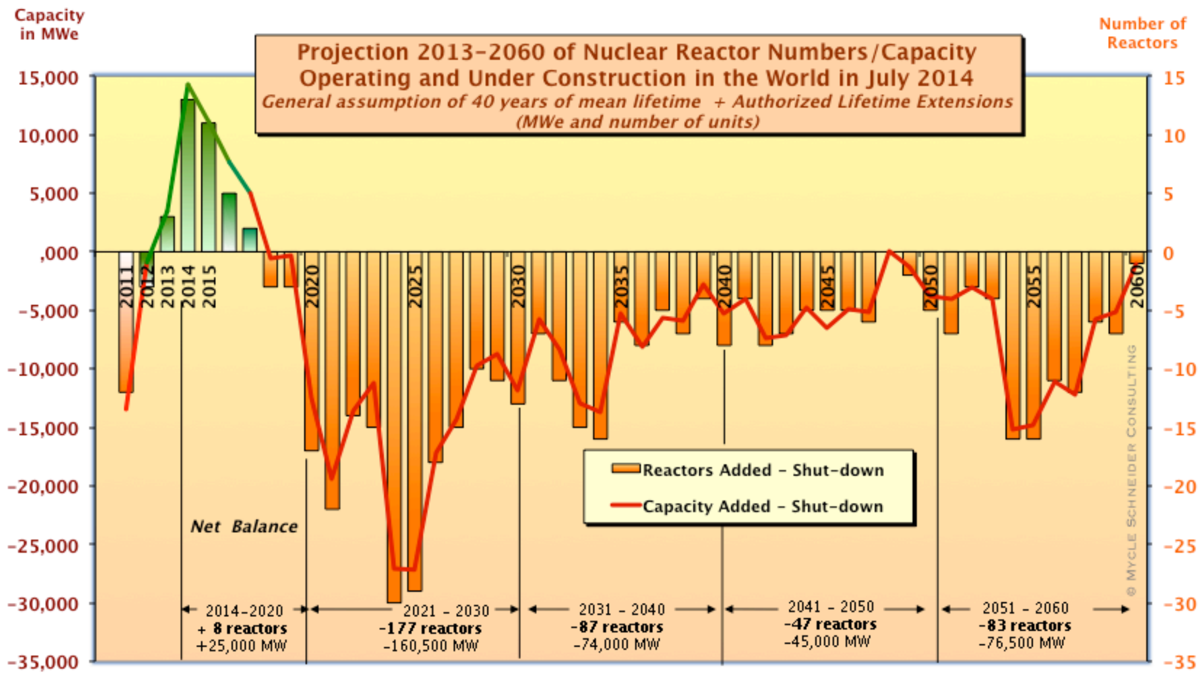


Sources: IAEA-PRIS, WNA, various sources compiled by MSC 2014

The achievement of the 2020 target 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 and generally hostile public opinion—aside from any other specific post-Fukushima effects.

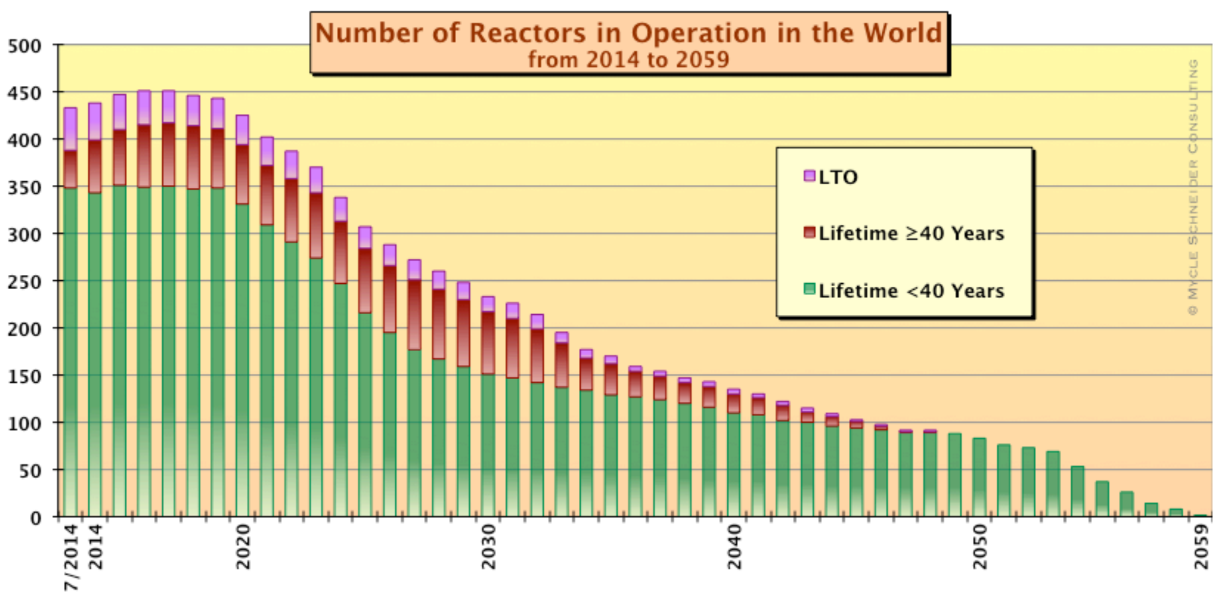
As a result, the number of reactors in operation will stagnate at best but will more likely decline over the coming years unless lifetime extensions beyond 40 years becomes widespread. The scenario of such generalized lifetime extensions is however even less likely after Fukushima, as many questions regarding safety need to be much more carefully addressed. Also, soaring maintenance and upgrading costs, as well as decreasing system costs of nuclear power's main competitors lead to an economic environment that already led to premature plant closures, notably in the U.S. and Germany.

Figure 10. The PLEX Projection



Sources: IAEA-PRIS, WNA, various sources compiled by MSC 2014

Figure 11. Forty-Year Lifetime Projection versus PLEX Projection *(in numbers of reactors)*



Sources: IAEA-PRIS, US-NRC, MSC 2013

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 has reduced Chinese ambitions. In addition, the average construction time for the 13 units in China was 5.9 years. At present, 28 units with about 28 GW are under construction and scheduled to be connected before 2020, which will bring the total to 45 GW. The prospects for significantly exceeding the original 2008 target of 40 GW for 2020 is unlikely (see China Focus). There are also indications that new reactors will be allowed only in coastal, not inland, sites, restricting the number of suitable sites available.

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. The net number of operating reactors would increase by 8 units and installed capacity by 25 GW in 2020. The overall pattern of the decline would hardly be altered, it would merely be delayed by some years. (See Figures 10 and 11).

Potential Newcomer Countries

A number of countries are actively developing and even constructing nuclear power plants for the first time. Many of these countries have long-held plans to develop nuclear energy, for decades in some countries. According to the World Nuclear Association (WNA), there are eight countries that are either actually building power plants for the first time (Belarus and United Arab Emirates [UAE]), have signed contracts (Lithuania and Turkey) or have committed plans for new-build (Bangladesh, Jordan, Poland, and Vietnam). This list of projects reflects important changes over the last few years with many countries experiencing a rolling-back from previously ambitious plans. This is in marked contrast to an analysis from the IAEA in 2012 that stated it expected Bangladesh, Belarus, Turkey, UAE, and Vietnam, and to start building their first nuclear power plants in 2012 and that Jordan and Saudi Arabia could follow in 2013.[45]

In all cases for these first time nuclear countries, even in the relatively rich Middle East, finance remains a if not the decisive one, in determining the choice of technology. However, what is striking is the extent to which in recent years the Russian industry has expanded its export policy through financial backing, with proposed projects in countries that are building reactors for the first time (Belarus, Turkey and possibly Bangladesh), as well as new proposals with financing in active countries like Finland and Hungary that already have nuclear power plants. The current situation in Ukraine raises questions over both the political support for such projects, especially in Europe, and with the threat of widening economic sanctions against Russia, the ability to fund all of the projects.

Other increasingly active players in the export market are Japanese companies, such as Toshiba and Hitachi. The lack of new-build opportunities domestically means that export markets have become essential to maintain their production capabilities, again with technology sales accompanied by a financial package. Like Russia, this effort encompasses proposals in countries that currently don't have programs (e.g. Lithuania and Turkey) as well as projects under development in more developed nuclear countries such as Bulgaria and the UK. The revised Japanese New Growth Strategy includes an explicit statement that the Government will actively support the export of nuclear power.[46]

The following section provides a country-by-country overview of potential newcomer countries.

Construction started in November 2013 at **Belarus's** first nuclear power plant at the Ostrovets power plant, also called Belarusian-1. According to World Nuclear News (WNN), construction of a second 1200 MWe AES-2006 reactor started in June 2014.[47] 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 February 2012,

[45] 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 5 May 2014.

[46] Satoru Koyama, "The Role of Export Credits in NPP Financing", Nippon Export and Investment Insurance, September 2013, see http://www.oecd-nea.org/ndd/workshops/wpne/presentations/docs/3_1_KOYAMA_2013_09_19_OECD_Seminer.pdf, accessed 14 July 2014.

[47] WNN (World Nuclear News), "First concrete for second Belarus unit", 3 June 2014, see http://www.world-nuclear-news.org/NN-First-concrete-for-second-Belarus-unit-0306144.html, accessed 14 July 2014.

Russian state-owned bank Vneshekonombank (VEB), and the Belarusian commercial bank Belvneshekonombank signed an agreement to implement the Russian export credit facility. 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.[48] The project assumes the supply of all fuel and repatriation of used fuel for the life of the plant. The fuel is to be reprocessed and the separated wastes returned to Belarus.[49] In December 2012, Vnesheconombank authorized a US$500 million credit line for the Belarusian Finance Ministry for preparation work.[50] This phase was scheduled to be completed by mid-2013 with concreting work to start in September 2013. 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.[51] However, these dates were revised and when construction was started, it was stated that the reactors will not be completed until 2018 and 2020.[52] More recently, it has been suggested that first power from unit 1 will be expected in November 2018.[53]

The Lithuanian Government has repeatedly criticized the safety of the project and has particular concerns as the proposed site is only 50 km from the capital Vilnius. In August 2013, the Lithuanian Prime Minister demanded that work stop on the project saying, "We have many concerns about safety and information we've asked for hasn't been provided, we urge Belarus to refrain from unilateral actions, we await their response and expect them to abide by international treaties they've signed."[54] In April 2013, a report by the Implementation Committee of the Espoo Convention concluded that the project was in violation of several of the Convention's rules, particularly in regard to site selection and public participation.[55] Despite this, construction is ongoing and in June 2014 first concrete was poured for the second unit. In functioning markets, insurance requirements would create a set of underwriters who would share a concern over site and plant safety. It sounds like this is not happening and that liability coverage for basic construction and operation may not even be in place.

In the **United Arab Emirates**, construction is underway at the Barakah nuclear project. In December 2009, a Korean consortium was awarded the contract for the construction; estimated at US$20 billion, the price reportedly excludes financing costs and the first fuel loads of four reactors. The consortium was reportedly awarded the contract because it could demonstrate the highest capacity factors, lowest construction costs, and shortest construction times and was chosen in preference to two other consortium one led by AREVA and the other by GE-Hitachi. The trade press has been unsure about this outcome, arguing that "it remains to be seen whether South Korea's bid was realistic, or whether it was seriously underpriced" and warning: "If things go wrong, Korea's entry to the nuclear export market could be short-lived.[56] Other press reports suggest that the original price did not include the cost of the first core, with a suggestion that Emirates Nuclear Energy Corporation (ENEC) has signed contracts worth about US$3 billion (Dh11.01 billion) to supply it with fuel for 15 years from the start of operations in 2017. The companies are ConverDyn (U.S.), Uranium One (Canada), Urenco (U.K.), Rio Tinto (U.K.) Tenex (Russia) and AREVA (France).[57]

The original financing plan for the project was thought to be US$10 billion from the Export-Import Bank of Korea, US$2 billion from the Ex-Im Bank of the US, US$6 billion from the government of

[48] NIW, "Belarus, Aided by Russia and Broke, Europe's Last Dictatorship Proceeds With NPP", 28 September 2012.
[49] WNN, "Construction start on first Belarus reactor", 7 November 2013.
[50] Belarusian Telegraph Agency, "Excavation of Belarusian nuclear station second power unit foundation pit begins", 1 February 2013.
[51] V.V. Kulik, Deputy Minister, Ministry of Natural Resources and Environmental Protection of the Republic of Belarus, Letter to the European Commission, dated 9 August 2011.
[52] Belarusian Telegraph Agency, "Excavation of Belarusian nuclear station second power unit foundation pit begins", 1 February 2013.
[53] Belarusian Telegraph Agency, "First core catcher for Belarusian nuclear station scheduled for installation in 2014", 2 April 2014.
[54] 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 10 June 2014.
[55] NIW, "Fast-Tracking New Build with First Concrete Pour", 8 November 2013.
[56] Energy Economist, "Prospects for Nuclear Power in 2012", Platts, February 2012.
[57] Gulfnews, "UAE's nuclear plans built on strong premises", 6 April 2013, see http://gulfnews.com/news/gulf/uae/general/uae-s-nuclear-plans-built-on-strong-premises-1.1163144, accessed 14 July 2014.

Abu Dhabi and US$2 billion from commercial banks[58]. However, it is now thought that this formula does not necessary reflect the final financial architecture, because ENEC is concerned about the size of interest over the 23 year debt package and also about higher total costs, which are said by some to be US$30 billion[59], with others suggesting that the costs are "closer to US$40 billion".[60]

In July 2010, a site-preparation license and a limited construction license were granted for four reactors at Barakah, along the coast 53 km from Ruwais.[61] The application is substantially based on the safety analysis prepared for South Korea's Shin-Kori units 3 and 4, the "reference plant" for the UAE's new-build program. A tentative schedule published in late December 2010, and not questioned since, projects that Barakah-1 will start commercial operation in 2017 with unit 2 operating from 2018. Construction of Barakah-1 officially started on 19 July 2012 and of Barakah-2 on 28 May 2013. In March 2013, the ENEC submitted its application for the construction of units 3 and 4, to the national regulator.[62] Construction is expected to start on unit 3 in 2014 and on unit 4 in 2015.

While steps have been taken to release information on the progress of construction through twice yearly reports from an International Advisory Board, it is noted that the level of detail "falls far short of what is customarily available to the public in new-build programs in other countries, particularly in the West."[63]

Lithuania had two large RBMK (Chernobyl-type) reactors at Ignalina which were shut down in 2004 and 2009 as part of the agreement to join the European Union. Since then there have been ongoing attempts to build a replacement 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 strategic investor and technology supplier to construct a nuclear plant by the end of 2020.[64] 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 get 22 percent and Latvia 20 percent.[65]

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.[66] 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".[67]

In March 2014, in response to the situation in Ukraine the seven parties represented in the Lithuanian Parliament signed an agreement on the strategic priorities through 2020. This included the construction of a Liquefied Natural Gas plant, the synchronization of the grid with other 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".[68] In April 2014, the Prime Minster revised his views and said that the project might proceed and that it was dependent on the answers to 80 questions submitted to Hitachi, which included questions on the costs of the project, the price of

---

[58] Sang-Baik Kim, Jan-Horst Keppler, "Case Studies On Financing And Electricity Price Arrangements — The Barakah Nuclear Power Plants, The United Arab Emirate", OECD Nuclear Energy Agency, Nuclear Development Division as presented at OECD NEA Workshop on Electricity Prices and Nuclear New Build, 19 September 2013, see http://www.oecd-nea.org/ndd/workshops/wpne/presentations/docs/4_2_KIM_%20Barakah%20presentation.pdf, accessed 14 July 2014.

[59] Bloomberg Businessweek, "U.A.E.'s Nuclear Power Program Said to Cost $30 Billion", 28 November 2011, see http://www.businessweek.com/news/2011-11-28/u-a-e-s-nuclear-power-program-said-to-cost-30-billion.html, accessed 14 July 2014.

[60] NIW, "United Arab Emirates: No Plans for Second NPP", 20 April 2012.

[61] ArabianBusinesss.com, "ENEC Welcomes Regulator's License Approval", 11 July 2010.

[62] WNN, "Application in for the next two Barakah units", 4 March 2013.

[63] NIW, "Oversight Board Cites Concrete Issue at Barakah", 3 March 2014.

[64] 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 10 June 2013.

[65] NIW, "Lithuania", 11 May 2012.

[66] Reuters, "Lithuanians send nuclear plant back to drawing board", 15 October 2012.

[67] NIW, "Lithuania, Prospective PM Wants to Scrape Visaginas", 9 November 2012.

[68] Ministry of Energy of Lithuania, "Lithuanian Parliamentary Parties Reached an Agreement Regarding the Key Strategic Energy Projects", 31 March 2014.

electricity and the capabilities of synchronizing with the Western electricity grid. The Energy Minister Jaroslav Neverovich, has said there is a good chance the projects will proceed.[69]

In **Turkey** two projects are being developed, but rather than proceeding with a single builder and design, the Government has decided to undertake two different reactor designs, two different sets of contractors, and two different financing models. 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 expected to start in 2015 and cost of US$20–25 billion for 4.8 GW. At the heart of the project is a Power Purchase Agreement (PPA), which is for 15 years and 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 will be sold at a guaranteed price for the first 15 years, with the rest to be sold on the market, where the average wholesale electricity price for 2010 was US$93.8/MWh. The electricity price within the PPA (excluding VAT) is reported to be U$123.5/MWh, with a possibility to increase the price up to US$153.3/MWh to ensure the payback of the project.[70] Furthermore, the fixed price of the PPA is above the feed-in tariffs being offered for renewables, as the prices for 10 years for hydro and wind are US$73/MWh, geothermal US$105/MWh and solar US$103 /MWh.[71]

The CEO of Akkuyu JSC, the project company set up by Russia's Rosatom, said in October 2013 that the project was going to be operational by mid-2020, a delay of about 18 months from an earlier planned start-up date. Further delays are likely as there have been problems with the Environmental Impact Assessment, which when submitted in July 2013 was rejected by the Ministry of Environment. To date, it is said the Russian government has invested US$2 billion in the project.[72] It is thought this latest timetable might also slip, as the Turkish Atomic Energy Authority (TAEK) has failed to attract suitable firms to undertake an independent review of Rosatom's design.[73]

The other project is at Sinop, on the Northern coast, where a 4.4 GW project has been proposed using an ATMEA reactor design. If completed this would be the first reactor of this design, jointly developed by Mitsubishi and AREVA. The estimated cost of the project is US$22 billion and involves a consortium of Mitsubishi, AREVA, GDF Suez and Itochu, who between them will own 51 percent of the project with 49 percent owned by Turkish companies including the State-owned electricity generating company (EUAS). The project is further complicated by the region's lack of large scale demand and the existing coal power stations, so1,400 km of transmission lines will be needed to take the electricity to Istanbul and Ankara. Further problems for the development of nuclear power in Turkey have been identified including the updating of nuclear liability laws and the establishment of the necessary legal and regulatory frameworks.[74] Industry analysts have concluded that "Turkey hasn't come close to establishing a viable regulator and remains more focused on securing a good financial deal".[75]

In November 2011, the **Bangladesh** Government's press information department said that it would sign a deal with the Russian Government for two 1000 MW units to be built by 2018 at a cost of US$2 billion.[76] Since then negotiations have been ongoing and the start-up date postponed, while the price has risen. In January 2013 Deputy Finance Minister of Russia Sergey Storchak and Economic Relations Division (ERD) Secretary of Bangladesh Md. 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).[77]The deal was only for US$500 million[78] and will only cover the site

[69] Baltic Course, "Lithuania waiting for Hitachi's answers to nearly 80 questions concerning NPP", 2 April 2014.
[70] Marco Cometto, "Financing the Akkuyu NPP in Turkey", OECD/NEA, Nuclear Development Division, as presented at OECD/NEA Workshop on Electricity price and Nuclear New Build, 19 September 2013, see http://www.oecd-nea.org/ndd/workshops/wpne/presentations/docs/4_1_Cometto_Akkuyu.pdf, accessed 14 July 2014.
[71] Chadborne and Parke, "Turkey Moves to Boost Renewable Energy; new feed-in tariffs and other incentives for renewable energy", January 2011, see http://www.chadbourne.com/Turkey_Renewable_Energy_projectfinance/, accessed 14 July 2014.
[72] NIW, "Rosatom Funds Akkuyu while Ankara Restructures Legal Infrastructure", 18 April 2014.
[73] Reuters, "Turkey's first nuclear plant facing further delays – sources" 7 February 2014, see http://uk.reuters.com/article/2014/02/07/uk-turkey-nuclear-delay-idUKBREA160P220140207, accessed July 2014.
[74] NIW, "Turkey's Second Project Totters Forward", 25 April 2014.
[75] NIW, "Newbuild: The Collapse of the Public Technology Tender", 25 April 2014.
[76] Bloomberg, "Bangladesh to Sign Deal With Russia to Build Nuclear Power Plant", 2 November 2011.
[77] Energy Bangla, "Bangladesh, Russia sign nuclear power pact", 17 January 2013.
[78] 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.

preparatory work.[79] In October 2013, a ceremony was held for the formal start of the preparatory stage,[80] but formal construction is not expected to begin until 2015. At the time of the October inauguration, the cost of construction was revised upwards and it was suggested that each unit would cost between US$1.5-2 billion.[81] These cost estimates rose again 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.[82] In Russia, it is expected that the total cost of the project is more likely to be around US$10 billion[83], the cost of similar deals in Belarus and Hungary. It is expected that Bangladesh will be responsible for 10 percent of the project with the rest of the financing in the form of a loan from Russia.

A former chief engineer of the Bangladesh Atomic Energy Commission has raised concerns about the timetable for construction and suggested that the power plant is unlikely to be in operation before 2023.[84] As with many other countries, access to water has been identified as a potential stumbling block of the Rooppur plant, as it is to be sited on the banks of the river Padma (a distributary of the Ganges that runs through India). During the first half of the year, much of the river's water resource is already withdrawn by India through the Farakka Barrage, leaving insufficient cooling water for the plant and other activities in Bangladesh.[85]

Jordan has been encouraging the development of nuclear power for some decades and has discussed possible projects with AECL, GDF-Suez, AREVA and KEPCO. In May 2010, three consortia were shortlisted: the proposed designs were the ATMEA-1 (from a consortium of AREVA and MHI, as projected in Turkey), EC6 (from AECL), and the AES-93 (from Rosatom). However, 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.[86] Prior to the vote, the Parliament's Energy Committee had published a report accusing the Jordanian Atomic Energy Commission (JAEC) of deliberately "misleading" the public and officials over the program by "hiding facts" related to costs.[87] The JAEC responded by saying it wouldn't be able to produce a full evaluation until the start of construction of the plant.[88]

Despite the parliamentary opposition, in October 2013, JAEC announced that the Rosatom reactor was the preferred bidder. The value of the engineering, procurement and construction contract is said to be US$10 billion for the two 1000 MW units. It is suggested that Jordan will cover 50.1 percent of the contract, with Rosatom covering 49.9 percent and therefore being an investor and operator of the plant.[89] It is now envisaged the earliest that construction start would be 2019.[90] As with other countries in the region, water is a critical factor and affects choices in the energy sector. 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".[91] There has been uncertainty about where

[79] The Star, "Russia to lend $1.5B to Bangladesh to build nuclear power station, buy arms", 15 January 2013.
[80] BBC, "Bangladesh nuclear power plant work begins", 2 October 2013.
[81] Bangladesh Awami League, "PM Sheikh Hasina inaugurates Rooppur Power Plant", see http://www.albd.org/index.php/en/updates/news/281-pm-sheikh-hasina-inaugurates-rooppur-power-plant, accessed 11 June 2014.
[82] The Independent (of Bangladesh), "Roopur N-plant cost to double", 7 April 2014, see http://www.theindependentbd.com/index.php?option=com_content&view=article&id=210774:roopur-n-plant-cost-to-double&catid=129:frontpage&Itemid=121, accessed 11 June 2014.
[83] Moscow Times, "Rosatom to Build Bangladesh's First Nuclear Power Plant", 3 October 2013.
[84] The Daily Star, "How to repay Russian credit for Rooppur?", 23 October 2013, see http://archive.thedailystar.net/beta2/news/how-to-repay-russian-credit-for-rooppur/, accessed 11 June 2014.
[85] A. Rahman, "Is Bangladesh Sleepwalking to Nuclear Power", New Age Online, 7 February 2013.
[86] Jordan Times, "Deputies vote to suspend nuclear project", 30 May 2012, see http://jordantimes.com/Deputies+vote+to+suspend+nuclear+project-48497, accessed 1 June 2012.
[87] Ibidem.
[88] Monitor Global Outlook, "Jordan clings on to nuclear ambitions, despite delays", 10 January 2014, see http://monitorglobaloutlook.com/news-story/jordan-clings-on-to-nuclear-ambitions-despite-delays/, accessed July 2014
[89] Construction Week, "Jordan seeks Russian help to go nuclear", 11 March 2014, see http://www.constructionweekonline.com/article-27022-jordan-seeks-russian-help-to-go-nuclear/#.U0VKGahdXD8, accessed 14 July 2014.
[90] NIW, "Briefs – Jordan", 18 April 2014.
[91] Mining.com, "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 11 June 2014.

the plant would be located, with the initial plans for siting it at Al-Aqaba being abruptly abandoned; current plans are to site the reactor at Al-Samra, which had initially been ruled out.[92]

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. This was subsequently subject to a Strategic Environmental Assessment (SEA), which was approved in January 2014. In April 2014, Greenpeace started legal procedures against the Assessment, as it did not include an adequate public participation process. The SEA drew around 60,000 submissions, a majority coming from neighboring Germany. The plan included 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.

In January 2013 the Polish utility PGE selected Australian consulting firm Worley Parsons 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.[93] Two potential sites are under investigation, one in the Lubiatowo Dunes in the municipality (Gmina) of Choczewo, the second on the old location at Zarnowiec in the community of Krokowa, both around 80 km north of Gdansk. A third location at Gąski, 150 km further west, was rejected by 95 percent of the votes in a local referendum, but has not formally been removed from the list of potential sites. The proposed US$13–19 billion project is to start with site selection in 2016 with construction scheduled to begin in 2019. It is intended that the first nuclear power station would be operational by 2024 and the second by 2035.[94] A number of vendors, including AREVA, Westinghouse, and GE-Hitachi, are all lobbying Warsaw aggressively.[95] PGE formed a project company PGE EJ1, which also has a 10% participation each from the other large Polish utilities, Tauron and Energia, as well as the state copper mining firm KGHM. PGE is now said to be looking for technology and financial partners for the project. 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. The consortium bidding included, Amec Nuclear (U.K.), Tractebel Engineering (Belgium), Mott MacDonald and Exelon Engineering. The winning consortium is expected to be announced later in 2014.

In October 2010, **Vietnam** 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), and with operations projected to begin in 2020.[96] In April 2013, the Song Da Corporation stated that it expected to start construction in the next 2–3 years,[97] but further delays were announced in January 2014, with a revised expectation that construction would begin in 2017 and therefore startup only in 2023.[98] 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 taking back used 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.[99]

Like Turkey, Vietnam has also signed an intergovernmental agreement with Japan for the construction of a second nuclear power plant in Ninh Thuan province, 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. In July 2011 the

[92] Ali Ahmad, "Can SMRs Rescue Jordan's Nuclear Program?", NIW, 17 June 2014.
[93] NIW, "Briefs – Poland", 8 February 2013.
[94] Economist, "Polish Energy, Going nuclear", 31 January 2014, see http://www.economist.com/blogs/easternapproaches/2014/01/polish-energy, accessed July 2014.
[95] NIW, "Potential and Existing Global Nuclear Newbuild Projects", 25 April 2014.
[96] Global Energy Magazine, "Japan and Russia to Build Ninh Thuan Nuclear Power Plants for Vietnam", 3 November 2010.
[97] Investvine, "Vietnam prepares for nuclear power", 13 April 2013.
[98] WNN, "Vietnamese delay confirmed", 28 January 2014, see http://www.world-nuclear-news.org/NP-Vietnamese-delay-confirmed-2801141.html, accessed 14 July 2014.
[99] WNA, "Nuclear Power in Vietnam", updated May 2014, see http://world-nuclear.org/info/vietnam_inf131.html, accessed 17 July 2014.

government issued a master plan detailing plans for the Ninh Thuan 1 & 2 nuclear power plants including a total of eight 1000 MWe-class reactors, one coming on line each year 2020–27 and then two more by 2029 at another central location. EVN is currently to be the sole investor in the reactors and is still preparing the feasibility studies.[100] In May 2013, the Government set up a National Council for Atomic Energy, which is designed to identify the strategies and priorities for the development of nuclear power.[101]

However, in February 2014, Anh Tuan Hoang, the director General of the Vietnam Atomic Energy Agency, told an industry conference in Cape Town that they would need to reschedule the construction plans in order to meet safety priorities, staffing concerns and investment regulations. He further concluded that "I myself think it takes several years to fulfill the necessary investment and safety requirements."[102]

Another group of countries has been actively developing nuclear power and in the past were said to have been close to launching new programs. For a variety of reasons, these developments have now been slowed or abandoned. These countries include Indonesia, Italy, and Saudi Arabia.

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 decades, 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.[103] In July 2007 Korea Electric Power Corp. and Korea Hydro & Nuclear Power Co. (KHNP) signed a memorandum of understanding with Indonesia's PT Medco Energi International to progress a feasibility study on building two 1000 MWe OPR1000 units from KHNP at a cost of US$3 billion. However, the current plans are much more modest and envisage the construction of a 30 MW plant, starting in 2015. The plant would be built in Serpong, Banten by the National Nuclear Energy Agency, or BATAN, and used to generate power for the surrounding areas.[104]

All of **Italy**'s nuclear power plants were closed following a post-Chernobyl referendum in 1987. This has not stopped the country's largest electricity utility, ENEL, from buying into nuclear power projects in other countries, including France, Slovakia, and Spain. In May 2008, the government introduced a package of nuclear legislation that included measures to set up a new national nuclear research and development entity, to expedite licensing of new reactors at the nuclear power plant sites, and to facilitate licensing of new reactor sites. The government's goal then was to build ten new reactors, meeting 25% of the country's electricity demand. ENEL and EDF subsequently stated that they intended to build four EPR reactors by 2020. In January 2011, however, the Constitutional Court ruled that Italy could hold a referendum on the planned reintroduction of nuclear power. The question posed in the June 2011 in the referendum, was whether voters want to cancel some of the nuclear legislative and regulatory measures that have been taken by the government over three years, but the debate was clearly about the use of nuclear power in Italy.[105] The referendum motion was supported by 94 percent of those who participated in the vote, i.e. an absolute majority of the population voted against the use of nuclear power in Italy, ending any new nuclear ambitions in the country.

[100] Nucleonics Week, "Vietnam might require investors to set up fund for closure costs", 11 January 2013.
[101] WNN, "New nuclear development council for Vietnam", 9 May 2013.
[102] NIW, "Vietnam, Behind the Pause", 2 February 2014.
[103] Hanan Nugroho, "Development of Nuclear Power in Indonesia: Stop or Go?", Jakarta Post, 5 May 2010.
[104] Investvine, "Indonesia to build first nuclear power plant", 8 February 2014, see http://investvine.com/indonesia-to-build-first-nuclear-power-plant/, accessed 14 July 2014.
[105] GreenOptimistic.com, "Italy's Nuclear Power Comeback, Facing Strong Opposition and Referendum", 13 January 2011.

In 2012, the IAEA suggested that in 2013 the Kingdom of **Saudi Arabia** might start building its first nuclear reactor.[106] 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 hydrocarbon resources."[107] 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 said that it 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 would be planned to be online in ten years and then two more per year until 2030.[108] However, the KA-CARE nuclear proposal has still not been approved by the country's top economic board, headed by King Abdullah, and in March 2013, it was reported that a KA-CARE official has said that a tender is now unlikely for 7–8 years. However, in November 2013, it was 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.[109]

Construction Times

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 12 illustrates, in the 1970s and 1980s construction times were quite homogenous, while in the past two decades they have varied widely. The two units that started up in the first half of 2014, a Chinese and an Argentinian reactor, took respectively 5.2 and 32.9 years to build. Four units connected to the grid in 2013, three Chinese and one Indian plant, averaged 7.4 years between them. The Chinese units were a lot quicker than the Russian-built Kudankulam-1 reactor in India that took over 11 years to complete.

The reasons for gradually increasing construction times are not well understood. It is clear that continuously increasing safety requirements and, in some countries, lengthy legal cases due to public opposition have played a role. Growing system complexity as a consequence of the previous conditions is also likely to have affected construction times and costs.

Most but not all countries have experienced this symptom and the latest generation of operating units provides an illustration of this. Over a 10-year period between 2004 and July 2014 a total of 36 reactors started up, with an average construction time of 9.4 years and a large range from 3.8 to 36.3 years. There are significant differences between the nine countries that started up reactors during that period. (See Table 2 for details.)

All 37 reactors, except for one (Argentina), that started up over the past decade are located in Asia (China, India, Iran, Japan, Pakistan, South Korea), or Eastern Europe (Romania, Russia, Ukraine).[110] With 13 units, China started up the largest fleet, followed by India (7) and South Korea (4).

Construction times over the past decade were most impressively short in Japan and South Korea with 4.4 years and 4.5 years on average for the four units built in each country. However, recent history has raised doubts in both countries over quality-control issues, with Japan having to reinvent a Nuclear Regulation Authority and South Korea recovering from a major scandal involving widespread forging of safety-relevant quality-control documents. The average construction time in China was just under six years, ranging from 4.4 to 11.2 years.

---

106 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 5 May 2012.

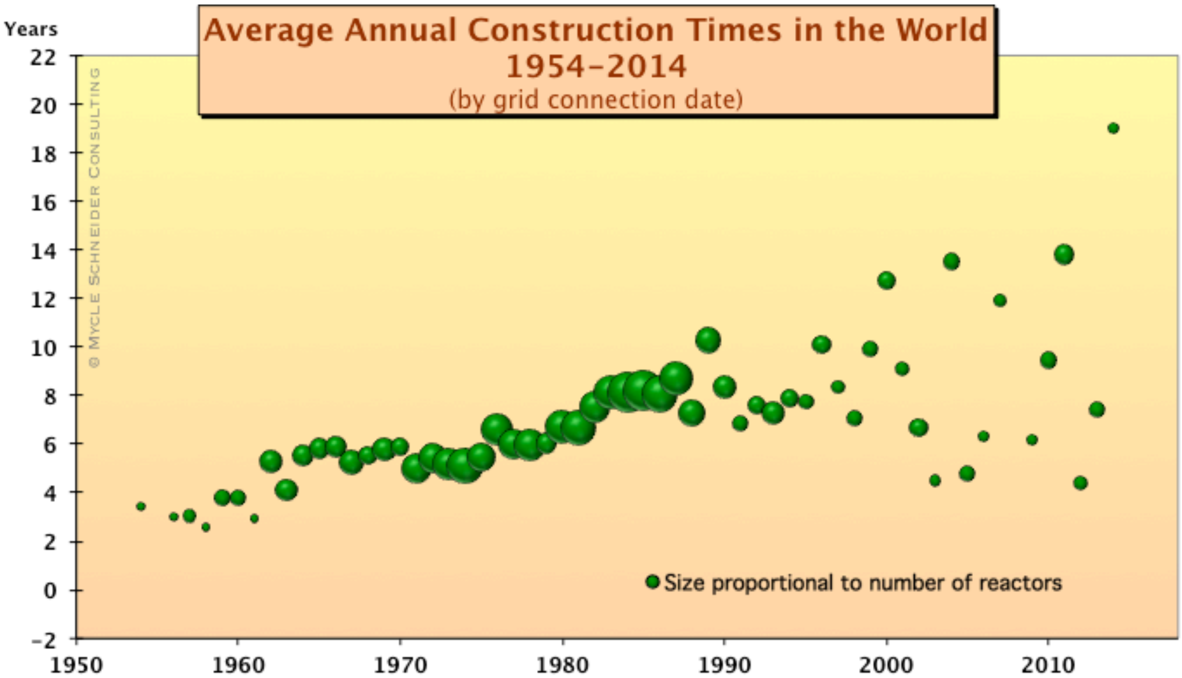
107 World Politics Review, "Saudi Arabia's Nuclear Ambitions Part of Broader Strategy", 16 June 2011, see http://www.worldpoliticsreview.com/articles/9186/saudi-arabias-nuclear-ambitions-part-of-broader-strategy, accessed 6 May 2012.

108 WNA, "Emerging Nuclear Energy Countries", February 2012, see http://www.world-nuclear.org/info/inf102.html, accessed 7 May 2012.

109 NIW, "Briefs, Saudi Arabia", 15 November 2014; See also Ali Ahmad and M.V. Ramana, "Too costly to matter: Economics of nuclear power for Saudi Arabia", Energy Journal, 2014.

110 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.

Figure 12: Average Annual Construction Times in the World 1954–2014



Sources: MSC based on IAEA-PRIS 2014

Note: The bubble size is equivalent to the number of units started up in the given year.

The last unit to start up in the world, on 27 June 2014, was Argentina's Atucha-2 reactor after 33 years of construction. However, Iran holds the record, with its only commercial nuclear power reactor taking over 36 years. Romania built for over 24 years to finish its second unit and Russia experienced an average of just under 24 years to complete three reactors.

Table 2: Reactor Construction Times 2004-2014

Construction Times (in years) *Startups between 2004 and July 2014*				
Country	**Units**	**Mean Time**	**Min**	**Max**
China	13	5.9	4.4	11.2
India	7	7.4	5.1	11.6
Japan	4	4.4	3.8	5.1
S. Korea	4	4.5	4.0	5.3
Russia	3	23.8	19.2	26.8
Ukraine	2	18.8	18.2	19.5
Argentina	1	32.9	32.9	32.9
Iran	1	36.3	36.3	36.3
Pakistan	1	5.3	5.3	5.3
Romania	1	24.1	24.1	24.1
Total	**37**	**10**	**3.8**	**36.3**

Sources: IAEA-PRIS, MSC, 2014

Construction Times and Costs of Reactors Currently *Under Construction*

As indicated in the General Overview section, at least 50 of the units listed as "under construction" have encountered costly construction delays, often of many years. All of the 17 remaining units were started within the past three years or have yet to reach their projected start-up date, making it difficult to assess whether they are on schedule.

The Economics of Nuclear Power—Rapidly Changing

Nuclear Power Plant Lifetimes

The drop-off of orders for new nuclear power plants, particularly in the developed world, from 1980 onwards, has left the world with an ageing stock of nuclear power plants. When these plants were built, it was generally assumed that they would last for 30 to 40 years and then be replaced by cheaper, more advanced designs. In fact, costs have escalated dramatically, so replacement is an extremely expensive option and in many cases is politically problematic. Consequently, there has been an increasing interest in lifetime extension of existing plants. However, at the same time, as operating costs increase, some plants are in danger of not covering their operating costs and hence being retired.

Early Closure

The assumption that operating costs are always so low that they are bound to be covered by income from sales of electricity is not justified. Around 1990, in the USA, when natural gas prices were low, a number of relatively new nuclear power plants were retired because their operating costs alone were expected to be higher than the cost of building *and* operating a new gas-fired power plant. In the U.K. at about the same time, the attempt to privatize the nuclear power plants revealed that their operating costs alone were about double the expected wholesale electricity price and the plants were only able to remain in service because of a large consumer subsidy (worth about £1 billion or US$1.7 billion per year).

In both cases, these high costs led to a serious attempt by the utilities to reduce operating costs. In fact the costs are largely fixed but by making the plants more reliable, both operating and capital costs can be spread over greater electricity sales. In the USA, the threat of early closure on economic grounds passed due to higher gas prices and more reliable operation. In the U.K., more reliable operation with the newer plants meant that the costs could be covered, allowing these newer plants—14 Advanced Gas-cooled Reactors (AGR) and one PWR—to be privatized in 1996 as British Energy. However, in 2002, when wholesale prices fell again, British Energy could no longer cover its operating costs and was bankrupted. Again, it was saved by public intervention. The re-launched company was bought by EDF in 2009. By then, the average operating costs of its plants had increased by 150 percent. However, the wholesale electricity price had increased even faster and the company remained profitable. EDF does not publish the operating costs of its U.K. plants so it is impossible to know whether costs have continued to increase, but wholesale prices have continued to increase.

A challenge to the continued operation of U.S. nuclear plants came in 2013, mainly as a result of low gas and wind power prices. Five retirement decisions were taken: Crystal River 3, Kewaunee, San Onofre 2 and 3, and Vermont Yankee.

- **Crystal River 3**: The Crystal River plant was commissioned in 1987 and was closed in 2009 for refueling and maintenance, including replacement of the steam generators. Steam generator replacement is a major and costly operation, expected to be carried out maybe once or twice during the life of a plant. However, during the operations, damage was done to the concrete walls of the containment building. Repairs were nearly complete in 2011 when further damage occurred, preventing the reactor being returned to service. The operator announced three months later that it wanted to rebuild the containment building by 2014 at a cost of up to US$1.3 billion. However, the new owner, Duke Energy, took a different view, and in February 2013 announced the retirement of the plant. The credit-rating agency Fitch cited "rising repair cost estimates, construction risks and the low gas price environment",[111] as justifying the decision. In short, the plant was at risk both from uncertainty about its own costs and the costs of alternatives, especially natural gas.
- **Kewaunee**: The Kewaunee plant was commissioned in 1974 and its present owners, Dominion Power, bought it in 2005. The reasons for its closure were much more straightforwardly its

[111] Nucleonics Week, "Duke decision to retire Crystal River-3 positive, financial analysts say", 7 February 2013.

operating costs with no major issues of repairs or plant condition.[112] When Dominion bought the plant, wholesale electricity prices in the region were about US$40-50/MWh, but by 2013, the low price of gas meant this price had fallen to only US$30/MWh, and increasing regional competition from wind power put even further downward pressure on wholesale prices. Kewaunee was a so-called "merchant plant", in other words, it had to compete to sell its power in the market, and with gas prices as low as they were in 2013, this was not possible.

- **San Onofre 2 and 3**: The retirement of the San Onofre units, completed in 1983/84, was related to the cost of replacing the steam generators.[113] The plants had been closed in January 2012 due to the discovery of tube wear in the steam generators, which had only been replaced as recently as 2010 (unit 2) and 2011 (unit 3) at a cost of US$602 million. The owners claimed in November 2012 that it was safe to continue to operate the plants at 70 percent capacity, but by May 2013, it had been unable to convince the NRC of its case and the plant was retired. The issue for the owners is how far it will be able to recover the replacement power costs from its consumers. California is a regulated state and in September 2013, there were doubts as to whether the regulator, the California Public Utilities Commission (CPUC), would allow these costs to be recovered.[114] By November 2013, it seemed likely that CPUC would rule that these replacement power costs would have to be refunded to consumers.[115] The closure of the plant therefore seemed more related to uncertainties about its own future costs and uncertainty about repair costs rather than to the cost of gas-fired alternatives.
- **Vermont Yankee**: Vermont Yankee is one of the USA's oldest operating reactors, commissioned in 1972. In August 2013, Entergy announced that Vermont Yankee would close in the third quarter of 2014.[116] As discussed later, the application to life-extend the plant had been problematic and permission was granted in 2011 after five years instead of the expected two years. However, state-level opposition to its operation meant its future was in doubt even when NRC permission to extend the lifetime of the reactor had been given, and especially after the Fukushima disaster where the oldest Fukushima reactor was of similar design to that of Vermont Yankee. Entergy cited low natural gas prices, the high costs of operating a single-unit nuclear plant and low wholesale electricity prices.

Energy analyst Mark Cooper identifies 38 further U.S. reactors as being under risk of closure on economic grounds, with 12 under particular threat.[117] Of these 12, one owner has already chosen to retire the plant (Vermont Yankee); five are at risk primarily because they are not economic (Nine Mile Point 1, Fitzpatrick, Ginna, Millstone 3, and Clinton); one is at risk due to poor performance (Fort Calhoun); one is at risk because of the high cost of repairs (Palisades); and four are at risk due to a combination of factors (Indian Point, Oyster Creek, Davis Besse and Pilgrim).

In May 2014, four reactors owned by Exelon, Byron, Oyster Creek and Quad Cities (two units), were also reported to be at risk of closure because they were not competitive in an auction to provide power to the grid.[118] Quad Cities and Oyster Creek were amongst the 38 plants Cooper identified as being at risk, but Byron was not. This shows how quickly the outlook for an operating nuclear plant can change with changes in fossil fuel prices, the need for significant repairs and the need for significant safety upgrades. The more reactors are exposed to unpredictable wholesale electricity markets, the more vulnerable nuclear plants become. The general trend toward higher operating costs (especially for major repairs that may increase with age) and lower wholesale power prices does not bode well for a substantial fraction of USA reactors now operating.[119]

A similar development is taking place in other countries. In Germany, E.ON announced in March 2014 its intention to close its Grafenrheinfeld plant in May 2015, seven months earlier than required by law, because of "lack of cost-effectiveness" arguing that the particular weight of the

---

112 For more details of the plant's retirement, see Nucleonics Week, "Dominion's Kewaunee nuclear plant shuts permanently", 9 May 2013.
113 Nuclear Fuel, "SCE decision to retire San Onofre came after delays in NRC action on restart", 10 June 2013.
114 Nucleonics Week, "Proposed CPUC decision would deny San Onofre cost recovery", 26 September 2013.
115 Orange County Register, "Edison to fight decision to refund $94 million in San Onofre costs", 23 November 2013.
116 WNISR, "Another US Reactor Scheduled for Closure", 28 August 2013, see http://www.worldnuclearreport.org/Another-US-Reactor-Scheduled-for.html, accessed 5 June 2014.
117 Mark Cooper, "Renaissance in reverse: Competition pushes aging US nuclear reactors to the brink of economic abandonment", 18 July 2013, see http://will.illinois.edu/nfs/RenaissanceinReverse7.18.2013.pdf, accessed 22 May 2014.
118 Chicago Tribune, "Auction results place Exelon power plants in jeopardy". 27 May 2014.
119 A.B. Lovins, "The economics of a U.S. civilian nuclear phaseout", Bulletin of the Atomic Scientist, March/April 2013, see http://bos.sagepub.com/content/69/2/44.full.pdf+html, and www.rmi.org/Knowledge-Center%2FLibrary%2F2013-09_ BulletinAtomicScientists, both accessed 21 July 2014.

German nuclear fuel tax would be unbearable considering the short remaining lifetime of the reactor.[120]

Lifetime Extension

The escalation in real construction cost of new reactors and the political issues new construction often raises has led utilities to examine whether extending the life of existing plants was economically more attractive than new-build. Two countries, USA and France, are in the lead in this process and represent rather different approaches to the issue.

There is variation between countries on the duration of the license for plants. In the USA, nuclear plants were permitted to operate for 40 years by the Nuclear Regulatory Commission (NRC), after which the plant must be shut down unless the license is renewed in time. In France, nuclear power plants are subject to a 10-yearly review by Nuclear Safety Authority (ASN), when they are cleared for a further decade of operation. This does represent an important difference with U.S. reactors required only to comply with their initial safety specification, while in France operating reactors must meet an evolving standard with the aim of requiring reactors meet current safety standards, or as close to those as possible.

This leads to an important distinction between how France and USA evaluate life-extension proposals. Pierre-Franck Chevet, President of ASN was reported as saying: "ASN will evaluate life extensions for all of France's nuclear reactors using the latest safety standards for generation III reactors, regardless of when the reactor was built. ASN's requirements are very different from how the U.S. nuclear regulator evaluates life extensions, because in the US, life extensions are based on the initial safety standards from when the reactor was built."[121] While "evaluating" extensions on the basis of latest standards is not the same as "imposing" the latest standards, this distinction does seem to go some way to explaining why the process of life extension appears to have been much smoother in the USA than in France.

Nevertheless, in the USA, the 40-year license does not give the operator *carte blanche* for 40 years; the license can be withdrawn at any time. For example, in 2002, severe reactor head degradation was found at the Davis-Besse plant, and the unit was kept offline for two years until repairs had been carried out to the NRC's satisfaction.[122]

USA

The USA has the largest and amongst the oldest stocks of reactors in the world and, as a result, consideration of life extension began there long before other countries. The diversity of the reactor stock, with four reactor vendors each with several different basic reactor designs often customized for a particular site means the process is much more complex than, say, France where there are essentially only three designs, all PWRs, only one of which (the 900 MW design) has reactors which are within 10 years of their 40th birthday.

The NRC makes clear that the decision to grant nuclear power plants a 40-year life was not based on an assessment of the likely operating life of reactors, but on economic and anti-trust considerations. NRC dates its work on lifetime extension to a 1982-workshop it ran, which concluded that life extension was likely to be feasible. After consultations and pilot projects, a new rule was introduced in 1995 allowing nuclear plant licenses to be renewed for up to 20 years on top of the original 40 years.

The main features of the procedure are:

- The process from application to decision on renewal is expected to take 30 months;
- Applications can be made any time up to 20 years before the expiry of the existing license;
- A plant for which an life-extension application has been made more than five years before expiry of the existing license can continue in operation until a decision is made if a decision has not been made at time of license expiry;
- A plant for which a life-extension application has been made less than five years before expiry of the existing license cannot continue in operation if a decision has not been made at time of license expiry.

[120] E.ON, "E.ON nimmt Kernkraftwerk Grafenrheinfeld vor Ende der Laufzeit außer Betrieb", 28 March 2014, see http://www.eon.com/de/presse/news/pressemitteilungen/2014/3/28/eon-nimmt-kernkraftwerk-grafenrheinfeld-vor-ende-der-laufzeit-ausser-betrieb.html, accessed 26 June 2014.
[121] Platts, European Power Daily, 21 February 2014.
[122] Inside NRC, "Seeking balance, NRC proposes $5.45-million fine for Davis-Besse", 2 May 2005.

The process involves two parallel review streams: one reviewing safety issues and one environmental issues. The standard the plant must achieve is the 'licensing basis', which represents an evolving set of standards as experience and knowledge grows. This suggests that an ALARA (for risk "as low as reasonably achievable") approach is being followed. Lifetime extension does not therefore mean the plant owner cannot be required to carry out safety upgrades after extension has been given. In addition, the NRC will carry out inspections to verify the information in the application, and NRC schedules public meetings where the public can question the application.

With one exception (Arkansas), multi-unit sites are dealt with under a single application even where different designs are involved and, in one case (Millstone), even where a different vendor was involved. By December 2013, only one plant (Oyster Creek) had submitted a lifetime extension application within 5 years of expiry of its existing license, and a significant number had been operating for fewer than 25 years when they applied for a lifetime extension. None of those yet to apply for a lifetime extension has been operating for more than 30 years.

Of the 45 lifetime extensions granted by December 2013, only seven were granted after the Fukushima disaster and none since May 2012. How far this reflects more stringent reviews post-Fukushima and how far it reflects that relatively few applications remain, some of which were seen as problematic before Fukushima, is not clear. There has been no specific statement from NRC that it is reviewing and tightening its requirements.

In August 2012, the NRC voted to impose a moratorium on new and extended operating licenses until there was a new decision on siting of a high-level waste repository following the Obama administration's decision to abandon Yucca Mountain. However, the process of the reviews is continuing.[123] The NRC has stated that it expects to receive applications for life extension from 60 to 80 years by 2017/18.[124]

France

Unlike the USA, in France reactors are not licensed for a pre-determined period but they are subject to conditional reviews effectively every 10 years, so the process of life extension as applied in USA where there is a time-limited license does not apply. However, the French Nuclear Safety Authority (ASN)[125] has said it could give indicative permission for 20-year operation based on a strong safety case.[126] The relatively limited period that EDF has some assurance of continued licensing does impose risks on EDF: an upgrade that would be economically justifiable if it gave 20 years more life might not be justifiable if only 10 years of operation was assured. Table 3 also shows that the very rapid rate of completion of plants during 1980-85 with 31 plants coming on-line in that period, will create a large call on capital to complete the upgrades required whilst at worst for EDF, if life-extension is not granted, it could lose nearly half its nuclear capacity in about six years. In terms of cost, a presentation by EDF to a French National Assembly Inquiry in February 2014 showed that in current money, the investment cost to build France's 58 operating reactors was about €100 billion (US$140 billion). Replacing them would cost about three times as much, while life-extending them appeared likely to cost about the same as the initial construction cost.[127]

ASN carries out a review at a maintenance outage after about 10 years of operation for each reactor in France to determine, in principle, what measures are needed to determine whether the plant can be licensed for a further 10 years (see Table 3). This review is also known as the Periodic Safety Review (PSR). ASN's reviews are in two parts. In the first part, generic issues for the three basic designs, 900MW, 1300MW and the N4 designs (Chooz B and Civaux) are identified. In the second part, a review for each reactor is carried out to determine the applicability of these generic issues to the particular reactor and also to identify any reactor specific issues.

---

[123] Nucleonics Week, "No final licensing votes until waste rule resolved: commissioners", 9 August 2012.
[124] NIW, "NRC and Industry at Odds Over 60-80 Year License Extensions", 28 February 2014.
[125] The Autorité de Sûreté Nucléaire (ASN) was previously known as Service Central de Sûreté des Installations Nucléaires (SCSIN) until 1991, Direction de la Sûreté des Installations Nucléaires (DSIN) until 2002, then Direction Générale de la Sûreté Nucléaire et de la Radioprotection (DGSNR) until 2006, when it became ASN. With this change of name, ASN was changed from a government administrative body to an independent regulatory body. ASN is advised by the Radiation Protection and Nuclear Safety Institute (Institut de Radioprotection et de Sûreté Nucléaire—IRSN).
[126] Nucleonics Week, "French regulator suspends review of post-40-year operation", 14 April 2011.
[127] According to a graph extracted from an EDF document, see *Le Journal du Dimanche*, "La facture astronomique du nucléaire", 2 March 2014, see http://www.lejdd.fr/Economie/Industrie/La-facture-astronomique-du-nucleaire-655350, accessed 15 July 2014; initial source: EDF CIPN - AAI CIPN - 3ème Rendez Vous Business du nucléaire civil en PACA, 29 January 2014.

Table 3: France's operating nuclear power plants

Site	Unit size (MW gross)	First grid connection
Fessenheim 1, 2	920	4/77, 10/77
Bugey 2, 3, 4, 5	2 x 945, 2 x 917	5/78, 9/78, 3/79, 7/79
Gravelines 1, 2, 3, 4, 5, 6	6 x 951	3/80, 8/80, 2/81, 6/81, 8/84, 8/85
Dampierre 1, 2, 3, 4	937	3/80, 12/80, 1/81, 8/81
Tricastin 1, 2, 3, 4	955	5/80, 8/80, 2/81, 6/81
St Laurent B 1, 2	956	1/81, 6/81
Blayais 1, 2, 3, 4	951	6/81, 7/82, 8/83, 5/83
Chinon B 1, 2, 3, 4	954	11/82, 11/83, 10/86, 11/87
Cruas 1, 2, 3, 4	956	4/83, 9/84, 5/84, 10/84
Paluel 1, 2, 3, 4	1382	6/84, 9/84, 9/85, 4/86
St Alban 1, 2	1381	8/85, 7/86
Flamanville 1, 2	1382	12/85, 7/86
Cattenom 1, 2, 3, 4	1362	11/86, 9/87, 7/90, 5/91
Belleville 1, 2	1363	10/87, 7/88
Nogent 1, 2	1363	10/87, 12/88
Penly 1, 2	1382	5/90,2/92
Golfech 1, 2	1363	6/90, 6/93
Chooz B 1, 2	1560	8/96, 4/97
Civaux 1, 2	1561	12/97, 12/99

Source: IAEA-PRIS, 2014[128]

The outage is typically extended while the studies required are carried out. Because of the high level of standardization with the French reactors, the process is more easily manageable than a comparable process would be in, say, the USA where there are a large number of different designs. Many of the issues identified are "generic" to a whole class of reactors. The 10th-year safety reviews for the 900 MW-class reactors was completed in 2002, 15 years after the last reactor of this type entered service. There were three generations of 900 MW reactor designs—the six first reactors, designated CP0, and the other 28, divided between the CP1 and CP2 designs.

The safety regulator identified a number of areas where the reactors had not matched up to their design bases. For example, an error in the original calculations of the seismic resistance of boric acid tanks was discovered, requiring the back-fit of a metallic belt around the tanks that holds them to the floor with 80 tie-rods. Improvements were also made, for example, for the qualification of plant equipment to lower temperatures more than the –15C to which the CP0 units were originally designed. Additional heat sources were installed, and changes made to buildings so that the plants could resist temperatures down to –38°C for six hours, and –29°C for seven days. The whole process took much longer than expected and was completed five years after the next 10th-year inspection was due to start for the CP0 reactors.[129]

For the 20th-year PSRs for the twenty 1300 MW reactors and the 30th year PSRs for the 900 MW reactors, among other issues, the regulator required that the calculations of the nuclear plants' seismic resistance be redone, potentially leading to the need for back-fits in some cases.[130] It is not clear how many reactors were back-fitted, but the total cost was estimated to be €1.9 billion (US$2.6 billion), of which, €1.2 billion (US$1.6 billion) was accounted for by the six CP0 units.[131] In 2011, Fessenheim received approval, with a number of conditions, to operate for up to 40 years, taking it to 2019.[132] However, the Hollande government vowed to shut down the two Fessenheim units by the end of 2016,

[128] See http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=FR, accessed 5 June 2014.
[129] Inside NRC, "Conformance checks on French reactors seen as key to improvement", 15 July 2002.
[130] Inside NRC, "DGSNR'S judgment on seismic issues sends EDF back to drawing board", 16 June 2003.
[131] Nucleonics Week, "French critics raise quake fears, but rules said already tightened", 19 July 2007.
[132] Nucleonics Week, "Fessenheim-1 safe for 40 years, with conditions, ASN says", 7 July 2011.

in line with the policy target to reduce nuclear generation from around 75 to 50 percent in the electricity mix. Despite this, EDF has been carrying out extension modifications and improvements to allow it to operate to its 40th year.[133]

The Fukushima disaster led to a major re-evaluation of the safety of reactors in Europe under the auspices of the European Union's "stress tests". These appear to have been more rigorously carried out in France than in most other countries.[134] ASN suspended the process of reviewing reactors for operation past 40 years whilst this process was carried out. IRSN in its recommendations to ASN reported in November 2011 that several reactors had deviations from their design bases that needed immediate action. The Bugey, Civaux, and Fessenheim sites were identified as having inadequate seismic protection, while Fessenheim, Tricastin, Cruas, Chinon and Saint Laurent needed upgrades to increase their protection against flooding.[135]

In January 2012, ASN submitted its report on the stress tests to the French energy minister. These provided a range of upgrades to be implemented at French nuclear sites, expected to take until beyond 2020 to be implemented. These included bunkered diesel generators and control rooms expected to cost many billions of Euros. However, EDF's CEO, Henri Proglio, was less pessimistic on cost claiming the Fukushima modifications could be done for less than €10 billion (US$14 billion) over 10 years. The Court of Account's estimate, based on EDF's own estimates, stood in 2012 at €55 billion (US$75 billion), of which €10 billion (US$140 billion) was for post-Fukushima reinforcement, to be spent before 2025. Since 2012, there has been increasing discussion about the figure of €55 billion, and it is more and more likely to rise. The uncertainty derives from two factors. One is the extent of post-Fukushima reinforcements. According to nuclear and energy consultancy WISE-Paris[136], only eight of the 55 requirements by ASN call for direct implementation. The rest are dependent on additional studies and proposals to be made by EDF. The other is the level of reinforcement of safety requirements that ASN will impose on reactors after 40 years of operation. The French Court of Account, asked by the National Assembly Inquiry to update its 2012 report on the costs of nuclear power in France[137], confirmed EDF's €100 billion (US$140 billion) estimate. Furthermore, the updated report casts a shadow on the profitability of such investments as it shows a 21 percent (16 percent in real terms) increase of its operational costs between 2010 and 2013, from €49.6/MWh to €59.8/MWh (US$67.8/MWh to US$81.7/MWh).[138]

The Court also pointed to the high level of uncertainty attached to the estimate of future life-extension costs. WISE-Paris had earlier developed an in-depth analysis of those uncertainties[139]. The Marignac report, also presented to the National Assembly Inquiry, mostly focused on the numerous issues that ASN has left open in terms of future safety requirements attached to reactors operation beyond 40 years. WISE-Paris concluded that the average cost of reinforcements per reactor could range from less than €0.5 billion (US$0.7 billion), in a deteriorated safety scenario, up to more than €4 billion (US$5.5 billion) if safety standards were to come close to those of Generation-III designs (including costly backfitting such as the construction of a robust containment for the spent fuel pool buildings). Moreover, the analysis pointed to the risks of further cost increases due to delays arising from various factors such as the implementation of a more stringent regulatory and licensing procedure for life-extension, the industrial challenge of managing complex work on such a large scale at numerous sites in a short time frame, or the impact of years-long work on the availability of reactors, etc. Another uncertainty lies in the range of life-extension that could be granted after such reinforcements, either up to 50 or 60 years. Using WISE-Paris assumptions and the Court of Accounts' calculation method, independent think tank Global Chance estimates that the generation cost of reactors through their life

[133] Nucleonics Week, "EDF will make Fessenheim-2 modifications", 2 May 2013.

[134] Peer reviews of the stress test under the auspices of the European Nuclear Safety Regulators Group ranked France's stress tests as one of the best five in Europe. Inside NRC, "European reactors need tougher rules, Ensreg reviewers say", 7 May 2012.

[135] Inside NRC, "French nuclear sites 'not dangerous' but need safety fixes: IRSN", 21 November 2011.

[136] Yves Marignac, "L'échéance des 40 ans pour le parc nucléaire français : Processus de décision, options de renforcement et coûts associés à une éventuelle prolongation d'exploitation au-delà de 40 ans des réacteurs d'EDF", WISE-Paris, report commissioned by Greenpeace France, February 2014, 169 p., see http://www.greenpeace.org/france/PageFiles/266521/greenpeace-rapport-echeance-40-ans.pdf, accessed 7 June 2014.

[137] Cour des Comptes, "The costs of the nuclear power sector", Thematic public report, January 2012, 432 p., see http://www.ccomptes.fr/content/download/43709/697228/version/2/file/thematic_public_report_costs_nuclear_+power_sector_012012.pdf, accessed 7 June 2014.

[138] Cour des Comptes, "Le coût de production de l'électricité nucléaire", Communication to the Enquiry Commission of the National Assembly, 27 May 2014, 227 p., see http://www.ccomptes.fr/Actualites/A-la-une/Le-cout-de-production-de-l-electricite-nucleaire, accessed 7 June 2014.

[139] Yves Marignac, 2014, op.cit.

extension could come close to €100/MWh (US$140/MWh), in the case of extension to 60 years, or even €130/MWh (US$180/MWh), in the case of extension to 50 years[140].

Reactor Vendor Strategies

Obtaining finance is probably the key barrier to getting reactor orders placed in markets where consumers do not effectively guarantee returns on the investment through cost pass-through and in countries with a relatively weak credit rating. This means that, typically, a national team involving not only the vendor but also the vendor's government and perhaps a national utility providing training and skills will make the bid. In this light, the key countries are:

- France through AREVA and Électricité de France (EDF);
- Japan through Hitachi-GE, Toshiba-Westinghouse and Mitsubishi;
- Korea through KEPCO;
- Russia through Rosatom;

and, for the future,

- China.

In addition there has been an increasing trend for vendors to take equity stakes in reactor projects, ranging from 10 percent in the case of AREVA in the NNB Genco case in U.K. to full ownership via a Build Own Operate (BOO) agreement in the case of Rosatom for the Akkuyu project in Turkey.

These equity stakes are not ones the vendors would have wanted to take, but they are seen as necessary to actually get orders placed. They represent a signal to the financial community of the commitment of the vendor to get the plant built efficiently. They also give the vendor greater leverage over the project and may be less risky than offering a "turnkey" (fixed price) contract to supply the plant. These have seldom been offered and where they have, they have generally resulted in heavy losses for the vendor, as is the case with the Olkiluoto plant supplied by AREVA.

French Vendors and Markets

The dominance of public ownership in AREVA, EDF, and the national nuclear R&D organization, Alternative Energies and Atomic Energy Commission (CEA), has meant that the French nuclear industry has to be seen as a national effort. The exit of Siemens from AREVA NP has strengthened this position. In terms of technologies, AREVA's options look limited apart from its EPR design. Its BWR design, Kerena, was mentioned for the Finnish Fennovoima project but is not being considered seriously there or elsewhere. The smaller PWR design, ATMEA, developed in collaboration with Mitsubishi, has been mentioned as an option for Jordan, Hungary, Argentina, and Turkey for the Sinop project. However, these are all, at best, long shots and unless ATMEA attracts interest in more prestigious markets and get comprehensive safety approval from a highly experienced regulator[141], it appears to have little future.

The optimism from EPR being the first Generation III+ design to win orders, first in Finland in 2003 (Olkiluoto), France in 2006 (Flamanville) and China in 2007 (Taishan), has dissolved with both Olkiluoto and Flamanville now nearly three times over-budget and at least nine years and four years late respectively. Even the Chinese plants are now about a year late.

The Olkiluoto order was placed in 2003 with a "turnkey" contract for €3 billion (US$4.1 billion). Construction started in 2005 with first power expected in mid-2009. As has been well-documented,[142] there were problems from the start and, by 2012, the expected cost had more than doubled and completion was not expected until 2016.[143] TVO, the customer, and AREVA are countersuing each other for some of the cost overrun in a case to be decided by the Stockholm court of arbitration. In 2013, AREVA increased the amount it is claiming to €2.6 billion (US$3.5 billion), while TVO is

[140] Benjamin Dessus, "Eléments économiques du débat sur la prolongation de durée de vie du parc nucléaire actuel", Les Cahiers de Global Chance, June 2014.

[141] It has been certified as licensable in principle in France and Canada but it has not undergone a generic review of the type carried out in the USA and UK that would resolve all major design issues.

[142] See for example, WNISR, "Nth Delay Announced for Olkiluoto 3 in Finland", 11 February 2013, see http://www.worldnuclearreport.org/Nth-Delay-Announced-for-Olkiluoto.html, accessed 5 June 2014; and WNISR "Nth Delay For Finnish EPR", 21 July 2012, see http://www.worldnuclearreport.org/Nth-Delay-For-Finnish-EPR.html, accessed 5 June 2014.

[143] Nucleonics Week, "EPR costs in Finland, France not sustainable, Areva executive says", 23 May 2013.

claiming €1.8 billion (US$2.5 billion).[144] In February 2014 the project appeared to reach crisis point with TVO abandoning the 2016 completion target giving no new target[145] but it was reported that it would be 2018 or later.[146] There were also reports of AREVA withdrawing workers from the site.[147] No updated completion cost was published but it seems highly likely the costs will have gone up further from the most recent estimate of about €8.5 billion (US$11.6 billion). In May 2014, the Standard & Poors credit rating of the owner, TVO, was maintained at BBB/A-2 but with the outlook changed from stable to negative reflecting "the risk that lower market prices and higher production costs could permanently reduce TVO's competitiveness."[148]

The Flamanville-3 unit started construction in 2007 with expected completion 2012 and cost €3.3 billion (US$4.5 billion). The project has gone little if any better than Olkiluoto and by 2013, completion was not expected until 2016 and cost was at least €8.5 billion (US$11.6 billion).

The Taishan orders have generally been presented as having suffered none of the problems that have plagued Olkiluoto and Flamanville. However, in February 2014 in a presentation to the IAEA, a Chinese official acknowledged that the two reactors were more than a year late and would not be on-line before mid-2015.[149] No estimate of any cost overrun was given.[150]

In calls for tenders in South Africa, Canada and UAE, the EPR price was either so high that the call was abandoned or it was outbid (UAE). Other target markets including Italy and USA are now effectively closed. The EPR is undergoing generic design review by the U.S. NRC, but with its main prospect for an order, the Calvert Cliffs project, now abandoned, there appears little reason to pursue certification. The NRC is no longer projecting a completion date for the review.

The deal to build six reactors at India's Jaitapur site, first announced in 2009, is still not concluded with the issue of vendor liability appearing to be a major sticking point. The deal has yet to be concluded and the costs are not known.

Even the agreement to supply two EPRs for the U.K. Hinkley Point site is far from sure to proceed. The agreed cost was £8 billion (US$13.6 billion) per reactor in 2012 prices. Remarkably, this is about 10 percent higher than the expected completion cost of both Flamanville and Olkiluoto, costs which an AREVA official described as not sustainable.[151]

There appears to be little prospect of further orders for EPRs for China. Its two Chinese collaborators, CNNC and CGN, may choose to offer their own independent designs in competition with AREVA perhaps because of AREVA's reluctance to transfer technology to them. Nevertheless, AREVA is sticking to its target of 10 new sales of EPRs by 2016, citing prospects in India, China, U.K., Poland and Saudi Arabia.[152]

EDF rather than AREVA has taken the role of equity investor in foreign projects, for example, in China and India, but it is expected to take a small stake in the Hinkley Point C project.

Japanese Vendors and Markets

Despite its long experience with nuclear technology going back more than 50 years and the considerable experience of its three vendors, all divisions of the most powerful companies in Japan (Toshiba, Hitachi and Mitsubishi), it was not till around 2006 that Japan contemplated entering international reactor markets (as opposed to component supply). Until that time, Hitachi and Toshiba had been licensed to General Electric for BWR technology and Mitsubishi to Westinghouse for PWR technology, although Hitachi and Toshiba had done much of the development work and supplied the markets for ABWR technology. There appeared to be little interest in GE's reportedly more advanced ESBWR technology. Mitsubishi had been working on an APWR design, which had been expected to

---

144 Nucleonics Week, "Areva, Siemens increase arbitration claim in Olkiluoto project", 31 October 2013.
145 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, http://www.tvo.fi/news/190, accessed 24 May 2014.
146 Esmerk, "Finland: OL3 construction site quieting down is normal at this stage, TVO says", 28 February 2014.
147 NIW, "Weekly round-up", 28 February 2014, p.1.
148 Standard & Poors, "Finland-Based Nuclear Power Producer Teollisuuden Voima's Outlook To Negative On Risk Of Declining Cost Competitiveness", 23 May 2014.
149 Shan Sun, "Challenges during construction of new NPPS", IAEA Technical Meeting, 6 February 2014, see www.iaea.org/nuclearenergy/nuclearpower/Downloadable/Meetings/2014/2014-02-04-02-07-TM-INIG/Presentations/37_S7_China_Sun.pdf, accessed 28 June 2014
150 NIW, "Sanmen – Two-Year Delay Pushes Costs Higher", 14 March 2014.
151 Nucleonics Week, "EPR costs in Finland, France not sustainable, Areva executive says", 23 May 2013.
152 NIW, "Areva Sticks to Target of 10 EPR Deals by 2016", 28 February 2014.

win orders from 1990 but by 2014, had still not started construction. Again, there appeared to be little interest in Westinghouse's reportedly more advanced AP1000 design.

This pattern changed when Toshiba bought Westinghouse from the U.K. government in 2006. As well as AP1000 technology, it continued to offer ABWR technology but independently from GE and Hitachi. Hitachi formed a new alliance with a joint venture Hitachi-GE in which it holds an 80 percent stake for non-U.S. markets and a joint venture GE-Hitachi (in which GE holds 80 percent) for U.S. markets. Mitsubishi had to follow a new technology path given that licensing to Westinghouse was probably not an option.

It was in 2010 that a Japanese "team" to rival those of Russia and France was set up with finance, cooperation with utilities, and all three Japanese vendors as part of a consortium, JINED (Japan International Nuclear Energy Development) to target export markets. The early success for this strategy was an agreement with Vietnam to build two reactors there. However, given that the technology and vendor had not been selected, this agreement was clearly far from final.[153] No financial details were published. The Fukushima events put a serious dent in this strategy, and it is still far from clear whether the Japanese government will continue to provide this support.

GE-Hitachi's ESBWR design is expected to complete its review by NRC in September 2014. However, it has no serious customers in USA or elsewhere. It chose to attempt to sell its APWR technology in the U.S. market and submitted it to the U.S. NRC for generic approval. However, its potential customer (Comanche Peak in Texas) is not likely to materialize, and the NRC is no longer even giving a projected completion date for its review.

Toshiba's AP1000 technology is one of the three front-running Generation III/III+ designs (with EPR and ABWR) and has won four orders in both the USA (Vogtle and Summer) and China (Sanmen and Haiyang). However, there are significant delays and cost over-runs at all of these, not on the scale of those at Olkiluoto and Flamanville, but still damaging to the credibility of the design. The reactors were reported to be about two years behind schedule and 20 percent over budget.[154]

The ABWR is portrayed as a proven reactor but the orders that have been placed are for a 1980s version. Approval for the version certified in 1997 by the U.S. NRC expired in 2012 before any orders were placed. Both, GE-Hitachi and Toshiba, have independently applied to renew design approval but it is not clear how extensive the required modifications will be, the NRC is not projecting a completion date for the reviews, and neither company has a strong prospect of a sale in the USA.

For European markets, both Toshiba and Hitachi-GE are developing a somewhat different design to meet the needs of European regulators. Hitachi-GE has submitted its design to the U.K. ONR in 2014.

Mitsubishi chose to attempt to sell its APWR technology in the U.S. market and submitted it to the U.S. NRC for generic approval. However, its potential customer (Comanche Peak in Texas) is not likely to materialize and the NRC is no longer even giving a projected completion date for its review.[155] For other markets, it entered a joint venture with AREVA to develop a smaller reactor, ATMEA (1100 MW). This was discussed for markets such as Jordan and Argentina, but in 2013, it was selected as the technology option for the Sinop project in Turkey. However, a detailed design is still to be completed and even then, there will be the issue of obtaining regulatory approval from a highly credible and experienced safety regulator.

As discussed above, in the USA, GE-Hitachi and Toshiba are trying sell the ABWR design, Toshiba has four orders for the AP1000, and Mitsubishi is trying to sell its APWR design. In the U.K., Toshiba is trying to sell the AP1000 while Hitachi-GE is offering the ABWR. Other Japanese sales efforts target Bulgaria, China, Lithuania and Turkey.

Summary

Japan's attempt to build a national "one-stop" capability to rival those of Russia and France was seriously hampered by the Fukushima disaster and its target markets, especially in Eastern Europe and the Middle East, have been problematic, often because of difficulties of funding. Nevertheless, with the AP1000 and the ABWR, it does have the two Generation III/III+ designs with the highest credibility.

[153] Nucleonics Week, "Vietnam signs reactor construction accords with Russia, Japan", 11 November 2010.
[154] NIW, "Sanmen – Two-Year Delay Pushes Costs Higher", 14 March 2014.
[155] WNISR, "License Application for New-Build at US Comanche Peak Site Suspended", 20 November 2013, see http://www.worldnuclearreport.org/License-Application-for-New-Build.html, accessed 5 June 2014.

Korean Vendors and Markets

Korea has a long history in nuclear power, importing reactors from Westinghouse, AECL (CANDU), Framatome and Combustion Engineering. However, by the 1990s, it was taking a much greater role in the construction of these plants and its vendor, Doosan, took a technology license with Combustion Engineering for its System 80 design, which was designated OPR-1000 for Korea. Twelve units of this design were built but from 2008 onwards, new orders have been for a new upgraded and uprated design, the APR1400 and by May 2014, four units were under construction with a number more planned. The structure of the Korean nuclear industry is rather different to that of other countries and seems to be led by the nuclear generation company, Korea Hydro & Nuclear Power Co, formerly part of Korean Electric Power Company.

However, it was not till 2009 that it entered the export market, winning an order for four APR1400s for UAE at the Barakah site. The first of these started construction in 2012 followed a year later by the second. Korean media reported the price was remarkably low, far lower than calls for tender in, for example, Canada and South Africa. The overnight cost of the APR was US$2,300/kW, compared to US$2,900/kW for the EPR and US$3,583/kW for the GE Hitachi ABWR.[156] These figures are difficult to reconcile with the reported contract price of about US$20 billion although this figure may contain elements not included in an overnight cost.

This failure led to much soul-searching in the French nuclear industry, with AREVA particularly critical of the safety features offered by the APR1400. The then CEO of AREVA, Anne Lauvergeon, "likened the APR1400 to 'a car without seat belts and airbags' because the South Korean design, unlike AREVA's EPR, doesn't have a double aircraft-crash-proof containment or a core catcher".[157] Subsequently the Korean nuclear industry has talked about upgrading the design to meet European standards and of submitting it to the U.S. NRC for generic approval. KEPCO did start searching for U.S. customers and submitted its design to NRC in September 2013, but this submission was rejected by NRC because of lack of important information.[158] It is not clear how far modifications to allow the design to allow it to meet European standards have got. There have been reports the design might be submitted to markets such as Jordan, Turkey, South Africa and Hungary, but these seem unlikely to be successful.

Korea's image as a high-quality nuclear operator building plants quickly and operating them reliably was seriously damaged by revelations of faked quality control documents. In November 2012, it emerged that quality control certificates for thousands of pieces had possibly been forged. Two reactors were closed (Yongwang 5 and 6) and five others already off-line remained closed.[159] The two Yongwang reactors were allowed back on-line in January 2013 but it was only after it was found that more than 2,000 parts (fuses, switches, cooling fans) had been given forged certificates and had to be replaced. Six other reactors were found to have significant numbers (100 to 300) of forged documents.[160]

Three more reactors were closed for seven months from May 2013 when it was found that tests for control cables had been fabricated.[161] Nearly 130 employees at KHNP and its suppliers were indicted, and hundreds of others reprimanded internally, as a result of this scandal, which continued to spread in 2014. How far this event has damaged Korea's nuclear industry's reputation remains to be seen.[162]

Russian Vendors and Markets

For much of the history of nuclear power, Russia largely confined its presence on the international market to Eastern Europe and other Soviet Republics. After the Chernobyl disaster, it did sell reactors to China and India and it did take over the completion of the Bushehr reactor in Iran. No new orders were placed in the former Soviet Republics or Eastern Europe with only completion of existing orders taking place, generally at a very slow pace.

However, around 2006, with the availability of the VVER1200 design, Russia restarted orders for its home market and began to compete in markets other than its traditional ones through Rosatom. Some of the markets were ones that its competitors were not willing to enter and were done on terms not

[156] Nucleonics Week, "Korea plans to expand APR horizon, backed by UAE vote of confidence", 7 January 2010.
[157] Nucleonics Week, "No core catcher, double containment for UAE reactors, South Koreans say", 22 April 2010.
[158] Inside NRC, "NRC halts APR1400 design review", 30 December 2013.
[159] Business Recorder, "South Korea widens nuclear lapses probe; KEPCO chief resigns", November 2010.
[160] Inside NRC, "Korean regulator NSSC approves restart of Yonggwang reactors", 14 January 2013.
[161] Nucleonics Week, "South Korea units shut in parts probe restarting", 9 January 2014.
[162] Korea Times, "Endless scandals hit nuclear power supplier", 1 September 2013, see www.koreatimes.co.kr/www/news/biz/2013/09/335_142036.html, accessed 25 May 2014.

previously offered. It has sold two more reactors to China (Tianshan 3 and 4, start of construction 2012/13) and two to India, where construction had not started by May 2014.

Bangladesh

In January 2013, Russia agreed to provide an initial US$500 million to help finance construction of the Rooppur plant, which would comprise two 1000 MW reactors of the old AES-92 design.[163] While the Bangladesh Prime Minister, Sheikh Hasina, laid a foundation stone at Rooppur in October 2013, the deal is not complete and construction is not expected to start until 2015 with completion in 2020 for the first unit and the second following on 6 months later.

Belarus

In July 2012, Belarus and Russia, through Rosatom signed a construction contract for the two reactors at the Ostrovets site at an estimated total cost of US$10 billion.[164] These will be of the latest AES-2006 design. Construction work on the first unit started in November 2013 with completion expected in November 2018. The second unit, on which construction started in June 2014, is expected to follow no more than two years later.[165] The details of the contract are not public but Russia will be providing the finance.

Bulgaria

The Belene project dates back to pre-Chernobyl times when a two-unit station started construction. Attempts to complete were eventually abandoned and the parts used at other sites. [166] Attempts to get new reactors built at the site were given up in March 2012 when the government cancelled the order, refusing to accept the offer of Russian finance.[167] There is still discussion of building at Belene or the site of Bulgaria's operating reactors, Kozloduy, but orders still seem a distant prospect.

Czech Republic

For several years, the Czech Republic, through CEZ, the state-controlled electric utility, has been trying to launch a project to build two new reactors at the Temelin site. In 2010, a call for tenders expected to be decided in 2012 was delayed a year. When the tender closed in July 2012, three bidders had entered: Westinghouse (AP1000), AREVA (EPR), and Rosatom (AES2006).[168] The AREVA bid was disqualified because CEZ stated it did not meet the specification.[169] Finally in April 2014, CEZ cancelled the tender. The CEO of CEZ stated: "While originally the project was fully economically feasible given the market price of electricity and other factors, today all investments in power plants, the revenues of which depend on sales of electricity in the free market, are threatened."[170] The sticking point appeared to be the unwillingness of the Czech government to grant sovereign loan guarantees. It seems unlikely that, despite this setback, the Czech government and CEZ will abandon the attempt to build more nuclear capacity.

Finland

The follow-up station to the Olkiluoto-3 project has long been discussed with a three different developers competing to be allowed to build the next plant. A Fortum consortium was ruled out by Parliament in 2010 leaving the Fennovoima and TVO (the builder of Olkiluoto 3) consortia.[171] TVO is not in a position to proceed leaving Fennovoima as the more advance project.

The Fennovoima project (at Hanhikivi) comprised 34 percent holding by E.ON with the balance with a Finnish company, Voimaosakeyhtio. The designs were under review: AREVA's EPR, the Toshiba ABWR and Rosatom's VVER-1200. However, in February 2013, E.ON withdrew from the consortium, leaving Voimaosakeyhtio as the sole owner.[172] Fennovoima began direct negotiations with Toshiba and also began to look at smaller options, appearing to put the EPR out of the running. By mid-2013, Fennovoima was negotiating with a Rosatom subsidiary, Rusatom, to effectively take up

[163] Nucleonics Week, "Bangladesh fast-tracks first nuclear project at Rooppur", 30 January 2014.
[164] Nucleonics Week, "Belarus authorizes first nuclear power plant", 7 November 2013.
[165] WNISR, "Unit 2 of Ostrovets Plant in Belarus Under Construction", 3 June 2014, accessed 5 June 2014.
[166] Nucleonics Week, "Bulgaria to add unit at Kozloduy rather than build at Belene", 29 March 2012.
[167] Nucleonics Week, "Rosatom charts overseas progress in 2012: Komarov", 20 December 2012.
[168] Nucleonics Week, "Three vendors submit bids to CEZ for Temelin-3, 4", 5 November 2012.
[169] Nucleonics Week, "Areva unlikely to save Temelin bid, says Skoda official", 11 October 2012.
[170] Power in Europe, "CEZ scraps Temelin tender", 14 April 2014.
[171] International Herald Tribune, "Finland approves 2 new nuclear power plants", 2 July 2010.
[172] Platts European Power Daily, "Germany's E.ON sells out of Finnish nuclear", 18 February 2013.

E.ON's stake, inevitably meaning the reactor choice would be a Russian design and this was agreed in December 2013.[173] Russia has indicated its willingness to increase its stake beyond 34 percent.[174] However, in March 2013 the approval for Fennovoima was returned to Parliament because the project had changed. Nevertheless, despite final Parliamentary approval not having been given, in May 2014, "a binding decision to construct and finance the Hanhikivi nuclear power plant in Finland [was] made by the shareholders of Fennovoima."[175]

Hungary

A tender for two reactors at the Paks site has been expected since 2011.[176] However, in January 2014, the Hungarian government abandoned the plan for a tender and signed an agreement to buy two AES-2006 reactors from Rosatom. The new units are to be financed by a 30-year interstate loan provided by Russia. The size of the loan is expected to be of the order €10 billion (US$14 billion) with total expected cost of the two units up to €12 billion (US$16.4 billion) and Russian loans would cover 80 percent of this.[177] The details of the loan were published on a Russian government site and foresee the loans would be repaid in 21 years with first repayment no later than 2026 whether or not the reactors had been completed.[178] The deal has provoked controversy and it is not clear whether it will go ahead.

Iran

Russia took over construction of the Bushehr reactor in 1992 and this reactor entered commercial operation in September 2013. In April 2014, the Iranian government announced it had reached agreement with Russia for the supply of two reactors with construction of the first, at the Bushehr site, starting in 2014.[179] This deal is far from complete and it will be difficult to meet the expected time-frame.

Jordan

After a protracted process of vendor selection going back to 2008, in October 2013, the Jordanian government announced that Rosatom was the preferred bidder for a two-unit nuclear station. Other vendors expressed an interest in the order but finally the choice was between Rosatom and the unproven AREVA/Mitsubishi ATMEA design. The expected technology is the AES-92 design as built at the Kudankulam site in India. The expected model of finance is the Build Own Operate (BOO) model expected to be used for the Akkuyu project in Turkey with Rosatom expected to take at least 49 percent of the project. Completion of the first unit is not expected until 2023, so the project is far from certain to proceed.

Kazakhstan

In 2014, Russia and Kazakhstan signed an agreement that might lead to the construction of a nuclear plant in Kazakhstan. However, there are many details to be decided, for example, the reactor size and design, so the project must be counted as no more than a long-term possibility.[180]

Turkey

In Turkey at the Akkuyu site, Russia won orders for four reactors in 2010 after a protracted tendering process lasting several years during which all Russia's competitors withdrew. The deal was unprecedented and included construction and operation of a nuclear plant abroad under a Build Own Operate (BOO) model, plus fuel and fuel cycle services and financing. A complex off-take deal to buy the power by the state-owned entity, TETAS, was reported to involve guaranteed purchase of 70

---

173 Nucleonics Week, "Finnish, Russian firms want contract for new unit by year's end", 5 September 2013.

174 NIW, "Fennovoima Commits to Newbuild", 18 April 2014.

175 European Daily Electricity Markets, "Finnish nuclear project moves forward", 17 April 2014, and WNN, "Hanhikivi investment decision", 15 April 2014, see http://www.world-nuclear-news.org/NN-Hanhikivi-investment-decision-1504144.html, accessed 5 June 2014.

176 Nucleonics Week, "Nuclear plant market unclear for at least a year: ASE president", 16 June 2011.

177 Nucleonics Week, "Russia financing new units at Hungary's Paks", 16 January 2014.

178 MTI Econews reported: "Interest payment will start in 2014 and the interest will be 3.95pc until the principal repayment starts. The interest will rise to 4.50pc in the first seven years of repayment, will grow to 4.80pc in the second seven-year period and to 4.95pc in the last seven years.", 14 March 2014.

179 Iran Economy News, "Russia to build two new nuclear plants in Iran", 22 April 2014.

180 NucNet, "Russia Signs Agreement For Possible Nuclear Station in Kazakhstan", see http://www.nucnet.org/all-the-news/2014/05/30/russia-signs-agreement-for-possible-nuclear-station-in-kazakhstan, accessed 5 June 2014.

percent of the output of the first two units at 12.35 Euro cent/kWh and 30 percent of the output of the second two units.[181] The project was subject to continual delays[182] and by May 2014, construction had still not started; a construction license was not expected until 2015 although first power was still expected for the first unit in 2020 with the following units coming on line by 2023.[183] The terms of the power purchase agreement were still being finalised.[184] Russia is not a front-runner for a follow-up station at Sinop.

Vietnam

In 2010, the Vietnamese government announced it had agreed to buy two reactors from Rosatom to be built at the Ninh Tuan site in competition with a Japanese consortium including Hitachi, Toshiba and Mitsubishi.[185] This consortium subsequently was selected for a second order. No decision was taken on whether the design would be the AES-92 or AES-2006 one. It was then expected that the first unit would come online in 2020. Progress was slow and in January 2014, a delay of several years was announced.[186] It is far from clear whether the project will still proceed, and the financial details are still to be determined.

Summary

Russia appears willing to operate in markets no other vendor would be able to and to offer terms such as finance and equity stakes that the other vendors would not be able to. Despite the large theoretical number of potential markets, Russia only has reactors under construction in Russia, China, and, at an early stage, Belarus. There are unanswered questions on how many reactors Russia has the supply chain to deliver, how much finance is available, especially for highly risky markets and whether its new design would satisfy an experienced regulator in Europe. Its plans to build in U.K. are particularly ambitious and cannot be achieved in less than about eight years.

Chinese Vendors and Markets

Since China began ordering nuclear plants on a large scale for its home market from 2007 onwards, there has been an increasing interest in the possibility of exports of Chinese nuclear power plants. The assumptions, with no real evidence to back them, are that Chinese reactors would be cheap and of high quality.

However, China's emergence on the world market has been hampered by its lack of technology. Most of the orders for the home market have been for the design licensed from AREVA, itself licensed from Westinghouse. This design has its roots about 45 years ago and would not be licensable in Europe or North America. The intellectual property is also still held by AREVA, who have made it clear they are not willing for China to export this design. There are two Chinese versions: most are the CPR1000 supplied by CGN (China General Nuclear, formerly China Guangdong Nuclear), while the others are the CNP1000 supplied by Chinese National Nuclear Company (CNNC). CNNC is a much longer-established and more influential company with its basis in the military nuclear program, while the smaller CGN has more civilian nuclear experience and participated in the first imported reactors in the second half of the 1980s.

It was clear that this old design could only be an interim measure, and China decided to import a Generation III+ design to be the basis for future orders. The AP1000 was selected over the EPR in 2008 in collaboration with a new player, the State Nuclear Power Technology Company (SNPTC), with the order for four reactors. Nevertheless, two EPRs were ordered from AREVA soon afterwards in collaboration with CGN. It became clear that both of the advanced designs were going to be much more expensive than hoped for and the three companies began to work on their own designs developed from these two imported designs. CNNC developed the ACP1000, essentially a scaled down EPR, while CGN developed the ACPR1000. Two ACP1000s have been ordered for construction in Pakistan with construction expected to start in 2014 or 2015. However, the Chinese government has

[181] Nucleonics Week, "Akkuyu plant construction to begin in 2011, says Turkish energy ministry", 27 May 2010.
[182] WNISR, "Further Delay in Akkuyu Turkish Nuclear Power Project", 13 February 2014, http://www.worldnuclearreport.org/Further-Delay-in-Akkuyu-Turkish.html, accessed 5 June 2014.
[183] Nucleonics Week, "Operation of first Turkish reactor still slated for 2020: executive", 27 February 2014.
[184] NIW, 18 April 2014, p 1.
[185] Nucleonics Week, "Vietnam signs reactor construction accords with Russia, Japan", 11 November 2010.
[186] WNISR, "Significant Further Delay for Vietnam's Nuclear Plans", 17 January 2014, updated 1 February 2014, see http://www.worldnuclearreport.org/Significant-Further-Delay-for.html, accessed 5 June 2014.

required CGN and CNNC to merge their designs in the Hualong reactor.[187] It is not clear when this design will be ordered.

SNPTC chose to improve the economics of the AP1000 by scaling it up to 1400 MW in the CAP1400, for which SNPTC claims to have the intellectual property. This was ordered for the first time in 2014 and was also being promoted as an option for South Africa.[188]

China remains some way from being a serious contender in international markets. The advantage its large home market gives it is offset by its lack of a fully-developed design meeting modern standards, approved by a high-credibility regulatory body. China clearly has ambitions not only for developing country markets, where price may be more important than safety credentials, but also in the developed world, as evidenced by its attempts to secure a position in the U.K. market.

Competitiveness of Vendors

For the 15 years up to 2006, the world market for nuclear reactors was at a low ebb. The vendors were mainly based in Europe—AREVA/Siemens—or North America—Westinghouse (then owned by the U.K. government via British Nuclear Fuels Limited from 1997 to 2006), GE and AECL. Nevertheless, there was optimism that the new generation of designs conceived post-Chernobyl would dramatically improve the competitiveness of nuclear power, with promises of US$1,000/kW or less common.

In 2014, the picture is dramatically different. The focus of the supply side has moved east with the market now dominated by China, Russia, Korea and Japan, and the number of new orders is higher, albeit dominated by orders for the home markets of China, Russia and Korea. On the economic side, competitiveness has deteriorated badly, with the Hinkley Point deal, at about US$8,000/kW, setting a new high for a reactor order. Even allowing for general inflation, which might have added about 50 percent to prices, this is an astonishing rate of price escalation. With the long-term implications of Fukushima on the design of new reactors yet to be felt, there is every chance this price inflation will continue.

Twenty-eight years after the Chernobyl disaster, none of the post-Chernobyl designs has entered service, and it is likely that the first will be in Russia and China, markets where reliable information is hard to come by and regulatory processes are not transparent. It will be in 2016 or later before operating performance information begins to emerge in France (Flamanville-3) for the EPR, the USA for AP1000 (Vogtle/Summer), or China for the EPR and/or the AP1000.

The expected cost of Russian export reactors appears to be little lower than Western prices, with a figure of US$11 billion typically quoted for two 1100 MW reactors ($5,000/kW). Experience suggests pre-contract prices will be less than contract prices, which, in turn, will be lower than actual prices. There appears to be a political element in the markets Russia chooses to pursue, and there are doubts it has the capacity to meet as many orders as it appears to have in hand.

South Korea announced its presence on the world market with a very low bid for the UAE order. It remains to be seen whether the reactors can be built to time and cost and whether such low prices are sustainable. South Korea has no strong prospects for further orders. If it is to break into Europe or North America, Korea has acknowledged it must upgrade its design to include, as a minimum, aircraft crash protection and a core-catcher. Including these will add substantially to its cost. Its first attempt to get its design reviewed by the U.S. NRC was an embarrassing failure.[189]

The political situation in Japan towards nuclear power has yet to stabilize after Fukushima and it remains to be seen whether the Japanese government will be willing or able to give strong support to its vendors. The Toshiba AP1000 has the advantage of having orders and while there have been construction problems, they have not been on the scale of the EPR. However, there is no evidence it will have any price advantage over the EPR. The ABWR is seen as more proven, although up-to-date designs are not yet complete and, again, there is no evidence they will be cheaper than EPRs or AP1000s.

Calls for tenders have been seen in the past six years as the best way for buyers to get the best terms, but, with the exception of the UAE tender, all have ended in failure, including Canada, South Africa, and, more recently Czech Republic, Jordan and Turkey. Countries wishing to proceed have had to select a preferred partner (Turkey) or they have ended up with only one interested seller (U.K.) and have had to proceed via bilateral negotiations.

---

[187] NIW, "Power Brokers Behind The Reactor Design Choice Struggles", 11 April 2014.
[188] NIW, "Weekly Roundup", 28 February 2014.
[189] NIW, "Behind KHNP's Travails with the NRC", 10 January 2014.

Finance remains a major hurdle with loan guarantees, either from the vendor's home government or from the buyer's government, seen as an important element to obtaining a deal. In the U.K., the government had to promise £10 billion (US$17 billion) in loan guarantees to reach agreement, while the Russian deals almost invariably require Russian finance. However, loan guarantees are not always the solution. In Europe, if the Hinkley Point C deal fails the European Commission's state-aid inquiry, loan guarantees for EU Member States may be problematic. In the USA, the Summer project, unlike the Vogtle project, is proceeding without loan guarantees because prevailing interest rates are low, it has strong state-level guarantees of cost pass-through to consumers, and the U.S. government charges an "economic" fee for granting loan guarantees.[190] For buyers' governments, loan guarantees are increasingly being seen as a major financial risk and, especially for countries with economies that are struggling, not justifiable: the tender for Temelin collapsed in part because of the refusal of the Czech government to grant loan guarantees.

More in desperation than choice, vendors are choosing to take equity stakes in projects. This is not a step they would want to take and in many cases, they would expect to retain ownership only until the reactor is online and the construction cost risk has passed. In the U.K., all three active consortia wanting to build nuclear have a vendor presence ranging from 10 percent for AREVA in NNB Genco to 10 percent for Hitachi-GE with Horizon. Only Russia appears willing to risk the Build Own Operate model of long-term ownership, for example, in Turkey.

For the future, China is seen as the best hope for the nuclear industry to improve its competitiveness. However, it is probably several years away from having a technology that meets latest standards, which is ready to build and for which it owns the intellectual property. The common assumption that Chinese reactors will be cheaper than those of other vendors can then be tested.

The Hinkley Point C Deal

The British government has been attempting since 2005 to revive nuclear ordering in the U.K. The U.K. has been one of the most strategically important markets for nuclear power to crack if the long-predicted "nuclear renaissance" were to materialize. Orders for the U.K. would have been a vote of confidence for so-called Generation III+ technologies. The U.K.'s civil nuclear sector, despite its poor record over the past 50 years, still retains prestige and credibility in many countries, which would see the U.K. as an example to emulate. For reactor vendors, the apparent openness of the process, the prestige of the market, and the apparent determination to force through the nuclear program almost regardless of cost has persuaded them to gamble on the British market.

However, the U.K. government promised from the start that nuclear power would be competitive with gas-fired generation and, as a result, any new nuclear orders would receive no public subsidies and, implicitly, would compete in the competitive British wholesale electricity market on equal terms with other generators.

What was particularly eye-catching about the initial publicity in surrounding the attempt to re-launch nuclear ordering in the U.K. was the very optimistic forecasts of the commercial and economic viability of new nuclear orders. Following the failure to privatize the British nuclear power plants and the lack of nuclear orders for electricity markets that had been opened to competition, the conventional wisdom was that, even if the price of power from nuclear plants were expected to be competitive with the cheapest options, nuclear would not be chosen because financiers would not be prepared to bear the economic risks associated with building nuclear.

By 2006, the original cost claims for a "nuclear renaissance", first talked about from 1998 onwards, for example that nuclear could be built for less than US$1000/kW, a price expected to make nuclear competitive with natural gas generation, had already been proved unrealistic. The claim that, in Britain, nuclear plants would be ordered on the basis that they would be able to compete in the market with the cheapest alternatives and would be offered no public subsidies was therefore a remarkable claim. All that would be required were a few "enabling" measures such as making suitable sites available, carrying out a Generic Design Appraisal (GDA) process and putting a cap on the cost of radioactive waste disposal.

The Enabling Decisions

On siting, the assumption was that the sites of existing nuclear plants were less likely to be problematic in terms of public consent as well as technical suitability. The British government owned the sites of the 11 first-generation Magnox plants (most of which had been retired by then) through its Nuclear Decommissioning Authority (NDA). Some of these would not have been suitable for new

[190] NIW, "Could Vogtle's Loan Guarantee Be It?", 21 February 2014.

reactors but about half of them were worthy of consideration as well as the Sellafield complex, also owned by NDA. The government made six of these sites available for auction. The eight newer plants (at seven sites) were owned by British Energy, which had emerged from bankruptcy in 2005. In 2009, British Energy was taken over by French state utility EDF, giving it access to three sites deemed suitable for new reactors. These arrangements for sites were meant to ensure that developers would be able to compete on equal terms and there would not be a monopoly nuclear developer. Three consortia emerged: a consortium led by EDF, NNB Gen, with the British energy company, Centrica, taking a 20 percent stake; Horizon, a 50/50 consortium of the two leading German electric utilities, RWE and E.ON; and NuGen, comprising Iberdrola and GDF Suez (both 37.5 percent) and Scottish & Southern Energy (SSE) with the remainder. This meant that all six of the major energy companies active in Britain (widely known as the 'Big 6') had a stake in a nuclear consortium with GDF Suez, often seen as a potential new entrant as the seventh player.

The GDA process was intended to resolve all generic design issues for a number of designs, leaving only site-specific issues for any given project. This would mean that potential developers would be able to choose between several designs, confident that no significant technical issues would emerge. The GDA was initiated in 2007 with four competing designs entering the process: the AREVA EPR (PWR), the Toshiba-Westinghouse AP1000 (PWR), the GE-Hitachi ESBWR (BWR) and the AECL ACR1000 (Candu).

The measure that created most controversy then was the decision to fix the price for waste disposal at a level that would ensure the new developers would pay a "fair share" of the costs of waste disposal. There was ample scope for semantic disputes about what constituted a fair share—for example, would new developers pay only the marginal cost of expanding facilities to be built for existing ("heritage") waste? From a presentational point of view, the price was either the minimum developers would pay even if actual costs were lower or the maximum they would pay even if costs were higher. The government claimed this did not constitute a subsidy, although given that effectively this represented a price guarantee given at no cost to the companies, this claim was hard to sustain.

What Promises, What Offer?

The first public sign of the Blair government's decision to revive nuclear power was in November 2005 with Blair reportedly telling a dinner with the Confederation of British Industry (CBI) that nuclear power was "back with a vengeance".[191] The official documentation was more cautious. A Green Paper was published in July 2006 and a White Paper, published, in May 2007 concluded: "Therefore, the Government believes that new nuclear power stations could make a significant contribution to tackling climate change."[192]

The fairness of the consultation was challenged in the High Court by Greenpeace and the Court found that the consultation had been "manifestly inadequate" and "procedurally unfair", and that something "had gone clearly and radically wrong".[193] As a result, the consultation had to be repeated, albeit with similar results, and the Nuclear White Paper was published in January 2008, stating: "That is why the Government has today concluded that nuclear should have a role to play in the generation of electricity, alongside other low-carbon technologies".[194] This was based on some hopelessly over-optimistic forecasts of cost, of building an EPR for £2 billion (US$3.4 billion), at which price, it was forecast to be competitive with power from a gas-fired power station at any plausible carbon price.

However, as soon as the enabling measures were in place, the process began to unravel (see Table 4). Two of the designs entering the GDA, the ESBWR and the ACR1000, were withdrawn before significant progress had been made. By December 2011, the GDAs were still not complete and interim approvals were issued for the EPR and the AP1000 with a list of issues still to be resolved. This process was completed in December 2012 for the EPR when a Design Acceptance Certificate was issued. However, Toshiba-Westinghouse chose to suspend the process at that point until there was a

[191] The Mirror, "Nuclear issue'back with a vengeance', says Blair", 29 November 2005, see http://www.mirror.co.uk/news/uk-news/nuclear-issue-back-vengeance-says-567155, accessed 5 June 2014.
[192] Department of Trade and Industry (DTI), "Meeting the energy challenge: A White Paper on energy", BERR, HMSO, London, May 2007, see http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file39564.pdf, accessed 5 June 2014.
[193] The Times, "Splat! Ministers caught out cheating the public (again)", 17 February 2007.
[194] Department of Business, Enterprise and Regulatory Reform (BERR), "Meeting the energy challenge – A White Paper on Nuclear Power", BERR, HMSO, London, January 2008, see http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file43006.pdf, accessed 5 June 2014.

U.K. customer for their design. They have now taken a majority stake in one of the consortia, NuGen, and expressed intent to complete the GDA process, but have said this will not be before 2017.[195]

Table 4: The British Nuclear Power Program: Promises and Reality

What was promised	What is planned
No subsidies: would compete in the market on equal terms with all other sources.	Contract for 35-40 years indexed to inflation and potentially other cost factors. Government loan guarantees covering about 70 percent of the expected construction cost.
Competitive with other forms of generation generating at £31-44/MWh (US$52.8–75/MWh).	Most expensive power on system, £95-100/MWh (US$162–170.5/MWh), more than double 2013 wholesale electricity price.
Construction cost of £2 billion (US$3.4 billion) per reactor.	Construction cost of £7 billion (US$12 billion) per reactor.
First power 2017.	First power 2023.
Competition between developers & technologies.	"Hobson's choice" of EDF + EPR.
Program of 10 reactors.	No more than 2 reactors.

Source: Steve Thomas for WNISR, 2014

The construction consortia have seen an exit of the "Big 6" with only EDF retaining a share in them. E.ON and RWE sold the Horizon consortium to Hitachi-GE in October 2012 for £700 million (US$1.2 billion).[196] Centrica withdrew from the NNB Gen consortium in February 2013.[197] The composition of the NNB Gen consortium has not been finalized but when agreement was announced between the British government and EDF on the construction of Hinkley, EDF said the holdings would be: EDF Group (45-50 percent), CNNC and CGN (30-40 percent) and AREVA (10 percent). However, EDF stated: "Discussions are also taking place with a shortlist of other interested parties who could take up to 15 percent".[198] If 15 percent of the shares were taken up by Chinese interests, the most likely investors, this could give Chinese companies a majority stake and leave EDF with as little as 35 percent.

SSE gave up its stake in NuGen in September 2011, leaving GDF Suez and Iberdrola with 50 percent each of the shares. Iberdrola sold its stake and GDF Suez sold 10 percent of the shares to Toshiba-Westinghouse (giving it 60 percent) in January 2014 for £102 million (US$174 million).[199]

However, the most significant change came in 2010 when the then Energy Minister in the Labour Government, Ed Miliband, made a statement that, in effect, foreshadowed the abandonment of the competitive wholesale market in favor of a returned to a planned approach. He said:

> However, for the longer term, Britain will need a more interventionist energy policy. The scale and upfront nature of the low carbon investment needed is likely to require significant reform of our market arrangements to deliver security of supply in the most affordable way.[200]

This set in motion a process known as Electricity Market Reform, carried on by the successor Conservative-Liberal Democrat coalition government that culminated in the Energy Act 2013, passed in December 2013.[201] This contained the framework that provides the basis for the agreement between EDF and the British government in October 2013. This includes the option of Contracts for Differences (CfDs), a Feed-in Tariff (FIT), and creation of a government agency (yet to be named or given a legal basis) to sign contracts for purchasing the power.

---

[195] Power in Europe, "Toshiba takes NuGen majority", 20 January 2014.
[196] Nucleonics Week, "Hitachi to buy Horizon, bring ABWRs to the UK", 1 November 2012.
[197] Nucleonics Week, "EDF Energy considers new Hinkley partners", 4 February 2013.
[198] EDF Energy, "Agreement reached on commercial terms for the planned Hinkley Point C nuclear power station", 21 October 2013, see http://newsroom.edfenergy.com/News-Releases/Agreement-reached-on-commercial-terms-for-the-planned-Hinkley-Point-C-nuclear-power-station-82.aspx, accessed 5 June 2014.
[199] Nucleonics Week, "Toshiba to buy 60% of UK's NuGen, plan AP1000s at Moorside", 16 January 2014.
[200] Department of Energy and Climate Change, "Statement on Ofgem project discovery", see http://www.mynewsdesk.com/uk/pressreleases/department-of-energy-and-climate-change-statement-on-ofgem-project-discovery-368342, accessed 5 June 2014.
[201] Parliament.uk, "Energy Act 2013", see http://services.parliament.uk/bills/2013-14/energy.html, accessed 5 June 2014.

The Deal

The deal between EDF and the British government was announced on 21 October 2013.[202] The main points were[203]:

- The two reactors would cost £8 billion (US$13.6 billion) each;
- The U.K. Government would provide loan guarantees for about £10 billion (US$17 billion);
- The "strike price", the initial guaranteed price, would be £92.5/MWh (US$157.7/MWh), and would be paid under a CfD to all power produced (FiT) for 35 years;
- This would fall to £89.5/MWh (US$152.6/MWh) if two follow-up reactors at Sizewell were completed;
- The strike price would be indexed to general inflation (using the Consumer Price Index), and there would be scope for real increases in operating costs to be passed through to consumers;
- EDF was adamant that the risk of construction cost escalation would be borne by EDF;[204]
- The consortium building the plant would be: EDF Group (45-50 percent); CNNC and CGN (30-40 percent); AREVA (10 percent), but EDF stated: "Discussions are also taking place with a shortlist of other interested parties who could take up to 15 percent"; and
- Expected first power would be 2023.

The details of the negotiations had been reported widely for the year or more that they had been going on and many of the elements of the deal were expected. These include the strike price, the contract duration, the use of a CfD and a FiT, and the indexation to general inflation. The granting of loan guarantees was a relatively late concession only mooted in June 2013.[205] However, other elements of the deal were unexpected.

Whilst a Chinese participation had been forecast, it was much larger than expected whilst the AREVA contribution had not been reported. It must be assumed that these elements were essential for the financial package to be viable.

The price was a surprise because right up to the day of the announcement, it had been reported as being £7 billion (US$12 billion), indeed, the CEO of EDF U.K. only a week earlier had quoted £7 billion as the likely price. EDF's explanation for the last-minute price rise was deeply unconvincing:

> The construction cost of the two nuclear power units at Hinkley Point, expressed in 2012 money, is expected to be £14 billion. In addition to the construction costs, the project and its partners will have incurred £2 billion of other costs before first operation. These include land purchases, achieving the different consents, construction of a spent fuel storage facility and preparing the 900 strong team which will run the station. This means that the total costs to first operation are expected to be close to £16 billion, expressed in 2012 money.[206]

It seems highly unlikely that a package of land purchases, training, and the like would amount to £2 billion (US$3.4 billion) and these costs were clearly known about long before the announcement, so, at best, to reveal them only at the last minute was disingenuous and at worst deceptive.

The date of first power was also a surprise that has not been adequately explained. It was clear that the early target for first power of late 2017 was not feasible, but given the expectation of a construction period of five years and the government's hope the inevitable state-aid inquiry might be completed by mid-2014, it might have been expected that a completion date of around 2020 would be forecast. The completion date of 2023 implies construction start as late as 2018. It is probably no coincidence that

---

[202] EDF Energy, "Agreement reached on commercial terms for the planned Hinkley partners", 21 October 2013, see http://newsroom.edfenergy.com/News-Releases/Agreement-reached-on-commercial-terms-for-the-planned-Hinkley-Point-C-nuclear-power-station-82.aspx, accessed 5 June 2014; and Department of Energy & Climate Change, The Rt Hon Edward Davey MP, The Rt Hon David Cameron MP and Prime Minister's Office, 10 Downing Street, "Initial agreement reached on new nuclear power station at Hinkley", 21 October 2013, see https://www.gov.uk/government/news/initial-agreement-reached-on-new-nuclear-power-station-at-hinkley, accessed 5 June 2014.

[203] Exchange rates in this chapter as of 31 December 2012, as prices have been given for in 2012 money.

[204] Nucleonics Week "UK, EDF reach deal on Hinkley Point C", 24 October 2013.

[205] WNN, "Loan guarantee for Hinkley Point C", 28 June 2013, see http://www.world-nuclear-news.org/NN-Loan_guarantee_for_Hinkley_Point_C-280613ST.html, accessed 5 June 2014.

[206] EDF Energy, "Agreement reached on commercial terms for the planned Hinkley Point C nuclear power station", 21 October 2013, see http://newsroom.edfenergy.com/News-Releases/Agreement-reached-on-commercial-terms-for-the-planned-Hinkley-Point-C-nuclear-power-station-82.aspx, accessed 5 June 2014.

EDF hopes to life-extend its two oldest Advanced Gas-cooled Reactors (AGRs), at Hinkley Point B and Hunterston, until 2023 so these plants would be closed only when Hinkley Point C was complete. Again, this suggests the difficulty EDF has in financing the deal.

Whether the deal really does mean that all the construction cost overrun risk will be borne by EDF is difficult to know. The U.K. government has said the contract will be published but with commercially confidential details redacted, giving ample scope for price escalation pass-through clauses not to be disclosed.

The State-Aid Inquiry

It was inevitable once the CfD framework had been disclosed that the deal would be subject to a state-aids inquiry by the European Commission. There are three basic tests that must be applied to any such agreement: Is it state aid; does it distort markets; and is there an applicable exemption from state aid rules? The agreement clearly is state aid that could distort markets and there is no applicable exemption.[207] The nuclear industry had hoped that a review of state-aid guidelines for energy would give nuclear power the same status as renewables, which are, effectively, exempt from state-aid legislation. Draft proposals in July 2013 were reported to include provisions to give nuclear power similar status to renewables.[208] However, there was strong opposition to this draft from some member states and in October 2013, the Commission made it clear nuclear power would not be given special status in any new guidelines.[209] This was finally confirmed by the Guidelines on State aid for environmental protection and energy 2014-2020, as published in the Official Journal of the European Union on 28 June 2014, which have now entered in force.[210]

The Hinkley deal was notified to the European Commission in October 2013 and the Inquiry formally opened in February 2014. A second Inquiry was also required to review the arrangements for pricing the waste disposal. The initial view of the Commission on the Hinkley Point deal was almost entirely negative. It concluded:

> The Commission considers at this stage that the notified measure involves State aid within the meaning of Art 107(1) TFEU. The Commission doubts that the aid might be considered as compatible aid for the provision of a SGEI under the SGEI Framework. Finally, the Commission has doubts that the notified measure can be declared compatible under Article 107(3) (c) TFEU and in particular that it effectively addresses a market failure and is appropriate. It also questions whether the notified measure can be deemed to have an incentive effect, to be proportionate, and is concerned about its distortive effects on competition. The Commission does not intend to prejudge whether State aid to nuclear energy might be appropriate. The Commission merely aims to highlight issues of concern which it has identified in the specific measures proposed by the UK, and aims to carry out a more in-depth assessment of such issues in a formal investigation.[211]

Prospects for other consortia

With the waning of interest by the Big 6 in nuclear expansion in the U.K., the other two consortia, Horizon and NuGen, appeared to have little future. However, the deal being negotiated by EDF and the likely terms, as well as paucity of orders worldwide, led Hitachi-GE and Toshiba-Westinghouse to essentially take over these two companies.

Horizon had made significantly more progress than NuGen and had acquired two Magnox sites, Wylfa and Oldbury. It had not chosen between the EPR and the AP1000, but the re-imposition of the phase-out policy in Germany left the two German owners, RWE and E.ON, with little interest in pursuing nuclear power and they announced their intention to withdraw from Horizon in March 2012, although the decision had been predicted for some time.[212] Hitachi-GE bought the company in October 2012. The price of £700 million (US$1.2 billion) was remarkable. It bought two viable sites, although the

---

[207] For a detailed description of the applicable rules for state-aids, see Steve Thomas & Dörte Fouquet, "The new UK nuclear power programme – a FIT for nuclear and a blueprint for illegal state aid?", on behalf of Greens/EFA Group – European Parliament, Belgium, 2013.

[208] Nucleonics Week, "Draft EU state aid guidelines includes chapter on nuclear energy", 25 July 2013.

[209] Nucleonics Week, "EU drops nuclear power section from state aid guidelines: Almunia", 10 October 2013.

[210] European Commission, "Guidelines on State aid for environmental protection and energy 2014-2020", Official Journal of the EU, 28 June 2014, see http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2014.200.01.0001.01.ENG, accessed 24 July 2014.

[211] European Commission, "State aid SA. 34947 (2013/C) (ex 2013/N) — United Kingdom Investment Contract (early Contract for Difference) for the Hinkley Point C New Nuclear Power Station", 18 December 2013, see http://ec.europa.eu/competition/state_aid/cases/251157/251157_1507977_35_2.pdf, accessed 5 June 2014.

[212] The Independent, "RWE npower and E.ON halt nuclear plant development", 29 March 2012.

Oldbury site would be likely to be problematic, and a capability. However, if the deal with EDF cannot be completed, for example, if it fails the state-aid inquiry, the Horizon consortium would be highly unlikely to proceed. In addition, it is proposing to build a design, the ABWR, which had not started the GDA process so Horizon would be unlikely to be in a position to start building much before 2020.

The ABWR is often portrayed as a proven design, but the reactors in operation (three reactors in Japan) and under construction (two in Taiwan and two in Japan) are all the version from the mid-1980s, predating Chernobyl.[213] An updated version was given generic design approval in the USA in 1997, but that design was never ordered and approval expired in 2012. GE-Hitachi applied to renew approval in 2010 but the U.S. Nuclear Regulatory Commission is still reviewing the design and has published no expected completion date for the process. GE-Hitachi has no firm U.S. customers, so there is little incentive to complete the process.

A design able to satisfy European regulators would differ again from the U.S. version. The process of review in the U.K. started in March 2014.[214] Given the lack of experience of the U.K. regulator (the Office of Nuclear Regulation [ONR]), with BWR technology, it seems unlikely the process can be completed in much less than the five years the EPR took. Whilst it is possible the reactor design can complete the GDA successfully, the requirements imposed may increase the expected cost significantly. It therefore seems there is still ample scope for the Horizon consortium to fail.

The NuGen consortium only acquired one site, adjacent to Sellafield, Moorside. This would require major new grid connections to get the power out, and was widely seen as one of the less attractive options. The NuGen consortia did not appear to have progressed much. It had not chosen a technology and it had made no significant progress with the site. From 2010 onwards, reports of lack of interest from the partners began to appear and first SSE, then Iberdrola withdrew. Iberdrola's withdrawal led to Toshiba's taking a majority stake in January 2014. This appeared to revive the prospects for the AP1000, and NuGen has said it hopes to build up to three AP1000s at Moorside.[215] Toshiba has stated it does not expect to complete the GDA before 2017, although it is not clear when it will formally request that ONR re-commence its review. How far this delay is down to an expectation that the remaining issues will not be quick to be resolved and how far it is down to NuGen's seeing no advantage in committing resources to the project before it is certain that the Hinkley deal can be finalized is not clear. The price for Toshiba's 60% stake in NuGen of about £100 million (US$170 million) is substantially less than that paid by Hitachi-GE for Horizon.[216] This may reflect the fact that only one site, potentially problematic was acquired, that the capability in NuGen was much less developed than that in Horizon and that if the Hinkley deal fails, other deals will not be viable. However, the AP1000 is a quicker and probably less risky choice of design. Overall, as with Horizon, the odds are still probably against the NuGen consortium building a plant.

Rosatom has been looking at the U.K. as a potential new market for some years and in September 2013, it concluded an agreement with the U.K. government to cooperate on nuclear matters and signed agreements with Rolls Royce and Fortum (Finland) to advise it on entry into the U.K. market. In November 2013, it also had a 2-day information exchange on the GDA process, presenting its latest VVER-1200 design. However, Russia's role in the unrest in Ukraine put a question mark against its entry into U.K.[217] If this is resolved quickly and no other major problems arise, Russia would still have to acquire a site and would probably not be able to get a reactor in operation much before the late 2020s.

China's third nuclear vendor, SNPTC

SNPTC was reported to looking to buy a stake in the NuGen consortium. SNPTC was Westinghouse's technology partner for orders of the AP1000 for China and has developed a larger version, CAP1400, which is reported to have received regulatory approval from the Chinese regulator in January 2014 and is expected to be built in Pakistan as well as China.[218] CNNC and CGN may also have plans to offer Chinese technology, either through the NNB Genco consortium or through an independent venture.

[213] The ABWR is offered by three separate companies. In the USA, it is offered by GE-Hitachi, a consortium of GE (80%) and Hitachi (20%) whilst outside USA, it is offered by Hitachi-GE (80% Hitachi). Toshiba, which participated in the development of the ABWR and supplied some of the reactors broke away in 2006 and offers its own version of the ABWR, although not in the UK.
[214] Office for Nuclear Regulation, and the Environment Agency, "UK ABWR", see http://www.onr.org.uk/new-reactors/uk-abwr/index.htm, accessed 5 June 2014.
[215] Nucleonics Week, "Toshiba to buy 60% of UK's NuGen, plan AP1000s at Moorside", 16 January 2014.
[216] Financial Times, "Westinghouse to buy 50 per cent stake in NuGen", 15 December 2013.
[217] NIW, "United Kingdom", 28 March 2014, p 8.
[218] Sunday Times, "China eyes Sellafield", 29 September 2013.

Given that independent Chinese technology is still at best only just available and would require rigorous review under the GDA process, the completion of Chines-designed plants is probably as distant as Russian technology.

Financial Markets, Nuclear Power and Changing Power Markets

The power sector is in the throes of a technology revolution that will lead to the transformation of the current utility business model. Across the board, financiers, bankers, independent analysts, industry officials and academics see that changes, and in most cases profound changes, are now inevitable. This is driven by a combination of technology innovation and subsequently falling prices, a desire for greater energy access and independence, higher costs of some fossil fuel extraction, and environmental concerns. The current situation is concisely summarized by Citi Group when they state for Europe:

> We expect a new business model to emerge with (i) upstream focus on renewables and decentralized energy with conventional generation only as a back-up, (ii) midstream focus towards the creation of local distribution networks feeding into a smart and Pan-European transmission grid and (iii) downstream focus on services and facilities maintenance instead of supply. The pace of change will vary by country and plenty of stumbling blocks exist, the biggest of which is the lack of innovation track record in the utilities sector. However, the trajectory of change in our view is set and although the pace will be evolutionary (two plus decades), the outcome will be revolutionary.[219]

Table 5: Views of the Future of Utilities and their Business Models

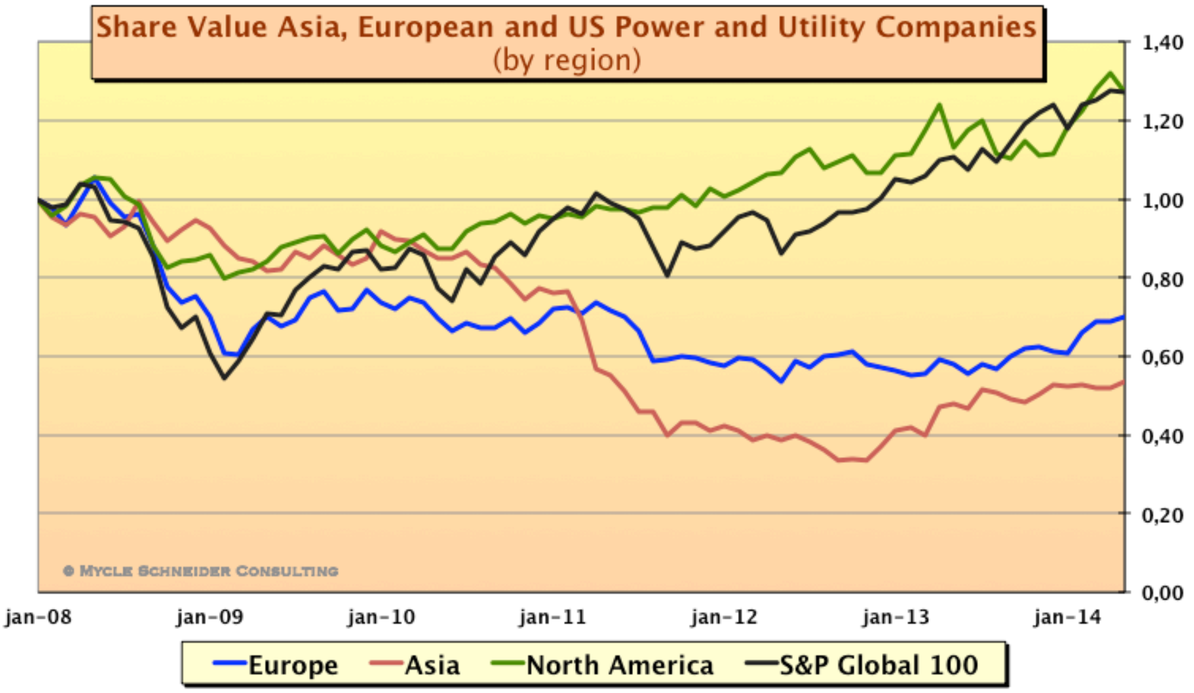
Brian A Dames CEO, Eskom	The power and utilities business is where banking and landline telephony were a decade or two ago, with new technologies the main driving force. Technology advancements, especially in distributed generation and energy efficiency, will have a definite impact on existing business models. This, together with a more informed and empowered customer, will shift the business model.[220]
Johannes Teyssen CEO, E.ON	Demand-side management will play a more active role and the integration of more PV and wind, i.e. more volatile generation, and of more decentralized generation, will determine future business models. In regions and countries with less of an established energy system, decentralized generation could play an even larger role.[221]
Deloitte	The more traditional business models that have served the electric power industry so well in the past simply may not be enough this time – the time for true innovation in the electricity sector may have arrived. By the application of insight and ingenuity, when the year 2020 comes, the successful electricity company may look very different from the electricity business as we know it today.[222]
Ernst and Young	Breaking with the past, on budgets with little elasticity, utilities have to wake up to the fact that they can no longer continue with business as usual.[223]
Citi GPS	This is not a “tomorrow” story, as we are already seeing utilities altering investment plans, even in the shale-driven U.S., with examples of utilities switching plans for peak-shaving gas plants, and installing solar farms in their stead.[224]
Plaxos	Renewables have not just put pressure on margins. They have already transformed the established business model for utilities.[225]

However, it is not just a European process and the extent to which the industry believes their business will change in the years ahead is highlighted in the Pricewaterhouse Coopers Annual Global Power and Utilities survey,[226] which reported that 94 percent of those surveyed believed that there will be the

[219] Citi, “Pan-European Utilities, The lost Decade – Where Next”, 17 June 2013.
[220] Ibidem.
[221] Ibidem.
[222] Deloitte, “The math does not lie – Factoring the future of the U.S. electric power utility”, August 2013.
[223] Ernst and Young, “Fit for the Future: how the power and utilities industry is facing up to transformation challenge”, Performance Magazine, 2013, see http://performance.ey.com/wp-content/uploads/downloads/2013/02/Fit-for-the-future.pdf, accessed 15 July 2014.
[224] Citi GPS, “Energy Darwinism – The Evolution of the Energy Industry”, October 2013.
[225] Dr Christos Papadopoulosm, “What is the best we can do when planning for capacity expansion under uncertainty?”, 5th Annual European Power Summit 28 & 29 April 2014.
[226] PwC, “Energy Transformation — The impact on the power sector business model”, 13th Pricewaterhouse Coopers Annual Global Power and Utilities Survey, October 2013.

complete transformation or important changes in the power utility business model by 2030. This included 69 percent of industry officials in Asia who believed that the industry will be transformed by 2030, while none in the region thought that industry will remain the same. The survey also found that 82 percent see distributed power generation as an opportunity as opposed to 18 percent who see it as a threat. Table 5 provides an overview of recent comments by utility leaders, banks, and consultancies that illustrate the profound and rapid nature of the expected change.

Figure 13: Share Value Asia, European and U.S. Power and Utility Companies (by region)



Sources: Yahoo Finance, Accessed June 2014

The extent to which the traditional role of utilities is likely to change is also reflected in the value of the large-scale electricity companies. Figure 13 shows for the three regions of the world presented that the average share values of the companies performed worse than the Standard and Poor's Global average. This, even—by a small margin—applies to US companies, where the favorable situation with the availability of shale gas, is balanced by flat electricity demand and growth in renewables squeezing out the traditional companies. According to the US EIA, electricity demand in 2013 was comparable to that of 2005, but retail sales revenue rose by 9.1% in 2013 over the previous year.[227]

In Europe and Asia the situation is significant bleaker, although it has improved slightly in 2013, with the share values of major electricity companies below that of 2008. The Asian picture is dominated by, but not solely as a result of the impact of Fukushima and the subsequent decision to suspend the operation of the nuclear power plants in Japan.

Overall in Europe, the utilities' shares have been the worst performers among 19 major sectors since early 2008 and the top 10 utilities have lost half of their €1 trillion (US$1.4 trillion) share value since then.[228] According to Société Générale, outside the financial sector the power utility sector is the most indebted in Europe.[229] While many of the financial and market conditions, such as falling or flat demand and limited access to capital, the affect has not been homogeneous, as can clearly be seen in Figure 14, which relates to share prices, as some utility companies have fared better than others. Of those assessed, SSE, in the U.K., which abandoned plans to invest in nuclear power in the 2012, has outperformed the others and is the only one that has seen a higher share price compared to 2008. Companies in France and Germany have fared the worst. In Germany, E.ON and RWE shares have fallen by almost half in the last five years, while the

---

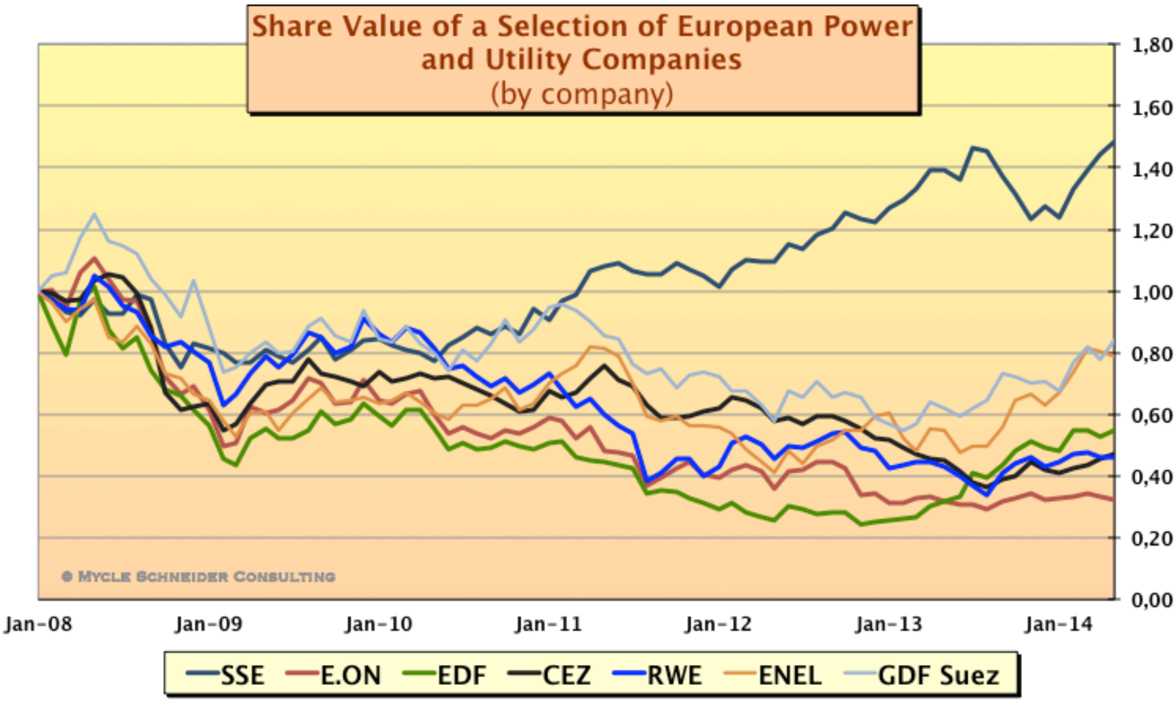
[227] US EIA, "Electricity Data", see http://www.eia.gov/electricity/data.cfm, accessed June 2014.

[228] Economist, "European Utilities: How To Lose Half A Trillion Euros. Europe's Electricity Providers Face An Existential Threat", 12 October 2013, see http://www.economist.com/news/briefing/21587782-europes-electricity-providers-face-existential-threat-how-lose-half-trillion-euros, accessed 17 June 2014.

[229] Ponti, A., "Europe Has a dream, Green Policies and Traditional Generators: Can They Live Together?", January 2014, see http://www.iefe.unibocconi.it/wps/wcm/connect/18d74f8e-279d-4dea-91dd-818582e913ff/Slides+Ponti.pdf?MOD=AJPERES, accessed 17 June 2014.

German stock market index has almost doubled.[230] The reasons given for this collapse in share value is the over-investment in fossil fuel capacity prior to the economic slowdown and a fall in demand combined with the rise of renewable energy, as well as the closure of some of their nuclear power plants (see Nuclear vs. Renewables Chapter for further analysis).

Figure 14: Share Value of a Selection of European Power and Utility Companies



Source: Yahoo Finance, Accessed May 2014

In Germany supply from the traditional sources in 2012 is 15 percent down, 60 percent due to the recession and 40 percent due to renewables.[231] For RWE this led to a fall in net income from a profit of €2.5 billion (US$3.4 billion) in 2012 to a historic, first time loss in 60 years, of €2.8 billion (US$3.8 billion) in 2013. Rather than representing an operational deficit—it actually filed an 8.3 percent lower but still comfortable operating result of €5.9 billion (US$8 billion)—RWE depreciated its conventional power plants by some €4.8 billion (US$6.6 billion). RWE has mothballed some 3,800 MW of gas-fired power plants and is expected to shut down more than 1,200 MW of hard coal capacity. And this is possibly not the end of the story. CEO Peter Terium stated that RWE's power plants "must at least cover their operating costs. And this is far from being the case with all of the stations we want to keep up and running".[232] RWE is also struggling with a €30 billion (US$41 billion) debt load. E.ON managed to limit a decline in income in 2013 to 4 percent, now €2.5 billion (US$3.4 billion), but had a net debt of €32 billion (US$44 billion) and a debt/EBITDA factor that rose to 3.4.

In France, EDF's net income totaled €3.5 billion (US$4.8 billion) for 2013, an increase of €242 million (US$330 million) or 7.4 percent compared to 2012. However, its net financial debt remains very high with €35.5 billion (US$48.5 billion), (2.1 times EBITDA),[233] at times when operational costs are rising constantly and very large investment needs are looming around the corner (backfitting, life-extension and post-Fukushima upgrading, decommissioning, waste management, etc.).[234] The other big French utility, GDF-Suez, also has a heavy debt burden of €30 billion (US$41 billion) (2.2 times EBITDA) and posts unprecedented impairments of almost €15 billion (US$20.5 billion), mainly depreciating thermal power plants and gas storage across Europe: "The Group believes that the change in environment in Europe is now serious and long-lasting and has

[230] Economist, "German Power Generators Looking for Lifelines", 7 June 2014, see http://www.economist.com/news/business/21603467-embattled-eon-and-rwe-turn-government-and-courts-help-looking-lifelines, accessed June 2014.
[231] Graham Weale, "Transition of the German Utilities: increasing the emphasis on the service component of supply", RWE, presentation at the Platt's European Power Summit, Berlin, 28 April 2014.
[232] RWE, "Annual Report 2013—Shaping the Future", March 2014.
[233] EDF, "Annual Results 2013", 13 February 2014.
[234] See also section on France in Annex 1.

therefore decided to draw the consequences for its asset values (…)”.[235] GDF-Suez CEO Gérard Mestrallet stated in an interview: “You cannot stick to the old world and the heritage of the monopolies. I want to change the company culture and invest into the new world (…)”.[236]

Table 6: Long Term Credit Ratings of Utilities with Nuclear Investments

Standard and Poor’s Long-Term Credit Rating (year-end or as noted)										
Company	**Date of last action**	**2014** June	**2013** June	**2012** June	**2011** June	**2011** April	**2010**	**2009**	**2008**	**2007**
Africa										
Eskom	Sept 2012	BBB	BBB	BBB+	BBB+	BBB+	A-	A-	A-	A-
Asia										
Kansia[237]	May 2012	A-	AA-	AA-	AA-	AA	AA	AA	AA	AA
KEPCO	Sept 2012	A+	A+	A	A	A	A	A	A	A
TEPCO	May 2012	B+	B+	B+	B+	BBB+	AA	AA	AA	AA
Europe										
EDF	Jan 2012	A+	A+	A+	AA-	AA-	A+	A+	AA-	AA-
E.ON	July 2012	A-	A-	A	A	A	A	A	A	A
ENEL	July 2013	BBB	BBB+	BBB+	A-	A-	A-	A-	A-	A-
RWE	July 2012	BBB+	BBB+	A-	A-	A-	A	A	A	A+
GdF-Suez	May 2014	BBB+	A	A	A	A	A	A	A	A
TVO	May 2014	BBB	BBB	BBB	BBB	BBB	BBB	BBB	BBB	BBB
North America										
PG&E	Dec 2011	BBB	BBB	BBB	BBB	BBB+	BBB+	BBB+	BBB+	BBB+

Sources: S&P, Financial Times, Reuters, Company websites and Annual Reports, compiled by MSC

Despite a slight upturn in the share values of the major utilities in the last year the rating agencies have not significantly changed their credit ratings. However, over the last seven years, the rating agencies have downgraded their views of the major utilities companies listed in Table 6.

However, the rating agencies views of other utilities involved in nuclear have changed for some over the last year, especially in relation to new-build. The Finish owner of Olkiluoto, Teollisuuden Voima Oyj (TVO), which has experienced significant cost over-runs and delays in recent years has seen its rating from Fitch fall from 2009-2013 A- to BBB. While it remained stable in 2014, another agency, Standard and Poor’s, concluded that they were “revising our outlook to negative from stable and affirming our 'BBB/A-2' ratings on TVO”. The reasons given for this were:

> Difficult market conditions in the Nordic electricity markets have put further pressure on electricity prices--future prices for the coming three years now trade 15% lower than they were a year ago. At the same time, TVO faces continued significant delays in its construction of a new nuclear power plant, Olkiluoto 3, which could increase its total production costs above current expectations.[238]

---

235 GDF-Suez, “Annual Results 2013”, Press Release, 27 February 2014.
236 Le Monde, “Pertes record à GDF-Suez, son PDG s’explique au ‘Monde’”, 27 February 2014.
237 Moody’s rating cited because Kansia is not rated by S&P.
238 S&P, “Finland-Based Nuclear Power Producer Teollisuuden Voima's Outlook To Negative On Risk Of Declining Cost Competitiveness”, 23 May 2014.

The April 2014 decision by Czech utility CEZ not to proceed with the construction of a new nuclear power plant was perceived by Moody's as "credit positive". Interestingly Moody's sees the potential restart of reactors in Japan as leading to a possible credit positive development. However, the rating agency warned of the Japanese situation that:

> The six utilities have reduced their losses over the past two years, but their return to profitability is not assured, and profitability will not necessarily lead to an immediate improvement in their overall financial strength.[239]

In a global review of the impact of nuclear generation on credit quality, Moody's reached the conclusion, that nuclear construction of nuclear power plants is generally credit negative as it was vulnerable to low power prices and that cost over-runs are more frequent than in other technologies. The agency further concluded that the European power markets in their current state do not support new-build nuclear.[240] During the same conference at the OECD's Nuclear Energy Agency, business advisory KPMG concluded about the financial risk of nuclear power that "financial investors are unlikely to consider nuclear power in the near future due to construction risks, lack of early yield and lack of long term yield certainty". KPMG further noted that any investors would need to be insulated by large developer balance sheets or Government support.[241] The extent to which this has occurred can be seen in the Reactor Vendor Strategies section of this report.

The view from the financial community is absolutely crucial given the scale of investment that is needed in the sector over the coming decades to replace retiring power stations and to meet growing demand in emerging and developing economies. The IEA's 2014 World Energy Investment Outlook, estimate that this could reach US$16.2 trillion by 2035. Importantly, the IEA anticipates that renewable energy will dominant investment in power plants and that existing policies will mean that investment in solar and wind power will exceed that of fossil fuels or nuclear power on the global level. Furthermore, in countries like China that have traditionally been heavily investing in centralized energy sources, this trend will be even more extreme, with suggestions that the total investment for solar and wind by 2035 will be over US$700 billion—plus another US$300 billion for hydro—while the combined investment of nuclear and fossil fuels is expected to be less than US$600 billion. Furthermore, in the IEA's scenario in which investments are in line with attempts to ensure that global emissions do not lead to temperature rises above 2 degrees centigrade, their so-called 450 scenario, the absolute and relative investment in renewables is far greater.[242]

As clearly illustrated in the section on Nuclear vs. Renewables – Paying to Produce, this greater use of renewables has already significantly impacted upon the operating regime of power plants in Germany, both nuclear and fossil fuel. However, in other countries in Europe, a similar, if less pronounced effect can be seen with the operating hours of conventional generators decreasing. In Spain, CCGT plants operated on average over 5,700 hours per year in 2004, but this had fallen to below 1,000 hours in 2013, in Italy they fell from 5,000 hours in 2007 to below 3,000 hours in 2012.[243] As in Germany, it is not just the gas power stations that are affected, as in Italy, the load factors of coal plants fell from 60 percent in 2012 to 56 percent in 2013, while in Spain they fell from 60 percent to 48 percent over the same period.[244] The anticipated increase in the use of renewable will further undermine the operating regimes of not just the fossil plants but, as has been seen in Germany, the nuclear power plants. The global deployment of renewables will further accelerate the need for the reform of the utility sector and continue to undermine the financial viability of nuclear power.

---

[239] Moody's , "Moody's: Credit quality of Japan's nuclear-reliant power utilities to diverge", 27 March 2014.

[240] Moody's, "Nuclear Generation's Effect on Credit Quality – Moody's Perspectives on Operating Risks and New Build", September 2013, see http://www.oecd-nea.org/ndd/workshops/wpne/presentations/docs/2_2_LUND_OECD_Sept%2019_Lund_Moodys_Nuclear_Generations_effect_on_Credit_Quality.pdf, accessed 14 June 2014.

[241] Dominic Holt, "Under Which Conditions Are Pension Funds and Other Infrastructure Investors Interested in Nuclear New Build?", KPMG Infrastructure, September 2013, see http://www.oecd-nea.org/ndd/workshops/wpne/presentations/docs/2_3_HOLT_Nuclear_Fin_Workshop_KPMG_Sept%202013_vers_distribution.pdf, accessed 14 June 2014.

[242] IEA, "World Energy Investment Outlook", Special Report, International Energy Agency, June 2014.

[243] Eurelectric, "Flexible Gas Markets for Variable Renewable Generation", May 2014.

[244] Societe Generale, "Investigating the consequences of European climate policies", Alberto Ponti, Platts European Power Summit, 28 April 2014.

Fukushima – A Status Report

More than three years have passed since the 3/11 East Japan Great Earthquake and Fukushima Nuclear Power Plants Catastrophe started unfolding. The situation of the Fukushima Daiichi nuclear reactors remains far from stable. Many questions remain as to how the accident occurred, and why it could not be prevented. Contaminated water leakage was a great concern from the beginning, but no definitively effective measures to solve the issue were implemented to date. Consequently, contaminated water leaks are frequent with some of them reaching the sea. The complexity of the task to stabilize four severely damaged reactors in a disaster zone turned out so challenging that many measures turned out ineffective or simply failed. The site will remain vulnerable to another catastrophic event that could occur during this remediation process, including another big earthquake and/or tsunami, a gigantic typhoon or a severe tornado.

However, at least one highly positive development occurred in November 2013 with the beginning of the unloading of spent fuel from the cooling pond of unit 4, thus reducing the risk of a spent fuel fire in the case of loss of cooling potentially resulting in a massive new release of radioactivity. Still, the people of Fukushima are suffering physically as well as mentally, many with no prospect of returning home.

On 11 March 2011, a long and strong earthquake followed by a series of once-in-1,000-years-grade tsunami waves devastated the east coast of *Tohoku*, the northeastern region of *Honshu*, Japan's main island. The earthquake and tsunami affected 14 reactors in 4 nuclear power stations on the Pacific coast, namely from north to south, Onagawa with 3 BWR units operated by Tohoku Electric Power Co., Fukushima Daiichi with 6 BWRs and Fukushima Daini with 4 BWRs[245], both operated by Tokyo Electric Power Co. (TEPCO), and Tokai Daini (1 BWR) operated by Japan Atomic Power Co. (JAPCO). Units 1 to 4 of the six Fukushima Daiichi units were devastated, resulting in massive release of radioactivity into the environment. The other 10 reactors escaped meltdowns and radioactive release by a series of lucky circumstances, but they were nevertheless damaged considerably. The Rokkasho reprocessing plant on the Pacific coast of Aomori, 300 km north of Onagawa, escaped major damage, it lost all external power supplies, but emergency generators worked to keep liquid high-level waste from boiling and thus from releasing large additional quantities of radioactivity.

Off-site Challenges: Evacuation, Decontamination

The vast scale of the economic loss, real-estate devaluation, primary-industries damage, environmental hazards, and enormous personal and community sufferings caused by the Fukushima accident is hard to grasp in its totality. As of 10 March 2014, officially, more than 130,000 people in Fukushima Prefecture are still evacuated. The total number of evacuees in the three earthquake- and tsunami-stricken prefectures is about 267,000, so about half of the evacuees are from Fukushima Prefecture. Of these, about 102,000 are from designated evacuation order zones and from a former "emergency preparation zone".[246] Almost 48,000 evacuees live outside[247] and over 86,000 within Fukushima Prefecture, including those who self-evacuated to relatives' homes[248].

As of 20 February 2014, over 28,500 people in Fukushima still live in temporary housings, mainly from Minami-Soma city, Namie-town, and Naraha town.[249] Evacuees still in temporary housing three years after 3/11 officially total 98,144, not only in the Tohoku region but including Ibaraki, Tochigi, Chiba, and Nagano Prefectures.[250]

---

[245] *Daiichi* means "The First" and *Daini* "The Second"; thus the stations may also be referred to as Fukushima-I and Fukushima-II, respectively.

[246] Reconstruction Agency, "Reference Material 3", 10 March 2014, (in Japanese) see http://www.reconstruction.go.jp/topics/main-cat7/sub-cat7-1/20140310_sanko03.pdf, accessed 25 April 2014.

[247] Fukushima Prefectural Government 28 March 2014, in Japanese, http://www.pref.fukushima.lg.jp/uploaded/attachment/54979.pdf, accessed 26 April 2014.

[248] Reconstruction Agency (2014), Total number of Evacuees in Japan, 25 April 2014, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat2/sub-cat2-1/20140425_hinansha.pdf, accessed 25 April 2014.

[249] Fukushima Minpo News, 25 February 2014, (in Japanese), see http://www.minpo.jp/pub/topics/jishin2011/2014/02/post_9280.html, accessed 25 April 2014.

[250] Reconstruction Agency (2014), "Reference Material 3", 10 March 2014, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat7/sub-cat7-1/20140310_sanko03.pdf, accessed 25 April 2014.

In Fukushima Prefecture, deaths recognized as related to the Fukushima nuclear plant accident have increased to 1,671, more than those killed by earthquake and tsunami, which were 1,603.[251] These people died due to stress and mental exhaustion while evacuating, or during life at evacuation centers and temporary housings, due to lack of medical care or suspension of hospital functions. According to the National Police Agency, suicide numbers have risen most significantly in Fukushima Prefecture, to 23 people in 2013—the largest number amongst the three 3/11-stricken prefectures—up from 13 in 2012 and 10 in 2011.[252]

Rearrangement of the Restricted Zones

Immediately after the accident was triggered, the government ordered the evacuation of all people living within a 20 km radius of the Fukushima Daiichi nuclear power plant. The 20-30 km radius was designated as an area where the population was requested to stay within buildings. On 21 April 2011, the 20 km radius area became a Restricted Zone,[253] in which it was estimated that the dose limit of 20 mSv/y would be exceeded. The 20-30 km radius zone was designated as a Deliberate Evacuation Zone. However, on 26 December 2011, the Nuclear Emergency Response Headquarters of the government declared that Step 2 of the "Mid-term Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station"—cold shutdown condition—had been achieved and that the nuclear power plant site would be in a stable condition.[254] Subsequently, the government rearranged the evacuation zones into three categories depending on the radiation dose level:[255]

- Area 1: Areas where evacuation orders are ready to be lifted, with radiation dose to be 20 mSv/y or less.
- Area 2: Areas where residents remain evacuated, with radiation level expected to be more than 20 mSv/y.
- Area 3: Areas where annual radiation doses are 50 mSv/y or more currently and will still be more than 20 mSv/y for the next five years, meaning it will be difficult to return for a long time to come.

Returning Or Not Returning Home?

Rearrangement of the evacuation zones started in April 2012, but only on 1 April 2014 was an Area 1 designated part of Tamura city's evacuation order lifted for the first time and some residents returned to their homes after three years. Schools and kindergartens opened, but some of the pupils commute to the schools from their current residence outside the city. This is because the radioactivity levels in some areas are still as high as 0.40–0.49 microSv/h.[256] Tamura City has hired a firm to do re-decontamination of such high exposure areas.[257] The daily *Asahi Shimbun* did an interview survey in the first week of April 2014, visiting each household to find out how many people actually returned,

[251] Fukushima Minyu Shimbun, 11 March 2014, (in Japanese), see http://www.minyu-net.com/osusume/daisinsai/serial/140311-4/news1.html, accessed 26 April 2014; and Fuminori Tamba, "The formation of local communities in the development of living bases for long-term evacuees", Fukushima University, presentation at Japan Atomic Industry Forum event, 15 April 2014, see http://www.jaif.or.jp/english/annual/47th/47-s3_tamba-e.pdf, accessed 25 April 2014.
[252] National Police Agency, "Suicide data of 2013", 13 March 2014, (in Japanese), see http://www.npa.go.jp/safetylife/seianki/jisatsu/H25/H25_jisatunojoukyou_03.pdf, accessed 26 April 2014.
[253] Japan Atomic Energy Relations Organization, "Fukushima Daiichi Nuclear Power Plant Accident-Evacuation", (in Japanese), see https://www.jaero.or.jp/data/02topic/fukushima/effect/evacuation.html, accessed 1 May 2014.
[254] See http://japan.kantei.go.jp/policy/documents/2012/__icsFiles/afieldfile/2012/03/07/road_to_recovery.pdf, March 2012, accessed 26 April 2014.
[255] Nuclear Emergency Response Headquarters, "Rearranging restricted areas and areas to which evacuation orders have been issued, etc.", 30 March 2012; and METI, "Reference to Practical operations for designating areas to which evacuation orders have been issued as newly designated areas", see http://www.meti.go.jp/english/earthquake/nuclear/roadmap/20120330_01.html, accessed 26 April 2014.
[256] Year round exposure to this level would lead to an annual exposure of 3.5-4.3 mSv/y. This compares to the normal regulatory dose limit of 1 mSv per year for the general public; Tamura City Radioactivity Monitoring Results of 8 April 2014, (in Japanese), see http://www.city.tamura.lg.jp/uploaded/attachment/8488.pdf, accessed 26 April 2014.
[257] Outline of Tamura City's Decontamination Contract, 10 April 2014, (in Japanese), see http://www.city.tamura.lg.jp/uploaded/attachment/8475.pdf, accessed 26 April 2014.

and reported on 9 April 2014 that only one quarter of the households have returned.[258] Many people commute to the city from their evacuation residence outside the city.

The Kawauchi village has some parts within the 20 km exclusion zone is expected to be lifted of its evacuation order sometime in July 2014. But the mayor of the village gives the villagers the choice to return or not to return.[259] Only half of the population that had self-evacuated had returned to the village as of October 2013, and the biggest reason for not returning is "fear of radiation effects", according to a survey the village conducted in February 2012.

On 18 April 2014, it was disclosed that the government in October 2013 had done a separate survey and simulation of the dose rate the residents would be exposed to but had not released it to the public. However, following its discussion in the media the government finally released the report. The survey and simulation was undertaken in August 2013 by the National Institute of Radiological Sciences and Japan Atomic Energy Agency, commissioned by the Cabinet's Team in Charge of Assisting the Lives of Disaster Victims, and the report was finalized in October 2013.[260] The objective of this research was to find out what dose levels the residents would actually receive from a specific air dose rate monitored by airplanes. The research was based on the assumption that after residents return to their homeland, the cumulative dose assessment of each individual should be calculated on the basis of individual dosimeter measurements, and not by estimating from the air dose rate of the area. Thus the research was done by placing monitoring dosimeters in different locations at different exposure levels in the evacuated area. This way, the ratio between individual exposure and air dose rate was estimated. According to the report[261] the actual dose rate for the residents could be calculated by multiplying by a factor of 0.7 the accumulated dose estimated from the air dose rate of each area. However, the dose rate differs according to the life pattern of each individual, such as forestry workers, agricultural farmers, office or school workers, and old people who are presumed to spend 23 hours per day inside the house. Accordingly, "cumulative dose rates should be measured by each individual using dosimeters" as was proposed during the Nuclear Regulation Authority (NRA)'s 4th Meeting of the "Study Team on Safety and Security Measures for Evacuees to Return Home" held on 11 November 2013.[262] In fact, this was already suggested in the "Third Proposal for an Accelerated Remediation from the Nuclear Accident"[263] made by the ruling Liberal Democratic Party (LDP) led by parliamentarian Tadamori Oshima, head of the LDP's Headquarter to Accelerate the Remediation from the Great East-Northern Earthquake Disaster.

Though the NRA November 2013 Meeting does not explicitly refer to the "factor 0.7", it does say;

> It has been acknowledged that the data of individual dose vary depending on individual daily life, and individual dose data collected by municipalities have a tendency to be lower than the exposure doses estimated from the air dose rates.
>
> Therefore, the evaluation of exposure doses of people who returned homes should be implemented on the basis *not* of the exposure dose estimated from the air dose rates *but* of the individual dose measured actually." (Emphasis added.)

Based on the above conclusion, the NRA Report recommends that

> the Japanese Government should implement the following measures before the evacuees return their homes:
>
> • To collect individual dose data, daily life conditions and occupations of people who routinely enter the areas to which the evacuation directive is ready to be lifted; and

---

[258] Asahi Shimbun, "Only 1/4 households actually returned home", 9 April 2014, (in Japanese).
[259] Yuko Endo, "Initiatives of Kawauchi Village for the Return of its Residents and Issues", at Japan Atomic Industry Forum, 15 April 2014, (in Japanese), see http://www.city.tamura.lg.jp/uploaded/attachment/8475.pdf, accessed 26 April 2014.
[260] METI, Team in Charge of Assisting the Lives of Disaster Victims, "Explanation of the research to simulate individual dose rate", 18 April 2014, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/radioactivity/pdf/20140418_03.pdf, accessed 26 April 2014.
[261] National Institute of Radiological Science & Japan Atomic Energy Agency, "Researches on the Characteristics of Personal Doses after the Accident of TEPCO Fukushima Daiichi Nuclear Power Plant", April 2014, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/radioactivity/pdf/20140418_02.pdf, accessed 26 April 2014.
[262] Nuclear Regulation Authority (NRA), "Basic Principles for a safe and secured returning to homelands", 11 November 2013, (in Japanese), see http://www.nsr.go.jp/committee/yuushikisya/kikan_kentou/data/0004_02.pdf, accessed 26 April 2014; and NRA, "Practical Measures for Evacuees to Return Their Home", 20 November 2013, see http://www.nsr.go.jp/english/library/data/special-report_20140204.pdf, accessed 30 April 2014.
[263] Liberal Democratic Party and Komei Party, "Accelerating the Remediation from the Nuclear Accident Disaster", 8 November 2013, (in Japanese), see https://www.jimin.jp/policy/policy_topics/pdf/pdf118_1.pdf, accessed 26 April 2014.

• To provide information to the evacuees in an easy-to-understand manner, for instance, by developing radiation maps based on individual dose data.

But these measures, as of the middle of 2014, were not implemented by the government.

The data of the original report conducted by the National Institute of Radiological Sciences and Japan Atomic Energy Agency showed that the dose exposure for the residents of cities in the evacuated areas would be below the 20 mSv/y limit, but not below the 1 mSv/y level, the pre-accident legal exposure limit. After the report was revealed, severe public criticism arose, and the METI Minister had to apologize about not disclosing this data before the evacuation order was lifted in Tamura city. This information could have been of help to the residents on deciding whether to return or not. The theoretical factor of 0.7 itself is a "pretty rough estimate", according to Dr. Hajime Suzuki of the International University of Health and Welfare in an interview with *Asahi Shimbun*.[264] The government now intends to use the individual dose rate for decontamination decisions rather than the air dose level that was previously used, de facto this may lead to a relaxation of the decontamination standards.

The NRA Report refers to how the decontamination work should be done as follows:

• Implement appropriate decontamination activities depending on personal dose measuring results and specific exposure in daily life.

• Indicate locations of contamination sources based on integrated data of various monitoring results that have been measured by various organizations at the time when the results of environmental monitoring are provided to the residents (e.g. to indicate locations where high radiation doses on maps and in the fields).

• Decontamination activities should be implemented in line with the residents' point of view.

Decontamination

Under the "Special Law to Manage the Radioactivity released by the Nuclear Accident on 11 March caused by the Great East Japan Earthquake", adopted on 30 August 2011 by the then ruling Democratic Party of Japan (DPJ), the former Japanese Government designated 101 municipalities (cities/towns/villages) in eight prefectures as a Scheduled Contamination Survey Zone, where an additional radiation dose of 1 to 20 millisievert per year (mSv/y) is predicted. Areas where the additional dose is over 20 mSv/y are designated as a Special Decontamination Zone.

In the Survey Zone, the Law designates local governments responsible, with national government subsidies, to conduct decontamination and/or remediation work to decrease radiation dose rates. In the Special Decontamination Zone, a 235-km^2 area in 11 municipalities of Fukushima Prefecture, the national government is responsible for the radiation remediation projects.

The Special Law defines the Ministry of Environment (MOE) to be responsible for managing and proceeding with the decontamination program and send the bills to TEPCO for reimbursement. The Law requires the nuclear power company that caused the accident to pay all the costs, including not only the decontamination operations, but also the identification of interim storage sites and development of disposal methods and technologies.

However, the decontamination operations did not proceed as scheduled, due to three main reasons: technical difficulties, lack of waste disposal arrangements and shortage of manpower. There is no place to store the sludge, soil, water, and other debris that stem from decontamination operations. All are put into plastic bags and stored in the immediate vicinity as stipulated in the Special Law.

To date the operations did not achieve the planned radiation reduction. Even if contamination levels dropped after the operation, in many places it was re-contaminated via trees, rainwater and dust from areas that had not been decontaminated.

MOE started rejecting decontamination operations that were requested by local residents, claiming that work could not be carried out unless approved by TEPCO, while TEPCO did not pay the bills sent from MOE. The decontamination budget for the three fiscal years 2011 to 2013 totaled almost ¥1.3 trillion (US$13 billion) but, according to the Board of Audit of Japan, only about ¥470 billion (US$4.7 billion), 36.4 percent of the budget, were spent.[265] Of that amount, TEPCO refunded only ¥6.7 billion (US$67 million), so far withholding 83 percent of the requested reimbursements.

[264] Asahi Shimbun, 18 April 2014, (in Japanese).

[265] Board of Audit of Japan (2013), "Regarding the Decontamination of the radioactive materials released into the environment from the nuclear power accident in the aftermath of East Japan Great Earthquake as of August 30, 2013", 16 October 2013, (in Japanese), see http://www.jbaudit.go.jp/pr/kensa/result/25/pdf/251016_zenbun_3.pdf, accessed 26 April 2014.

TEPCO's arguments for not paying were that items such as a feasibility study for an interim storage site, public relations activities on decontamination operations, monitoring the temporary storage places are not relevant to the Special Law, and that these should be paid for by the government as the nuclear programs were part of national energy policy.[266]

The Minister of Environment answered at a press conference on 12 November 2013, that the cost of decontamination should be paid for by TEPCO, as the Special Law requires it.[267] Minister Ishihara said that the spirit of the Special Law is the polluter-pays principle of the OECD, so it is TEPCO that should pay for the decontamination work. On 13 November 2013, the Environment Committee of LDP adopted a decision to demand MOE and TEPCO that under the current Special Law, TEPCO is obliged to pay the remaining bill, which was 33.7 billion yen (US$3.3 billion).[268]

On the other hand, the Minister of Finance, Taro Aso, stated at a press conference on 29 October 2013[269] that nuclear policy was a national policy and that the decision by the former government to make TEPCO take the full responsibility was too big a burden to TEPCO and as a result the process is not going forward. On 8 November 2013, the LDP drafted the "Third Proposal for Accelerating the Remediation from the Nuclear Power Accident", in which it proposed that the government take the main responsibility for decontamination. The proposal suggests that the goal of decontamination program is to meet the 20 mSv/y standard, with the previous public-safety 1 mSv/y limit considered only a long-term target, a view the public would need to understand.[270]

Compensation

The victims of the Fukushima nuclear accident have three options to get compensated. First, they can direct their compensation request directly to TEPCO. Second, if TEPCO turns down the request, they can ask the statutory mediator—the Center for Dispute Resolution for Compensating Nuclear Accident, the so-called Nuclear ADR—to represent their compensation towards TEPCO. Thirdly, if the two previous options do not provide any results, victims can file a legal complaint.

As of 11 July 2014, more than 2.2 million compensation claims had been filed by individuals, corporations, trade unions, and local governments against TEPCO, of which TEPCO has paid ¥4 trillion (US$40 billion) in total settling around 2 million claims.[271] In addition, there are around 12,000 cases handled by the Nuclear ADRs, of which about 9,000 have been settled.[272]

In case of nuclear accidents, the 1961 Act on Compensation for Nuclear Damage applies. Article 18 requires the establishment of a Dispute Reconciliation Committee for Nuclear Damage Compensation (established in April 2011), which defines the guidelines for compensation (the first Interim Guidelines issued in August 2011). The Nuclear ADR is expected to accelerate the indemnification of the victims of the nuclear accident. The Interim Guidelines did not cover those who voluntarily left areas not designated as evacuation zones. Other issues such as the loss of homeland, mental disruption from separation of families, and compensation for houses and lands were not included. This was criticized by the Japan Federation of Bar Association (JFBA) from the outset.[273]

---

[266] Asahi Shimbun News, "TEPCO refuses to pay decontamination fee", 27 October 2013, (in Japanese). Asahi found this out by acquiring documents sent by TEPCO to MOE on 27 February 2013 following a freedom of information request to MOE.

[267] MOE, Press Conference Summary, 12 November 2013, (in Japanese), see http://www.env.go.jp/annai/kaiken/h25/1112.html, accessed 26 April 2014.

[268] Satsuki Katayama's blog, 13 November 2013 (in Japanese), see http://satsuki-katayama.livedoor.biz/archives/8136959.html, accessed 26 April 2014; and press conference on Youtube, (in Japanese), see https://www.youtube.com/watch?v=uxBHmlpYFrE, accessed 26 April 2014.

[269] Press conference summary, 20 October 2013, (in Japanese), see http://www.mof.go.jp/public_relations/conference/my20131029.htm, accessed 26 April 2014.

[270] Liberal Democratic Party and Komei Party, "Accelerating the Remediation from the Nuclear Accident Disaster", 8 November 2013, (in Japanese), see https://www.jimin.jp/policy/policy_topics/pdf/pdf118_1.pdf, accessed 26 April 2014.

[271] TEPCO, "Records of Applications and Payouts for Indemnification of Nuclear Damage", 11 July 2014, see http://www.tepco.co.jp/en/comp/images/jisseki-e.pdf, accessed 16 July 2014.

[272] See http://www.mext.go.jp/a_menu/genshi_baisho/jiko_baisho/detail/1329118.htm, (in Japanese), accessed 18 July 2014.

[273] Japan Federation of Bar Associations, Statement on 30 September 2011, see http://www.nichibenren.or.jp/en/document/statements/year/2011/20110930_2.html, accessed 30 April 2014.

TEPCO made their own "Compensation Standards" based on the first Interim Guidelines[274], and assessed each bill from the victims accordingly. It seems as if TEPCO interpreted the Interim Guidelines as their ceiling for compensation, not the minimum level. TEPCO is asking victims to provide receipts of all expenses on lodging and transport, and refuses to pay more than a limited amount. TEPCO also stated that it will only compensate the damage from the nuclear power accident and excluding damage from earthquake and tsunami, a difference for which the victims must supply evidence.

JFBA criticized TEPCO for this practice and also for not including crucial issues such as loss of business in tourism, retail shops and restaurants, and cesium contamination of beef, which were however included in the Interim Guidelines.[275] Such economic damages are routinely included in calculations of losses in U.S. environmental damage cases, for example. JFBA was also highly critical of the huge amount of paper work burden on the victims to submit claims. In December 2011, in a first modification of the Interim Guidelines, the authorities added 23 municipalities from which people had self-evacuated and which are located outside the special designated areas.[276]

On 20 December 2013, the Cabinet approved the paper drafted by Nuclear Emergency Response Headquarters, "For Accelerating the Reconstruction of Fukushima From the Nuclear Disaster"[277] This was a radical change in approach from an "All Evacuees to Return" policy to "Support Evacuees to Start New Life in New Places". Accordingly, the Dispute Reconciliation Committee for Nuclear Damage Compensation issued the Fourth Addition to the Interim Guidelines on 26 December 2013[278], indicating how much compensation would be provided for those in Area 3 where there is no prospect of returning in the foreseeable future, and for those from areas where returning seems difficult and who might be better starting a new life elsewhere. The payments would be made in lump sums. Details of the additional compensation schemes for others are given such as how their houses and land would be compensated for along with the support needed for evacuees to start a new life, at a location of their choice. But the monthly compensation fee would be limited to one or a few years after they start a new life. The aim of this decision is to accelerate the return of people to areas where evacuation orders are planned to be lifted as soon as possible. In spite of this one-off lump sum compensation, evacuees seem to be more worried than satisfied,[279] since it concludes their compensation rights.

Lawsuits

Evacuees have filed numerous lawsuits for compensation to courts in Chiba, Tokyo, Fukushima, Sapporo, Nagoya, Kobe, Yokohama, Osaka, Kyoto, Niigata and Maebashi local courts.[280] Further group actions have started such as the Plaintiffs for Criminal Prosecution of the Fukushima Nuclear Disasters,[281] and TEPCO Shareholders Suit against TEPCO's Board of Directors[282], in addition to a

[274] TEPCO, Press Release 30 August 2011, see http://www.tepco.co.jp/cc/press/11083005-j.html; and Summary of the Guidelines, 30 August 2011, see http://www.tepco.co.jp/cc/press/betu11_j/images/110830e.pdf; both in Japanese and accessed 1 May 2014.

[275] Japan Federation of Bar Associations, "Statement Regarding Compensation for Damage Caused by the Tokyo Electric Power Company's Fukushima No.1 and No.2 Nuclear Power Plant Accidents for those Evacuated from Outside Evacuation Areas", 30 September 2011, see http://www.nichibenren.or.jp/en/document/statements/year/2011/20110930_2.html, accessed 30 April 2014.

[276] METI, "First Addition to the Interim Guidelines of August 5, 2011 regarding voluntary evacuees", 6 December 2011, (in Japanese), see http://www.mext.go.jp/b_menu/shingi/chousa/kaihatu/016/houkoku/__icsFiles/afieldfile/2012/01/18/1315180_1.pdf, accessed 20 July 2014.

[277] METI, "For Accelerating the Reconstruction of Fukushima From The Nuclear Disaster", 20 December 2013, (Provisional Translation), see http://www.meti.go.jp/english/earthquake/nuclear/roadmap/pdf/20140410_01.pdf and http://www.meti.go.jp/earthquake/nuclear/pdf/131220_hontai.pdf, accessed 30 April 2014.

[278] Ministry of Education, Culture, Sports, Science and Technology, (in Japanese), see http://www.mext.go.jp/component/a_menu/science/detail/__icsFiles/afieldfile/2013/12/27/1329116_011_1.pdf, accessed 30 April 2014.

[279] Asahi Shimbun, "TEPCO to pay evacuees additional 7 million yen for 'loss of hometowns'", 27 December 2013, see http://ajw.asahi.com/article/0311disaster/fukushima/AJ201312270055; and New York Times, "Villagers who fled radiation in Japan reluctant to return", 27 April 2014, see http://www.nytimes.com/2014/04/28/world/asia/forced-to-flee-radiation-fearful-japanese-villagers-are-reluctant-to-return.html?_r=0, both accessed 30 April 2014.

[280] Ministry of Justice, "Lawsuits Demanding National Compensations", as of 14 March 2014 (in Japanese), see http://www.moj.go.jp/shoumu/shoumukouhou/shoumu01_00046.html, accessed 1 May 2014.

[281] See "The Complainants for Criminal Prosecution of the Fukushima Nuclear Disaster filed suit against TEPCO officials for releasing contaminated water", 17 December 2013, see http://kokuso-fukusimagenpatu.blogspot.jp/p/blog-page_5112.html, accessed 1 May 2014.

collective lawsuit against the manufacturers of nuclear reactors, such as Hitachi, Toshiba, and GE.[283] This was launched by 4,128 citizens from 39 countries as of 10 March, 2014[284], including well-known musicians, writers, former nuclear engineers, and NGOs. U.S. Navy Sailors also filed a court case against TEPCO for being exposed to radiation while they were offering help in the "Operation Tomodachi" right after the accident.[285]

Cause of the Accident: Wave or Shake?—Questions and Findings

By 2013, six separate investigations into the Fukushima accident had been carried out and published (mostly in Japanese). They are in order of publication: (1) Ohmae project[286], (2) RJIF[287], (3) TEPCO[288], (4) NAIIC[289] commissioned by the Diet (Parliament)[290], (5) the Government[291], and (6) the Atomic Energy Society of Japan (AESJ).[292] The reports differ not only in their perspectives but also in many of the details in their analysis of the accident sequences.

The most important difference among the above reports is about whether the main cause of the Fukushima Daiichi disaster was the earthquake shocks or the tsunami inundation. Only the NAIIC report claims that ruptures in piping or destruction of generator(s) could have caused decisive failures prior to the tsunami arriving. Other investigation reports consider the tsunami the cause. The quake/tsunami issue bears a key influence on the matter of the country's safety regulations of nuclear facilities in general, and the controversy in particular of whether to restart other power reactors under the current seismic codes.

The NAIIC investigation presents a strong argument that the loss of coolant accident at Unit-1, leading to its meltdown quicker than other reactor units, had been caused by the earthquake strikes *before* the tsunami crippled the emergency generators. Onsite investigation, particularly in level-3 to level-5 floors of the Unit-1 building, is needed to specify how much and what kind of damage is found in which parts of the building and installations. NAIIC's repeated request for onsite inspection was refused by TEPCO for safety reasons.

---

[282] See http://tepcodaihyososho.blog.fc2.com/, (in Japanese), accessed 1 May 2014.

[283] Greenpeace Japan, 21 November 2013, see http://www.greenpeace.org/japan/ja/news/press/2013/pr20131121/; and Japan Daily Press, via Channel News Asia, "Thousands more join lawsuit against nuclear suppliers of Fukushima", 13 March 2014, see http://japandailypress.com/thousands-more-join-lawsuit-against-nuclear-suppliers-of-fukushima-1345731/, accessed 13 March 2014.

[284] "Group to file lawsuits against nuclear manufacturers", (in Japanese), see http://maker-sosho.main.jp/about-us/, accessed 1 May 2014.

[285] Environment News Service, "US Sailors Sue Japanese Nuclear Plant Owner TEPCO", 3 January 2014, see http://ens-newswire.com/2014/01/03/u-s-sailors-sue-japanese-nuclear-plant-owner-tepco/, accessed 1 May 2014.

[286] K. Ohmae, "The Last Conditions of Reboot: Final Report of the Investigation Project of the Fukushima Daiichi Accident", Shogakkan Publishers, 2012, (in Japanese).

[287] Rebuild Japan Initiative Foundation (RJIF), usually called Minkan Jikocho (Minkan means private sector and "jikocho" is short for Accident Investigation Committee) was chaired by Professor K. Kitazawa, former President of the Japan Science and Technology Agency (JST), "The Independent Investigation Commission on the Fukushima Nuclear Accident—Investigation Report", RJIF, 1 March 2012, (in Japanese), see http://rebuildjpn.org/en/fukushima/, for an English summary, accessed 19 June 2013.

[288] TEPCO, "Fukushima Nuclear Accidents Investigation Report", 20 June 2012, see www.tepco.co.jp/en/press/corp-com/release/2012/1205638_1870.html, accessed 7 May 2013.

[289] National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission.

[290] National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), usually called "Kokkai Jikocho" (Kokkai means the Japanese Diet, the National Parliament) was chaired by Emeritus Prof. K. Kurokawa of Tokyo University. NAIIC, "The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission", The National Diet of Japan, 5 July 2012 (NAIIC 2012). English edition at http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/report/, accessed 30 April 2013.

[291] Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (ICANPS), usually called "Seifu Jikocho" (seifu is the national government) was chaired by Emeritus Prof. Y. Hatamura of the University of Tokyo. ICANPS, "Final Report on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company", 23 July 2012, english edition at http://www.cas.go.jp/jp/seisaku/icanps/eng/final-report.html, accessed 30 April 2013.

[292] AESJ, "Investigation Committee on Fukushima Daiichi Nuclear Accident", September 2013, (in Japanese), see http://www.aesj.or.jp/jikocho/rep20130902.pdf, accessed 30 April 2014.

On 28 March 2013, upon request from Hiroshi Kawauchi, the former chairman of the House of Representatives Special Committee on Science, Technology and Innovation,[293] TEPCO took a video recording of level-4 of Unit-1 and published it on its website.[294] Mitsuhiko Tanaka, science journalist and former member of NAIIC interpreted the footage as showing a degree of devastation much more significant than previously estimated, and made him more confident that, apart from the big explosion on level-5, there was also a hydrogen explosion on level-4 destroying piping systems connecting reactor vessel and isolation condenser.

Based on these video and photos, Tanaka, together with attorney Yoshinori Ito, made a request on 27 August 2013 to the Speaker of the House of Representatives and to the Chair of the House of Councilors to continue the investigation and let them go inside reactor building of Unit-1.[295] The reason for this is that Tanaka believes that there was a small-break Loss of Coolant Accident (LOCA) with small cracks developing in the piping directly connected to the ice condenser units on level-4 due to the prolonged violent seismic motion continuing for several minutes causing the coolant water to burst out from the ice condensers. This water leakage, according to Tanaka, was witnessed by several employees working on level-4 at the time of the earthquake. The second reason he gives is that there is no evidence that the main steam release safety valves (SR valves) functioned. The SR valve is a device for reducing pressure in a nuclear reactor by releasing steam, automatically or by manual operation, but when this happens, a large dynamic force is known to occur in the pressure suppression chamber (S/C) with a violent vibratory noise in the chamber. But during the NAIIC investigation that he conducted, not one worker heard that sound. If any of the SR valves were not functioning, it indicates that one pipe or another into or from the reactor (e.g. an ice condenser pipe) had been damaged by the earthquake motions, and the coolant leaking from it reduced the pressure so that the pressure inside the reactor never rose as high as would be expected, and as a result the SR valves did not function. Tanaka wants to prove this by going into the reactor building and look for further evidence.[296]

However, on 4 and 5 December 2013, TEPCO installed a lifting device equipped with cameras and lights on level-1 of the building of Unit-1 below the equipment hatch opening, and took photos of surrounding building frames via remote control. This was to confirm whether the damages to the building frames inside the Unit-1 reactor building are stemming from the earthquake or not. After this photo investigation, TEPCO stated that "no remarkable damage was found, but these results will be reflected in the seismic resistance evaluation in the future."[297]

TEPCO's report was published on 13 December 2013 and, referring to the questions raised by Tanaka, states: "After the opening operation of the large S/C [pressure suppression chamber] vent valve, the D/W [drywell] pressure decreased from 14:30 through about 14:50. Later at 15:36, hydrogen in the reactor building exploded and the roof and outer walls of the uppermost floor were damaged. It can be considered that hydrogen gas generated mainly by water-zirconium reactions leaked together with steam and finally reached the reactor building, resulting in the hydrogen explosion. But its leak path, volume, explosion aspects and ignition source are unknown. Examinations of these items remain. (Common/Issue-11)."[298] Lawyer Ito commented: "This conclusion is a step back compared to the 'Investigation Report' TEPCO produced in 2012 saying clearly that the explosion occurred on level-5.

[293] Kawauchi is an ex-Member of Parliament and the former Chairman of the House of Representatives Special Committee on Promotion of Science, Technology and Innovation. This committee tried actively to inquire into the Fukushima accident before the official parliamentary commission, NAIIC, was organized.

[294] TEPCO, Pictures of level-4 of Unit-1, taken on 28 March 2013, see http://photo.tepco.co.jp/date/2013/201303-j/130328-01j.html, accessed 2 May 2014.

[295] Mitsuhiko Tanaka, Letter to the Chairpersons of the Lower and Upper Houses of the Diet, 27 August 2013, (in Japanese), see http://www.cnic.jp/wp/wp-content/uploads/2013/09/c8bdd0da39b9cdb14f81af5192a93cb8.pdf, accessed 1 May 2014.

[296] Mitsuhiko Tanaka, "What does the Enormous Damage on Level 4 of the Fukushima Daiichi Unit-1 Nuclear Reactor Building Mean?", Monthly magazine "Kagaku", Iwanami Shoten, September 2013, (in Japanese).

[297] TEPCO, "Results of Investigation into Building Frames around Unit 1 Reactor Building Equipment Hatch at Fukushima Daiichi NPS", 6 December 2013, see http://www.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_131206_07-e.pdf, accessed 26 March 2014.

[298] TEPCO, "Evaluation of the situation of cores and containment vessels of Fukushima Daiichi Nuclear Power Station Units-1 to 3 and examination into unsolved issues in the accident progression", 13 December 2013, p.15, see http://www.tepco.co.jp/en/press/corp-com/release/betu13_e/images/131213e0102.pdf, accessed 1 May 2014.

It assures that at least they have no proof to exclude our option of the small LOCA [loss of coolant accident] leading to a small hydrogen explosion on level-4."[299]

The NRA concluded in an interim report released on 18 July 2014 that the disaster was "almost certainly" triggered by the tsunami.[300]

TEPCO's Roadmap Towards Restoration and Decommissioning

TEPCO released its first "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station" on 17 April 2011.[301] Its initial plan was to flood the reactors with water to keep them cool and then retrieve the melted debris. The plan was revised in December 2011[302], but the process is not proceeding as planned and the current effort is behind schedule.[303]

The delay is mainly due to contaminated water leakages from basements, above- and underground tanks, and pipes. To pursue the flooding plan, leaking parts must be identified and repaired, so workers have had to be shifted from other essential tasks to monitoring storage tanks and wells, building new tanks, replacing bolted with welded tanks, moving contaminated water between tanks, etc.

The objective stated in the roadmap to decommissioning is still to flood the reactor building up to the top of the reactor pressure vessels, then remove the molten fuel, but the government and TEPCO have started investigating another option of cooling the reactor cores by blowing air through the fuel. TEPCO is quite negative to this plan[304], but the discussion is ongoing. TEPCO is considering this possibility, as it would drastically reduce the amount of contaminated water.[305]

In December 2013, TEPCO decided to decommission Units-5 and -6 and use the two reactors as "full size mock-up testing (actual equipment verification testing) facilities for remote decontamination of the inside of reactor buildings, investigation of the inside of primary containment vessels, and equipment to remove fuel debris".[306] The decision was requested by Prime Minister Abe after Tokyo had won the 2020 Olympics bidding in the beginning of September 2013.

On 18 November 2013, work began to remove spent fuel from Unit-4 following the installation of a cover for the entire building. Unit-4 had 1,533 fuel assemblies stored in the pool including 202 unirradiated, fresh fuel assemblies. As of 10 July, 2014, 1,188 fuel assemblies, including 22 fresh fuel assemblies, had been removed to the common pool. Fifty-four times a transport cask has been moved from Unit-4 to the common pool. The operation is currently interrupted for "annual ceiling crane checkup". Work is scheduled to resume in early September 2014 to be completed by the end of the year.[307]

Another step forward is the establishment of a separate company within TEPCO tasked solely on decommissioning and cleanup. This was announced[308] following the Cabinet approval of the Nuclear Emergency Response Headquarter's paper "For accelerating the Reconstruction of Fukushima From

---

[299] Lawyer Ito's website, (in Japanese), see http://www.shomin-law.com/katudoukashiwazakikariwasashitomejunbishomen17.html, accessed 1 May 2014.
[300] Asahi Shimbun, "NRA blames tsunami for equipment failure at Fukushima plant", 19 July 2014.
[301] TEPCO, "Roadmap towards Restoration from the Accident at Fukushima Daiichi Power Station", Press Release, 17 April 2011, see http://www.tepco.co.jp/en/press/corp-com/release/11041707-e.html, accessed 25 March 2014.
[302] TEPCO, "Mid-and-long-Term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Units 1-4, TEPCO", Press Release, 21 December 2011, see http://www.tepco.co.jp/en/press/corp-com/release/11122107-e.html, accessed 25 March 2014.
[303] METI, "Progress Status and Future Challenges of the Mid-and Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4", Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, 30 January 2014, see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20140130-e.pdf, accessed 25 March 2014.
[304] METI, see http://www.meti.go.jp/earthquake/nuclear/pdf/131128/131128_01pp.pdf, (in Japanese), accessed 25 March 2014.
[305] TEPCO, 27 February 2014, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/roadmap/images/d140227_06-j.pdf, accessed 25 March 2014.
[306] Naomi Hirose, "Regarding the Decommissioning of Units 5 and 6 at Fukushima Daiichi Nuclear Power Station", President of TEPCO, Press Release, 18 December 2013, see http://www.tepco.co.jp/en/press/corp-com/release/2013/1233020_5130.html, accessed 25 March 2014.
[307] TEPCO, "Fuel Removal from Unit 4", see http://www.tepco.co.jp/en/decommision/index-e.html, accessed 19 July 2014.
[308] TEPCO, "TEPCO to create new entity focused on Fukushima Cleanup", Press Release, 20 December 2013, see http://www.tepco.co.jp/en/press/corp-com/release/2013/1233100_5130.html, accessed 2 May 2014.

the Nuclear Disaster"[309] on 20 December 2013. The new company was established on 1 April 2014 under the name "Fukushima Daiichi Decontamination & Decommissioning Engineering Company", and is headed by Naohiro Masuda, who was head of Fukushima Daini at the time of 3/11 Earthquake and Tsunami.[310] The mission of the company is to decontaminate and decommission the Fukushima Daiichi nuclear power station with expertise, safety and efficiency and to develop and preserve the expertise for others to apply for decommissioning in Japan and around the world.[311]

On-site Challenges: Water, Waste, Radiation

Difficulties with Radioactive Water Management

Cooling of the reactor vessels continues at Units-1, -2 and -3 as the reactor cores of all three units melted down and are likely to have melted through the vessels, so the normal reactor cooling systems are of no use. Operators know where and how the water is injected, but they do not know exactly where it then goes or where leakage occurs. The coolant (freshwater plus neutron-absorbing boron) is pumped and sprayed into the main vessels (i.e. pressure vessel, though the pressure is long lost), then leaks into the secondary containment through the holes and cracks at the bottom of the reactor vessels. After cooling the melted nuclear fuel somewhere in the primary and secondary vessels (the forms and distributions of the fuel debris being unknown), the water leaks out from unidentified ruptures of the containments and overflows into the basements of the reactor buildings and the connected turbine buildings. This drainage continuously washes out radionuclides from the destroyed reactors. Nonetheless, the water injection must continue to prevent the fuel from overheating.

Operators collect the drained radioactive water from the basements and send it through filter systems to decrease radioactivity and recirculate it back into the reactors. However, the decontamination facilities have encountered countless leaks and breakdowns (see below).

The extreme radioactivity (several billion Becquerel per liter prior to decontamination) of the outflow water is a serious problem by itself. Worse, the volume of the contaminated water is continuously increasing due to the influx of groundwater from the hillside into the reactor buildings through the broken walls.

Fukushima Daiichi is located at a very watery geological site where an underground stream from the mountains flows underneath the power plant site to the sea. Originally, it was estimated that the stream carries about 1,000 tons per day, of which 400 tons are presumed to flow into the basements of the facility buildings and get contaminated, while the remaining water flows directly into the sea. On 23 August, 2013, the 5th Meeting on Contaminated Water Issue was held at METI, and TEPCO presented their new estimation of the groundwater flow to be 800 tons/day, with 400 tons entering the basements of the power plant buildings, and 400 tons going into the sea.[312]

Another 400 tons of contaminated water is created each day by cooling the core, and one tank can store only 1,000 tons, so every 2.5 days a new tank is filled up. As a result, storage tanks are now covering the Fukushima Daiichi station site. As of 15 July 2014, more than 500,000 tons of contaminated water were stored at the site. In addition, about 90,000 tons of contaminated water are sitting in the basements of the nuclear power plant buildings.[313] On 28 April, at the "12th Meeting to discuss Contaminated Water Issues" of METI, TEPCO showed plans to increase the capacity of contaminated water storage tanks up to 800,000 tons by end of FY2014.[314]

Due to a shortage of tanks and areas to store the water, in early 2013, adjacent to the tanks TEPCO dug seven large (10,000-ton-class) sink ponds, which were cheaper and easier to build. But a series of

---

309 METI, "For Accelerating the Reconstruction of Fukushima From the Nuclear Disaster", see http://www.meti.go.jp/english/earthquake/nuclear/roadmap/pdf/20140410_01.pdf; and http://www.meti.go.jp/earthquake/nuclear/pdf/131220_hontai.pdf; both in Japanese and accessed 30 April 2014.

310 TEPCO, "New Leader takes over Fukushima cleanup, says top priorities are water, accountability, safety", Press Release, 4 April 2014, see http://www.tepco.co.jp/en/press/corp-com/release/2014/1235345_5892.html, accessed 2 May 2014.

311 TEPCO, "Fukushima Daiichi D&D Engineering Company: Mission and Profile", 4 April 2014, see http://www.tepco.co.jp/en/decommision/team/images/FukushimaDaiichiDandD_01.pdf, accessed 2 May 2014.

312 TEPCO, "Geological and underground water situation", 23 August 2013, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/pdf/130823/130823_01j.pdf, accessed 2 May 2014.

313 TEPCO, "Press release no.159", 16 July 2014, see http://www.tepco.co.jp/en/press/corp-com/release/2014/1239415_5892.html, accessed 24 July 2014.

314 TEPCO, "Plans to increase and replace contaminated water storage tanks", 28 April 2014, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/pdf/140428/140428_01j.pdf, accessed 2 May 2014.

radioactive leaks was detected in March and April 2013. On 5 April 2013, 120 tons of radioactive water leaked from this reservoir.[315] This is thought to have released the highest amount of radioactivity since December 2011, when the damaged reactors were declared to be in "cold shutdown".

In June 2013, it was revealed that the groundwater sampled from a monitoring well adjacent to the Unit-2 turbine building is contaminated with strontium and tritium, so the highly radioactive water that filled the unit's basement has already made its way into the aquifer and can easily flow into the sea.[316]

On 20 August 2013, TEPCO announced that about 300 tons of contaminated water leaked from a tank and that while a part of it was held back by a small dike around the tanks, the rest went into the soil.[317] Dose rates close to the leak location reached levels exceeding 100 mSv/h. The contamination level was measured at 100,000 Bq/l of Cesium-137 and 80 million Bq/l of Beta emitting radionuclides. In this context the NRA decided to rate this event at level-3 of the International Nuclear Event Scale (INES) rating.[318]

On 20 February 2014, TEPCO announced that another significant leakage of contaminated water had occurred at one of the bolted tanks. Apparently, 102 tons containing 230 million Bq/l of Beta and 9,300 Bq/l of Cesium 137 leaked.[319] It was the biggest reported leakage since August 2013, and TEPCO is investigating its cause. Some early findings indicate that a valve was left open and the water in the tank overflowed.

Attempts to Solve the Contaminated Water Problems

ALPS

TEPCO started a test operation of a new multi-nuclide removal equipment (Advanced Liquid Processing System or ALPS) in March 2013, which is intended to filter out 62 radionuclides other than tritium from the contaminated water and recirculate it in the reactor to cool the core. However, as of April 2014, there has been no successful continuous operation of the ALPS, due to ongoing technical problems.

Ice Wall

In September 2013, at the time of the final phase of Japan's candidature for the 2020 Summer Olympics, a proposal for a US$500 million project to create a frozen wall around the power plant was approved by the Government. The concept appears simple: a row of vertical 20–30-meter-long pipes would be put in the ground, and very-low-temperature antifreeze solution (liquid nitrogen) would be circulated through them to freeze the nearby groundwater into an underground "ice wall". The technology has been used in subway construction and mining to block the influx of groundwater over a distance of a few meters for a few days or so, but has never been applied over a distance of some 1,500 meters and for an undetermined amount of time. In addition, such a system would consume large amounts of electricity to maintain below-zero temperatures for a long period of time. It would probably have to run for many years while the reactors need coolant circulation and cannot be rendered water-tight.

---

315 TEPCO, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2013/images/handouts_130406_05-j.pdf, accessed 17 July 2014.

316 The contamination was confirmed in late May 2013, but it took TEPCO more than two weeks to publicly release the information, see TBS News, NHK News, Mainichi Shimbun, 19 June 2013. Also see, Enformable.com, "TEPCO confirms Fukushima Daiichi groundwater contaminated with strontium and tritium", 19 June 2013, see http://enformable.com/2013/06/tepco-confirms-fukushima-daiichi-groundwater-contaminated-with-strontium-and-tritium/, accessed 20 June 2014.

317 TEPCO, "Water Leak at a Tank in the H4 Area in Fukushima Daiichi Nuclear Power Station (Follow-up Information)", Revised version of 20 August 2013, see http://www.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_130820_03-e.pdf, accessed 17 July 2014.

318 NRA, "Background information and Press Release on INES provisional rating on contaminated water leakage from a water tank at Fukushima Daiichi NPS", Press Release, 28 August 2013, see http://www.nsr.go.jp/english/newsrelease/2013/0828.html, accessed 7 June 2014; and TEPCO, "Evaluation of Emissions of Radioactive Materials (Tritium, Cesium and Strontium), 21 August 2013, see http://www.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_130821_07-e.pdf, accessed 2 May 2014.

319 NRA, "News Release", 20 February 2014, see http://www.nsr.go.jp/english/newsrelease/data/20140220.pdf; and TEPCO, "Fukushima Daiichi NPS Prompt Report 2014", 20 February 2014, see http://www.tepco.co.jp/en/press/corp-com/release/2014/1234394_5892.html; both accessed 7 June 2014.

The drilling of holes for the pipes began on 2 June 2014 in spite of many critical voices, including from the NRA, which nevertheless authorized the beginning of the work. Toyoshi Fukeda, an NRA commissioner, stated: "We need to know if the frozen wall is truly effective" and "more importantly, will it cause unforeseen problems?"[320] Apparently, it does. A small section that had been installed around the four connecting points between the reactor turbine buildings and trenches housing electrical cables and water pipes did not work as anticipated. Freezing started on 28 April 2014 and was expected to be completed within a month. But by 8 July 2014, still no ice had formed. Apparently, the constant flow of water prevented the freezing.[321] TEPCO plans to operate the completed ice wall by March 2015.

Underground Water Bypass

This is a plan to pump up the underground water before getting contaminated by the highly radioactive water in the reactor basements, and then discharge it into the ocean. This would reduce the amount of groundwater reaching the reactor buildings by about 100 tons per day (about one-fourth). However, while TEPCO was trying to explain to the fishermen about the plan in August 2013, the contaminated water leakage of 300 tons was identified (see above), and negotiations were cancelled.

On 3 February 2014, TEPCO announced a new discharge standard authorized by the NRA,[322] and restarted negotiations with the fishermen's unions. The Fishery Union of Fukushima Prefecture approved the new standard on 25 March 2014 and accepted TEPCO's proposal to drain out the uncontaminated underground water through a bypass on condition that a third-party organization takes responsibility to watch and monitor the water for contamination.[323]

On 4 April 2014, after two years of discussion, TEPCO finally reached agreement with the Fukushima Prefectural Federation of Fisheries Co-operative Association to allow implementation of a plan to allow clean groundwater to bypass the Fukushima Daiichi plant and flow into the sea.[324] TEPCO agreed to the conditions that the Fishermen required to approve standards on discharge and operation, independent verification of the measurement data, broad public communication on safety of the discharge, and firm compensation for the fishermen who may be negatively affected by rumors. Subsequently, on 9 April, 2014, the first pumping of upstream groundwater into a storage tank began—the first step to bypassing the flow of uncontaminated groundwater and discharging it into the sea.[325]

Workers Exposure to Radiation

According to a report by TEPCO to the Ministry of Health, Labor and Welfare, as of 31 January 2014, a total of about 32,000 workers (4,000 TEPCO employees plus 28,000 contractors and subcontractors) have worked at the Fukushima Daiichi site since the accident started on 3/11. Among those, at least 173 people received radiation doses over 100 mSv (internal and external), including nine who received over 200 mSv, between March 2011 and January 2014.[326]

These figures exclude the contingent troops (firemen, policemen and the Self-Defense Forces) that entered or flew over the site in March 2011. The size and accuracy of the radiation dose estimations for these emergency servicemen seem to vary wildly. Under the emergency conditions of March–April 2011, there were a number of cases in which the workers were in high radiation areas without a radiation manager, who usually escorts the workers to supervise their radiological protection and monitor the dose rate of the work area. There were also frequent cases in which the workers did not

---

[320] NIW, "Japan: Experts Question Efficacy of the 'Great Ice Wall'", 6 June 2014.
[321] Asahi Shimbun, "TEPCO faces hurdles in construction of ice walls to block flow of contaminated water", 9 July 2014, see http://ajw.asahi.com/article/0311disaster/fukushima/AJ201407090052, accessed 15 July 2014.
[322] TEPCO, Handout, 3 February 2014, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2014/images/handouts_140203_04-j.pdf, accessed 7 June 2014.
[323] Asahi Shimbun, "Underground water release, a very difficult decision to make", 26 March 2014.
[324] TEPCO, "Fukushima Daiichi NPS Prompt Report 2014", Press Release, 7 April 2014, see http://www.tepco.co.jp/en/press/corp-com/release/2014/1235388_5892.html, accessed 1 May 2014.
[325] TEPCO, "Fukushima Daiichi NPS Prompt Report 2014", Press Release, 9 April 2014, see http://www.tepco.co.jp/en/press/corp-com/release/2014/1235426_5892.html, accessed 1 May 2014.
[326] Ministry of Health, Labor and Welfare, "Exposure Dose Distribution of the Workers at Fukushima Daiichi Nuclear Power Plant", provided by TEPCO as of 28 February 2014, see http://www.mhlw.go.jp/english/topics/2011eq/workers/irpw/index.html, accessed 2 May 2014.

carry individual dosimeters because of the shortage of the dosimeters in the emergency.[327] Thus the actual total dose could be considerably higher than the official figures given above.

The Ministry of Health, Labor and Welfare announced on 25 March 2014 that some of the internal worker doses were underestimated by TEPCO and that the records of 142 workers would be corrected.[328] The maximum correction was for one worker, a TEPCO employee, who had to add 90 mSv, leading to a total dose of 180 mSv, which is significantly above the national regulation limiting occupational exposure. At least two additional workers from a TEPCO subcontractor exceeded the annual dose limit of 50 mSv.

Radiation-exposed workers' legal dose limit in Japan is 100 mSv over a five-year period, but up to 50 mSv in any given year.[329] As a matter of fact, a number of workers who continuously work at Fukushima Daiichi easily receive their 5-year limit in less than a year, or the annual limit in only a few months. There are workers who intentionally "forget" to put on their dosimeters in the hope of securing longer months of employment. There were even cases where subcontractors put lead shielding around their dosimeters to lower their recorded exposures so they could work longer.[330] This criminal case might just be the tip of the iceberg.

By May 2014 at the Fukushima Daiichi site, a daily average of 4,200 workers were engaged on site, up from about 3,000 a year earlier. The ratio between TEPCO and subcontractor workers is officially about 50:50. The monthly average number of people registered for working at least one day per month is much higher and reached about 9,300 for the months December 2013 to February 2014.[331]

Recruitment of new workers is becoming more and more difficult, while experienced workers, such as tower crane operators, have to leave the site once they have achieved dose limits. This is a serious problem when particular expertise is needed to get work done properly within a limited time in order to avoid extra exposure. According to witnesses from subcontractor companies, some of the mistakes happen because there are not enough managers or team leaders capable of instructing workers appropriately.[332]

Off-site decontamination activities have also resulted in considerable workforce issues. The international press agency Reuters has identified 733 companies performing work under environment ministry contracts and 56 subcontractors "listed on environment ministry contracts worth a total of US$2.5 billion" in the most contaminated areas of the Fukushima exclusion zone. In a stunning investigation[333], Reuters illustrates how homeless people have become the target of recruiters for work in contaminated areas.

Asia specialist and labor expert Paul Jobin, Associate Professor at the University of Paris Diderot sums up:

- Public bids are now almost entirely controlled by the construction companies at the top (moto uke) and the yakuza [Japanese mafia] at the bottom;
- Though the Ministry of the Environment only authorizes two levels of subcontracting, in practice, the levels of subcontracting are even more numerous than at F1 [Fukushima Daiichi]

[327] Of the 5,000 dosimeters stockpiled in Fukushima Daiichi, only 320 survived the earthquake damage and the flood. TEPCO had to temporary suspend the rule that workers must carry individual dosimeter; the obligation was not resumed before May 2011, see Jiji Press, 1 April 2011; Tokyo Shimbun, 28 April 2011; Kyodo, 28 April 2011; Yomiuri Shimbun, 30 April 2011.

[328] Ministry of Health, Labour and Welfare, "Additional assessment of internal dose rate of Emergency Workers at Fukushima Daiichi Nuclear Power Plant", 25 March 2014, (in Japanese), see http://www.mhlw.go.jp/stf/houdou/0000041525.html, accessed 25 March 2014.

[329] In March 2011, the limit was temporary relaxed up to 250 mSv for emergency operations in Fukushima Daiichi (not applicable on other sites). The 100 mSv limit was resumed in Fukushima in November 2011. The extraordinary 250 mSv limit is still applicable to certain operations at Fukushima Daiichi.

[330] Asahi Shimbun, 21 and 22 June 2012; Mainichi Shimbun, 21 and 22 June 2012; Yomiuri Shimbun, 23 June 2012.

[331] TEPCO, "Summary of Decommissioning and Contaminated Water Management", 24 April 2014.

[332] @Happy11311, "700 days after 3.11, a Diary of tweets by Fukushima Daiichi Worker", Kawade Shobo Shinsha, 20 October 2013; and Happy & Yujin Fuse, "Stabling the Accident should be done by All-Japan", F1 Crisis Special Version, Sekai, January 2014, Iwanami Shoten (in Japanese).

[333] Reuters, "Special Report: Japan's homeless recruited for murky Fukushima clean-up", 30 December 2013, see http://www.reuters.com/article/2013/12/30/us-fukushima-workers-idUSBRE9BT00520131230, accessed 8 June 2014.

and other nuclear plants. Between his own employer and Shimizu Construction, the moto uke, Masato [a pseudonym for a labor activist] has counted 24 levels;

- Wage skimming is the norm and many workers only get a tiny portion—if any—of the 10,000 Yen hazard allowance;
- The majority of workers receive no health insurance benefits from their employer and for many reasons they do not register for the national health insurance system on an individual basis.[334]

Many illnesses that might develop amongst Fukushima workers are unlikely ever to be reported.

Current Status of Radioactive Releases to the Atmosphere

Radioactive emissions into the atmosphere from the four reactors continue. As of April 2014, the density of radioactive materials measured at the site boundary was estimated at 0.0013 Bq/m^3 leading to a calculated dose of 0.3 mSv/y[335]. This does not include the radionuclides that flow into the waste water and the unknown direct flow into the groundwater and Pacific Ocean.

Summary and Prospects

The reactor units are still in unstable conditions and the cooling system depends on temporary tubing. Aftershocks are continuing, and people remain concerned that an earthquake even larger than 3/11 could occur. The Government and the utility say it would take 40 years (or probably more) to retrieve the molten fuel from the three reactors. Questions thus remain whether the fragile onsite conditions can possibly be sustained for that long.

The serious challenges the Fukushima Daiichi site is facing still include the following:

1. Cooling the molten fuel (corium), whose exact location remains uncertain, for 5 to 10 years; and to prevent re-criticality under frequent aftershocks, big and small.
2. Circulating the coolant in makeshift, provisional pipes and under the remaining threat of another flooding for years to come.
3. Managing very large, continuously increasing quantities of radioactive water that is building up in the basements of the reactors and turbine buildings. As a result, over 1,000 tanks have been built outside the buildings and occupying the site. These tanks are leaking from a variety of sources including connections, bolt holes, valves, tank tops, and dikes. Bolted tanks urgently need to be replaced by welded tanks.
4. Ensuring that the wrecked reactor buildings and spent fuel pools can continue to withstand aftershocks and potentially much larger new shocks..
5. Emptying the four spent fuel pools, located between the fourth and fifth floors of the reactor buildings, and transferring the fuel assemblies to a safe location (preferably in dry storage with passive cooling). The first operation at Unit-4 is encouraging, but massive challenges lie ahead, especially at the heavily damaged Unit-3.
6. Conducting surveys to pinpoint where and how the reactor containments (including the torus) are cracked and/or ruptured so that they can be mended and filled with water in order to start retrieving, if possible, the fuel debris.
7. Stopping leakages of radioactivity into groundwater, sea, and atmosphere, until a permanent physical containment is re-established.
8. Completing all of these radiation-exposed operations under a severe shortage of workforce, as most of the skilled operators are rapidly reaching their lifetime dose limit.
9. Organizing an international task force comprising nuclear experts from around the world to work on a full-time basis, to speed up the decommissioning process.[336]

---

[334] Paul Jobin, "The Roadmap for Fukushima Daiichi and the Sacrifice of Japan's Clean-up Workers", The Asia-Pacific Journal, 15 July 2013, see http://japanfocus.org/-Paul-Jobin/3967#sthash.70G5wSRF.dpuf, accessed 17 July 2014.

[335] TEPCO, "Summary of Decommissioning and Contaminated Water Management", 24 April 2014.

[336] Following considerable public attention around the large leak of contaminated water in the summer of 2013, calls for international assistance have intensified. Several international petitions have called for international action and the media has broadly covered the issue. However, little has changed since. See for example, Japan Times, "Japan under increasing pressure to accept outside nuclear help", (front page), 30 August 2013, see http://www.japantimes.co.jp/news/2013/08/30/national/japan-under-increasing-pressure-to-accept-outside-nuclear-help/#.U5Swdy86GRB; and Mycle Schneider, "Why Fukushima is worse than you think", Special to CNN,

Nuclear Power vs. Renewable Energy

The year 2013 brought a number of new developments that widened the gap between nuclear power and renewable energy trends. Spain has generated more power from wind—representing 21 percent of total—than from any other power source, outpacing nuclear for the first time. It is also the first time that wind has become the largest electricity source over an entire year in any country.[337] Spain has thus joined the set of nuclear countries that produce more power from renewables, excluding large hydropower, than from nuclear power; the set already comprises Brazil, China, Germany, India and Japan, and thus includes three of the world's four largest economies.

The April 2014 5th Assessment Report (AR5) of the International Panel on Climate Change (IPCC) suggests that under current policies, CO_2 emissions from the energy sector could double or triple by 2050. Reducing emissions to a level unlikely to cause dangerous climate change will require a significant drop in the energy intensity of global economies, along with the rapid reduction in the use of fossil fuels. The report also notes that decarbonizing the power sector is a key component of cost-effective mitigation strategies. It suggests that the share of low-carbon energy sources, which they define as carbon capture and storage, renewable energy, and nuclear power, needs to increase from approximately 30 percent to 80 percent of electricity generation by 2050. While the report does not make recommendations of low-carbon power options' relative priority, it does state:

> *Renewable Energy*
>
> Many RE[338] technologies have demonstrated substantial performance improvements and cost reductions, and a growing number of RE technologies have achieved a level of maturity to enable deployment at significant scale… Regarding electricity generation alone, RE accounted for just over half of the new electricity-generating capacity added globally in 2012, led by growth in wind, hydro and solar power.
>
> *Nuclear Power*
>
> Nuclear energy is a mature low-GHG[339] emission source of baseload power, but its share of global electricity generation has been declining (since 1993). Nuclear energy could make an increasing contribution to low carbon energy supply, but a variety of barriers and risks exist. Those include: operational risks, and the associated concerns, uranium mining risks, financial and regulatory risks, unresolved waste management issues, nuclear weapons proliferation concerns, and adverse public opinion.

The IPCC does not assume that nuclear power is essential for meeting further emissions reductions targets as it puts forward a scenario which envisages the gradual phase-out of nuclear power, *within* the framework of meeting carbon emissions reductions targets.[340]

Investment

According to an assessment jointly published by UNEP and Bloomberg New Energy Finance (BNEF), global investment in renewable energy—excluding large hydro—was US$214 billion in 2013, a second consecutive annual fall, down from US$300 billion in 2011, but still four times the 2004 total of US$52 billion, as illustrated in Figure 15. Of this the largest section of funding was for asset financing, which required US$133 billion of investment, followed by research and development of US$69.2 billion and small scale distributed projects acquiring US$59.5 billion. The investment in small-scale projects also fell after a record investment of US$80 billion in 2012.

---

30 August 2013, see http://globalpublicsquare.blogs.cnn.com/2013/08/30/why-fukushima-is-worse-than-you-think/; both accessed 8 June 2014.

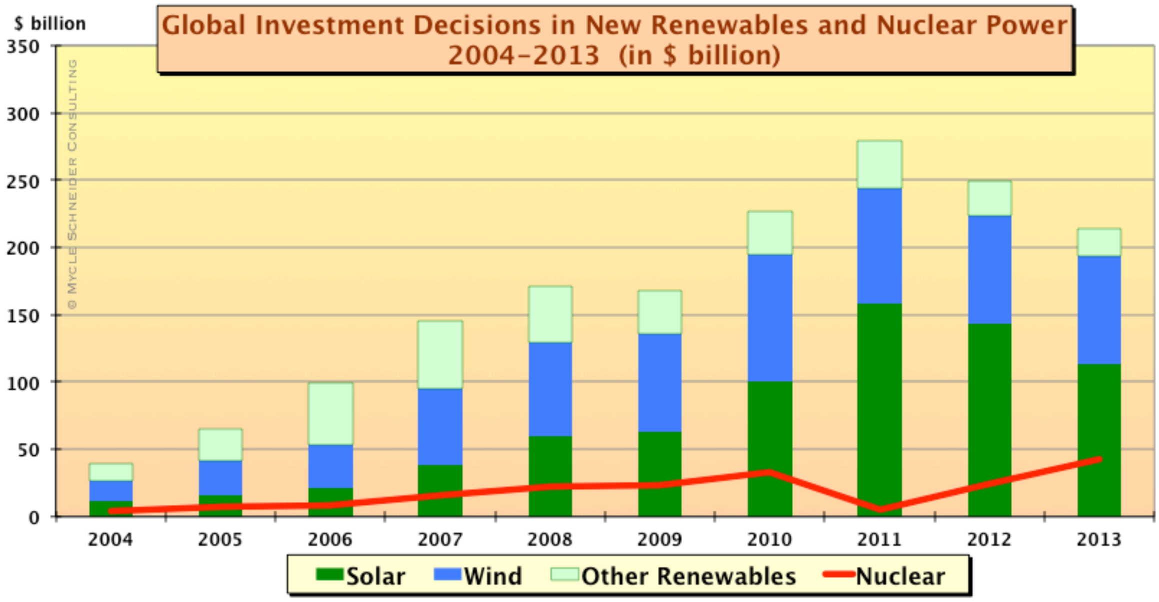
[337] AEE, "Spain was in 2013 the first country where wind energy was the first source of electricity for an entire year", 15 January 2014, see http://www.aeeolica.org/en/new/spain-was-in-2013-the-first-country-where-wind-energy-was-the-first-source-of-electricity-for-an-entire-year/, accessed 4 June 2014.

[338] RE = Renewable Energy

[339] GHG = Greenhouse Gas

[340] IPCC, "AR5, WG III", International Panel on Climate Change, 2014.

Figure 15: Global Investment Decisions in Renewables and Nuclear Power 2004-13 (US$ billion)



Source: UNEP 2014 and WNISR original research

However, as the UNEP report points out, a record of 39 GW of new solar photovoltaic (PV) capacity was installed in 2013, which required less financing than in 2012 when only 31 GW was deployed.[341] More broadly, BNEF's founder stated that the 2013 fall in global renewable investment was four-fifths due to lower costs and only one-fifth to decreased capacity additions,[342] (which, incidentally, are more than accounted for by a drop in U.S. wind power). The entire 2012 decline in investment, too, was more than accounted for by decreased costs, as installed capacity actually increased.

Figure 15 also compares the annual investment decisions for the construction of new nuclear compared to renewable energy since 2004. In the absence of comprehensive, publicly available investment estimates for nuclear power by year, the total investment costs[343] have been included in the year in which construction was started, rather than spreading out the investment over the construction period. Furthermore, the nuclear investment figures do not include revised budgets if cost overruns occur. Over this period the total investment in nuclear is nearly an order of magnitude lower than that renewable energy.

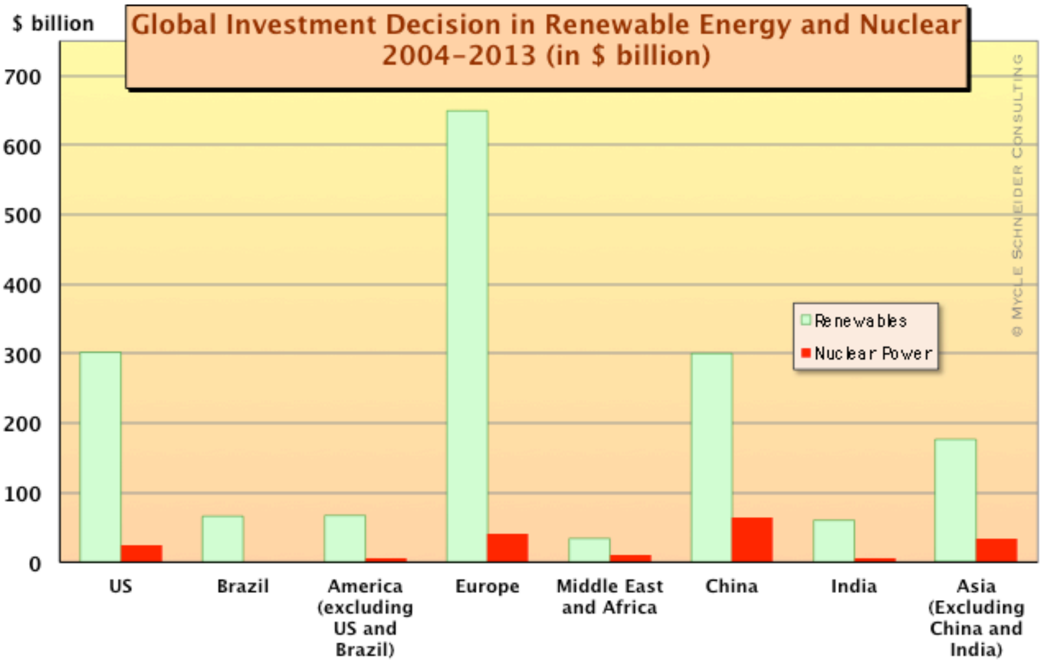
The regional breakdown of the investment in renewables and nuclear power can be seen in Figure 16. This highlights the importance of Europe to renewable investment, which over the past decade has invested nearly 40 percent of the US$1.6 trillion in total. While China is responsible for about 20 percent of renewable global investment it also has a 35 percent share in the spending in the nuclear sector.

According to the IEA, 2000–13 global investments in power plants were split between renewables (57 percent), fossil fuels (40 percent), and nuclear power (3 percent).[344]

Table 7 shows the national investment in "clean energy" (essentially new renewables, not including large hydro) from 2011 to 2013. This shows the consistent importance of China and the U.S. to the global sector and the changing investment status of Japan, which has seen renewable energy rising significantly since Fukushima in 2011, primarily due to investment in small-scale distributed generation. Also of note is the geographical spread of countries that are in the top ten in 2013 with India and South Africa maintaining a strong level of deployment.

[341] UNEP-BNEF, "Global Trends in Renewable Energy Investment 2014", Frankfurt School and United Nations Environment Programme Collaborating Centre and Bloomberg New Energy Finance, April 2014.
[342] Michael Liebreich, keynote, Bloomberg New Energy Finance Summit, New York, 7 April 2014.
[343] On the basis of publicly available estimates at the time of construction start.
[344] IEA, "Special Report, World Energy Investment Outlook", International Energy Agency, June 2014.

Figure 16: Regional Investment Decisions in Renewable Energy and Nuclear Power 2004-13



Source: UNEP 2014 and WNISR original research

Table 7: Top 10 Countries by Investments in "Clean Energy" in 2013

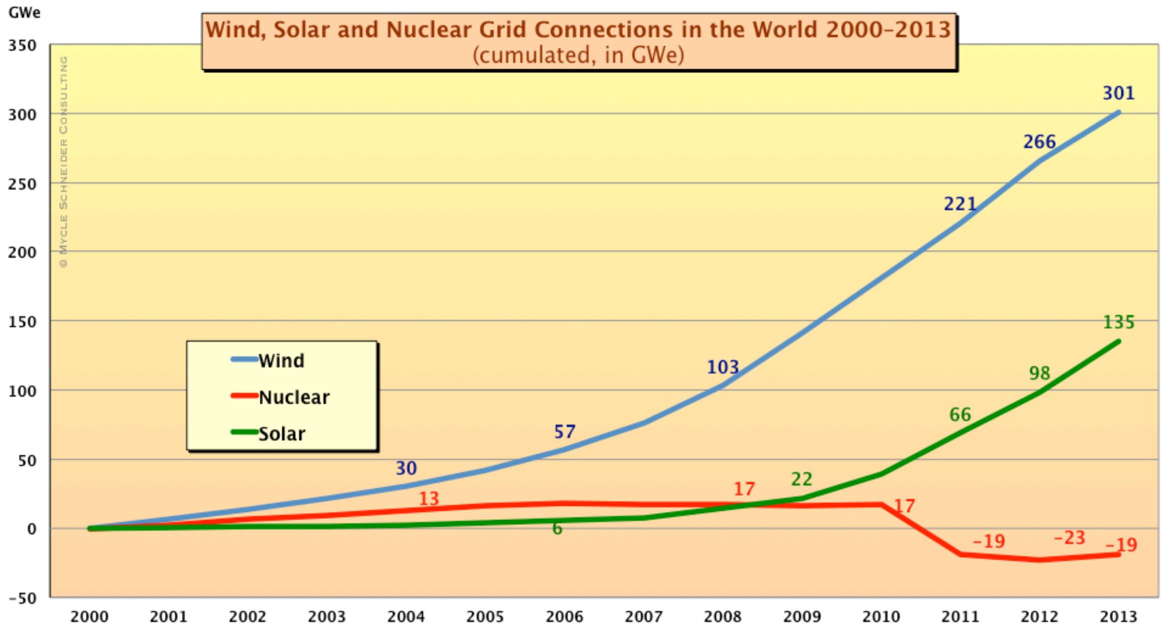
Country	Billion US$		
	2013	**2012**	**2011**
1. China	54.2	67.7	45.5
2. United States	33.9	44.2	48.1
3. Japan	28.6	16.3	8.6
4. UK	12.1	8.3	9.4
5. Germany	9.9	22.8	30.6
6. Canada	6.4	N/A	5.5
7. India	6.0	4.5	10.2
8. South Africa	4.9	5.5	0.03
9. Australia	4.4	N/A	N/A
10. Italy	3.6	14.7	28

Source: Bloomberg New Energy Finance, 2013-14

Installed Capacity

Figure 17 shows the changing capacity in renewable energy and nuclear since 2000 and highlights the massive growth in renewables. Over this period there was a 25-percent *annual* growth rate for wind and 43 percent for solar PV, while nuclear power declined by 0.4 percent.

Figure 17: Wind, Solar and Nuclear, Capacity Increases in the World 2000-2013



Source: IAEA-PRIS, EPIA, GWEC 2014

These figures illustrate the extent to which renewables have been deployed at scale since the new millennium, compared to the stagnation of nuclear power capacity, which over this period decreased by 19 GW. Even if reactors in LTO were considered "operational", nuclear capacity would have increased by a mere 17 GW over the 13-year period, compared to 37 GW of new solar PV and 35 GW of wind *in the single year 2013*.

Electricity Generation

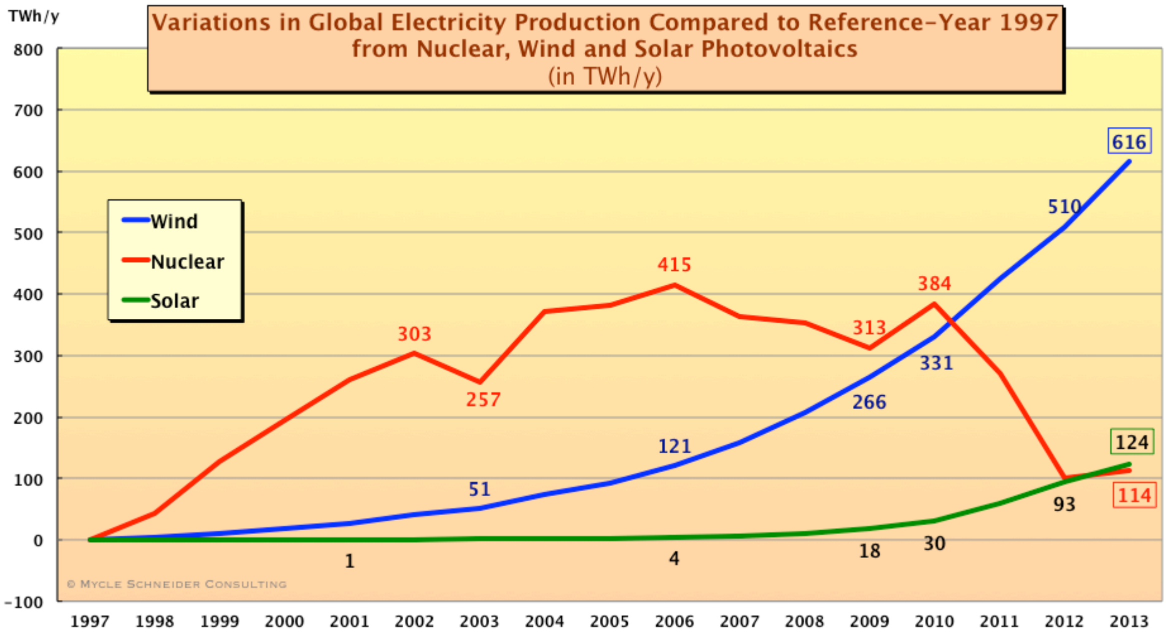
It is important to note the different characteristics of electricity generation. Those critical of renewable energy highlight the variable output of some technologies (wind power and photovoltaics—but not all solar power, since solar-thermal-electric plants typically have built-in heat storage so they can run into or through the night). A consequence of variability is the lower output per installed kilowatt over the year than that of traditional fossil-fueled or nuclear power stations, which more often than not try to operate as baseload plants operating, under normal conditions, continually. However, obviously no power plant operates continually and most nuclear plants have experienced extended unplanned shutdown periods, many exceeding a year. Despite their variable output, which can generally be forecasted at least as accurately as electricity demand, wind and solar photovoltaic power are now becoming significant. The Figure 18 below therefore presents the actual electricity produced by solar photovoltaics, wind and nuclear power and highlights the changing levels of production since 1997. As can be seen during this period there has been an additional of 616 TWh per year of wind power produced in 2013 compared to 1997, 124 TWh of solar photovoltaics and just 114 TWh of nuclear.

In 2013, growth rates for generation from wind power above 20 percent were seen in North America, Europe and Eurasia and Asia Pacific, with the two largest markets, the U.S. (19.4 percent) and China (37.8 percent) both continuing to deploy at scale. In the world of photovoltaics, North America saw a more than doubling of power generation, Asia Pacific a 75 percent increase, while Europe and Eurasia experienced a more modest 17.6 percent growth.[345] Other important milestones for the renewable energy are masked by the global figures, but are worth noting. In Denmark wind power covered one third of electricity demand, in Spain it provided just over one fifth, while in Italy solar photovoltaics provided 7.8 percent[346]—ten times its contribution in 2010 and two and half times higher than the

[345] BP, "Statistical Review of World Energy", June 2014.
[346] REN21, "Renewables 2014 Global Status Report", Renewable Energy Policy Network for the 21st Century, 2014.

maximum annual contribution ever made by nuclear power.[347] India's 12% growth in wind power in 2013 mean that it overtook nuclear power in terms of electricity production. As in China, this had already occurred in 2012.

Figure 18: Variation in Global Electricity Production from Nuclear, Wind and Solar



Sources: BP, IAEA-PRIS, MSC, 2014

The reference date in Figure 18 is 1997, as this was the date of the signing of the Kyoto Protocol. Despite attempts to restrict greenhouse gas emissions growth, worldwide emissions, primarily from the energy sector, have continued to grow and have risen from 32 billion tons per year in 1997 to 34.5 billion tons of CO_2-equivalent in 2012.[348] Consequently, additional efforts are needed to rapidly accelerate the use of low carbon energy sources. The current deployment and energy production trends reflect the level of public and political support as well as the views of the investment community in the different technologies.

Considering the low level of nuclear development over the past 15 years, it is surprising that agencies such as the IEA continue to assume in their decarbonization scenarios that there will be a significant increase in the deployment of nuclear power. While on the one hand they recognize the low level of nuclear investment since 2000, which the IEA calculate to be US$8 billion per year, they still assume that during 2014-35 the annual investment in their 450 Scenario would average US$78 billion, a near 10 fold increase.[349] This seems sharply divergent from current market sentiment and choices, so speeding up the decarbonization of the energy sector seems unlikely to be achieved by relying on the rapid deployment of nuclear power.

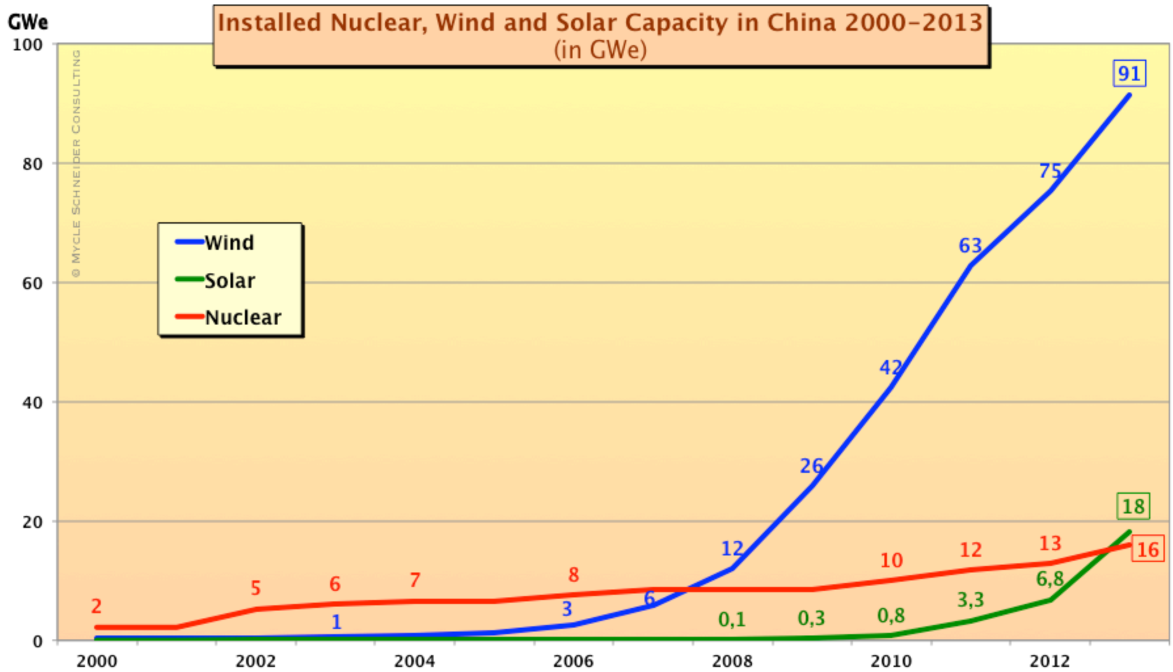
Status and Trends in China, the European Union and the United States

China continues to be a global leader for many energy sources and sectors. In 2013, China installed more wind power and solar photovoltaics than any other country, consequently it now has worldwide the largest capacity of wind power, the second largest of solar photovoltaics and the third largest of biomass power generation.[350] In addition, China installed more hydro and more nuclear capacity in 2013 than any other country. Investment in wind power was US$28 billion, solar photovoltaics US$20.6 billion, and small scale hydro and biomass US$2.7 billion each. In addition, in 2013, for the first time more new renewable than fossil fuel and nuclear based capacity was started up.[351]

---

[347] BP, "Statistical Review of World Energy", June 2014.
[348] World Resources Institute, "CAIT 2.0", WRI climate data explorer, see http://cait2.wri.org/wri/, accessed 6 July 2014.
[349] IEA, "Special Report, World Energy Investment Outlook", International Energy Agency, June 2014.
[350] REN21, "Renewables 2014, Global Status Report", June 2014.
[351] UNEP-BNEF, "Global Trends in Renewable Energy Investment 2014", Frankfurt School and United Nations Environment Programme Collaborating Centre and Bloomberg New Energy Finance, April 2014.

Figure 19: Installed Capacity in China from Nuclear, Wind and Solar



Source: EPIC, PRIS and GWEC

The extent of growth in wind power is obvious from Figure 19, as it is noteworthy that in 2013 solar photovoltaics overtook nuclear power by installed capacity. In 2013, China installed at least 12 GW of solar, which compares to 3 GW of installed nuclear and to a previously global installation record of 7.6 GW solar in Germany in 2011. It also exceeds total cumulative photovoltaics installation in the United States since it invented PVs 60 years ago. China's solar acceleration is remarkable, as just four years ago, nuclear power's installed capacity was ten times larger than solar. As in the previous year, in 2013 wind power alone, with 132 TWh, significantly exceeded nuclear's 111 TWh, while solar power output doubled to reach 12 TWh.[352]

Solar is not restricted to electricity production in China, where solar heaters are deployed without subsidies—one of six renewable technologies in which China is the world leader. In 2013, the annual production capacity of solar water heaters reached 63.9 million square meters, an increase of 11 percent, with 317 million square meters of solar heaters now installed in China.[353]

The photovoltaics targets within the current 12th Five Year Plan have continually been raised. Initially, it was suggested that 5 GW would be installed by 2015, then 10 GW, then 20 GW and now a 40 GW target is proposed[354]—rising to 70 GW in 2017. Since 14 GW is expected to be installed in 2014 that even the most recent target will probably be exceeded. China's 2015 wind power capacity target of 100 GW is also likely to be met early, with levels at the end of 2013 above 91 GW. This compares to nuclear power, which was initially expected to have 50 GW of nuclear power in operation by the end of 2015. The capacity of the currently operating reactors is 17 GW, with the likely capacity of around 34 GW in operation by the end of 2015 (the currently operating capacity plus 17 GW more from the 16 reactors likely to be completed by this time – see Annex 8 for details). Moreover, operation of the increasing number of Chinese fossil-fueled and nuclear plants is not keeping pace with their capacity as they are displaced by cheaper-to-run renewables. In 2012, for example, more new Chinese generation came from non-hydro renewables than from all fossil-fueled and nuclear plants combined.[355]

---

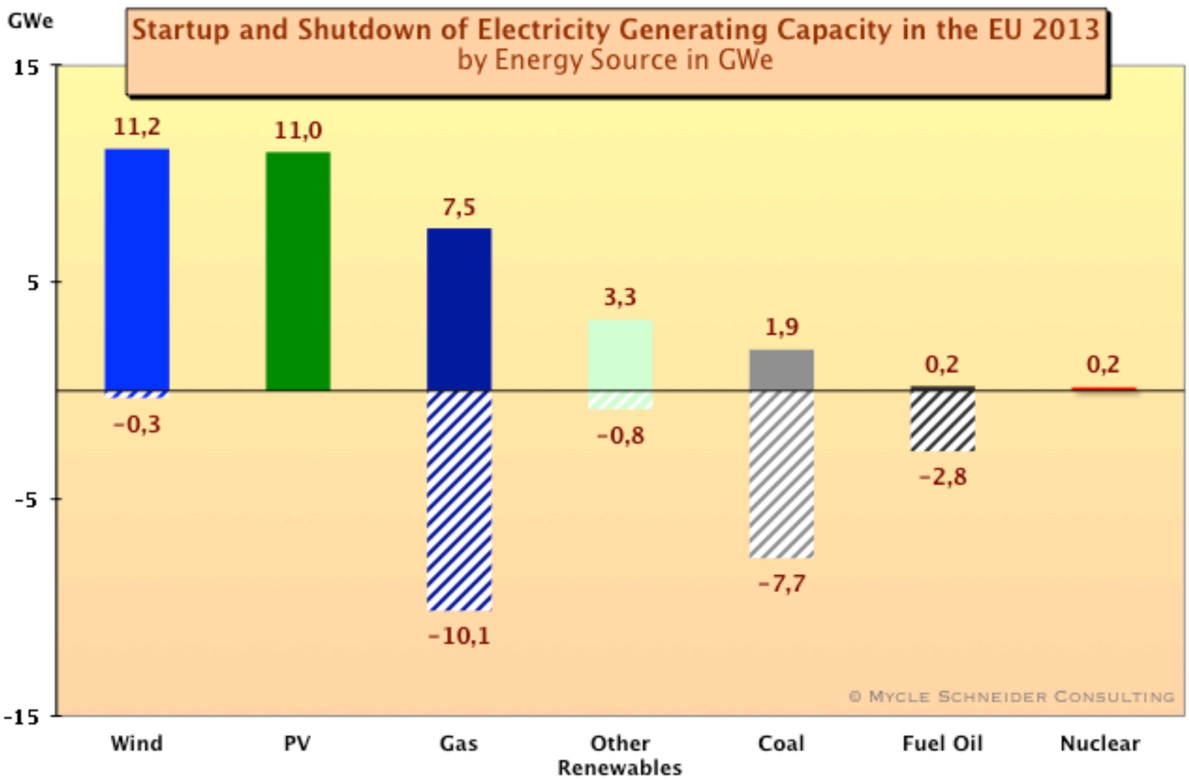
[352] BP, "Statistical Review of World Energy", June 2014.
[353] China National Renewable Energy Centre (2014), "Activities within China National Renewable Energy Centre", March 2014.
[354] CleanTechnica.com, "China to Double 2015 Solar PV Target to 40 GW", 18 September 2012, see http://cleantechnica.com/2012/09/18/china-to-double-2015-solar-pv-target-to-40-gw/, accessed 3 June 2014.
[355] Amory Lovins, personal communication, 22 July 2014.

In the **European Union**, between 2000 and 2013, the net changes in the capacity of power plants are estimated to be an increase of 105 GW in wind, 103 GW in natural gas, 80 GW in solar, while nuclear has decreased by 13 GW, coal 19 GW and fuel oil 24 GW.[356] The introduction and implementation of the 2009 Renewable Energy Directive has led to renewable energy rising from just under 8 percent in 2004 to 13 percent in 2012. Under the terms of the directive, by 2020, renewable energy is expected to provide 20 percent of the EU's primary energy, including approximately 32 percent of electricity. In the electricity sector, it is estimated that in 2013, renewables contributed around 22 percent.

This increase in production is likely to continue, as in 2013, 32 percent of the new power capacity added was wind and 31 percent was solar photovoltaics.[357] Figure 20 shows the changes in generating capacity in 2013. In addition to the growth in renewable energy there has been a net decrease in the installed capacity of gas (-2.6 GW) and coal (-5.8 GW). However, these figures hide the true extent of the reduction in the operated fossil fuel plants. In the two years of 2012 and 2013 alone, there were about 50 GW of closures or mothballing of gas plants by European utilities as the facilities cannot be operated profitably under current market conditions.[358]

In January 2014 the European Commission published its proposed policies for energy and climate for 2030. This included a binding target to reduce GHG emissions by 40 percent from 1990 levels and for 27 percent of energy to come from renewable energy sources both by 2030. Given the different views of the Member States, the Commission did not propose that the renewable energy target be binding on each country, but rather that it would take measures to ensure that collectively the target was binding on the EU. This is a new approach for the energy sector and therefore its effectiveness is yet to be proven. The Commission assumes that in order to meet the 27 percent energy target, 45 percent of electricity must come from renewables by 2030. As is being demonstrated in Germany, even at lower penetrations of renewables this target will significantly and detrimentally affect the economics of nuclear power (see Chapter Paying to Produce).

Figure 20: Startup and Shutdown of Electricity Generating Capacity in the EU in 2013

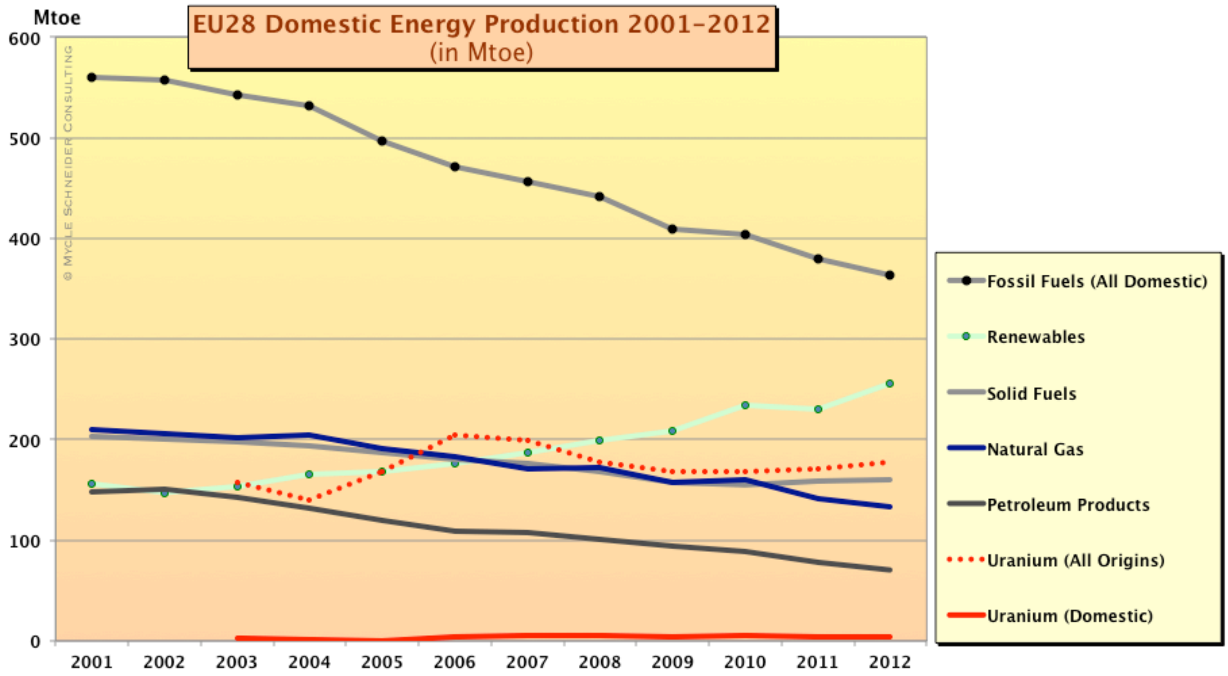


Source: EWEA 2014[359]

[356] EWEA, "Wind in Power, 2013 European statistics", European Wind Energy Association, February 2014.
[357] Ibidem.
[358] French Government, "The Crisis of the European Electricity System – Diagnosis and possible ways forward", Commissariat général à la stratégie et à la prospective, January 2014.
[359] Ibidem.

This increase in production is likely to continue, as in 2013, 32 percent of the new power capacity added was wind and 31 percent was solar photovoltaics.[360] Figure 18 shows the changes in generating capacity in 2013. In addition to the growth in renewable energy there has been a net decrease in the installed capacity of gas (-2.6 GW) and coal (-5.8 GW). However, these figures hide the true extent of the reduction in the operated fossil fuel plants. In the two years of 2012 and 2013 alone, European utilities closed or mothballed about 50 GW of gas plants that cannot be operated profitably under current market conditions.[361]

Figure 21: Domestic Primary Energy Production in the EU



Source: Sources: Eurostat, Euratom Supply Agency, BEE/Raffaele Piria, 2014[362]

In January 2014 the European Commission published its proposed policies for energy and climate for 2030. This included a binding target to reduce GHG emissions by 40 percent from 1990 levels and for 27 percent of energy to come from renewable energy sources both by 2030. Given the different views of the Member States, the Commission did not propose that the renewable energy target be binding on each country, but rather that it would take measures to ensure that collectively the target was binding on the EU. This is a new approach for the energy sector and therefore its effectiveness is yet to be proven. The Commission assumes that in order to meet the 27 percent energy target, 45 percent of electricity must come from renewables by 2030. As is being demonstrated in Germany, even at lower penetrations of renewables this target will significantly and detrimentally affect the economics of nuclear power (see Chapter Paying to Produce).

A group of 10 EU countries,[363] nine of which operate nuclear plants, has signed a letter to the European Commission openly asking for subsidies for nuclear power: "Nuclear energy's significant role in the

[360] EWEA, "Wind in Power, 2013 European statistics", February 2014.

[361] French Government, "The Crisis of the European Electricity System – Diagnosis and possible ways forward", Commissariat général à la stratégie et à la prospective, January 2014.

[362] Note: Only fossil fuels and uranium extracted in the EU-28 are considered; only biomass grown in the EU is considered. Electricity generated by hydro, wind and solar converted to an equivalent primary energy, assuming an average 38% efficiency in thermoelectric power plants, as used in the BP Statistical Review of World Energy (2013). Source for the conversion of the units is: MIT, "Units, and conversion fact sheet", see http://www.carbonlighthouse.org/wp-content/uploads/2010/10/UnitsAndConversions.pdf, accessed July 2014.

[363] Bulgaria, Czech Republic, France, Hungary, Lithuania, Poland, Romania, Slovakia, Slovenia and the United Kingdom. Lithuania does not currently operate any nuclear power plant, but has done so in the past. The nuclear countries that have not signed are Belgium, Finland, Germany, the Netherlands, Spain and Sweden.

European energy mix should be clearly recognized" and considering "a number of failures in energy markets across Europe … national support mechanisms … may therefore be needed."[364]

The Ukrainian crisis has increased political and public focus on access to secure and affordable energy resources. As can be seen in Figure 21, in 2012 renewable energy was the largest source of domestically produced primary energy in the EU. This is due to a combination of factors including that the vast majority, with the exception of some biofuel and biomass, of renewable energy is domestically produced and its use has increased, while there has been a decline in the production of fossil fuels for a combination of geological and economic reasons. The figure has included two trend lines for uranium, firstly, one which shows the energy coming from domestically produced uranium, which is very small as over 95% of it is imported, and a second line which shows the total energy production (domestic and imported uranium). This has been included as Eurostat and other agencies, mistakenly in our view, categorize nuclear-produced energy as domestic although nearly all of its fuel is imported. Therefore even under this misclassification, renewables are a more important source of energy than nuclear power.

In the **United States,** much has been said about the importance of shale gas and how it has fundamentally changed the energy sector. While the significance of shale gas is indeed well documented, it is not the only development that profoundly altered the energy landscape. Since 1997, practically all (94 percent) of the power generating capacity added to the grid was either natural gas or renewables. In 2012, the 18 GW of renewables installed—13.8 GW of which were wind—represented more than half of the installed capacity.[365] In 2013, while 6.8 GW of gas capacity was added, there was also 2.9 GW of solar and 1 GW of wind. However, surprisingly, given the current market, 1.5 GW of coal was added, but these two units were both delayed projects. The wind volume was low due to the cessation of the key incentive Production Tax Credit (PTC) at the end of 2012, which had led to the addition of a record 13.8 GW that year. In 2013, nine U.S. States generated more than 10 percent of their electricity from wind of which two (Iowa, South Dakota) exceeded 25 percent.

In June 2014, the Obama Administration proposed a new regime that would require a reduction in GHG emissions from the power sector. This state-by-state but nationally coordinated initiative, called the Clean Energy Plan, would, if adopted lead, to a 30 percent reduction in power sector emissions by 2030, relative to a 2005 baseline. While the new initiative will accelerate the switch from coal to gas, it is also expected to accelerate the current trends in the non-fossil sector. While this could theoretically result in more interest in nuclear power, rather than stimulating nuclear new-build, what is ultimately far more likely is that the current investment trends will accelerate the deployment of more renewable energy, due to its generally lower costs and financial risks. Since August 2005, U.S. nuclear new-build has been offered construction subsidies rivaling its construction costs, as well as operating subsidies greater than those offered through 2012 to wind power; yet no proposed merchant nuclear plant has been able to get a penny of private investment, and the four units under construction by regulated utilities all shifted their entire cost and risk to customers and taxpayers via special laws. The obvious inference is that nuclear new-build has no business case.

The same appears to be true globally. In each of the past three years, renewables other than big (>50 MW) hydroelectric dams have received a quarter-trillion dollars of private investment and added over 80 GW, while nuclear investment has all been conscripted (no free-market competitive plants are being built anywhere) and net capacity additions turned negative even before Fukushima.

Paying to Produce

The rapid deployment of wind and solar energy is radically transforming power systems, with an increasing economic impact on the operation of traditional power stations, including nuclear power plants. This section looks at the following issues: how do wind and solar transform power systems? What is the physical behavior of nuclear power plants facing high shares of wind and solar? What are the economic consequences?

---

364 WNN, "Ten nations petition Brussels for nuclear", 4 July 2014, see http://www.world-nuclear-news.org/NP-Ten-nations-petition-Brussels-for-nuclear-0407141.html, accessed 6 July 2014.

365 BNEF, "Sustainable Energy in America—Factbook", Business Council for Sustainable Energy, February 2014.

The Traditional World of Nuclear Baseload

"This diagram shows that much of the electricity demand is in fact for continuous 24/7 supply (base-load)."

World Nuclear Association
April 2014

Figure 22: WNA—"Load Curves for Typical Electricity Grid" [366]

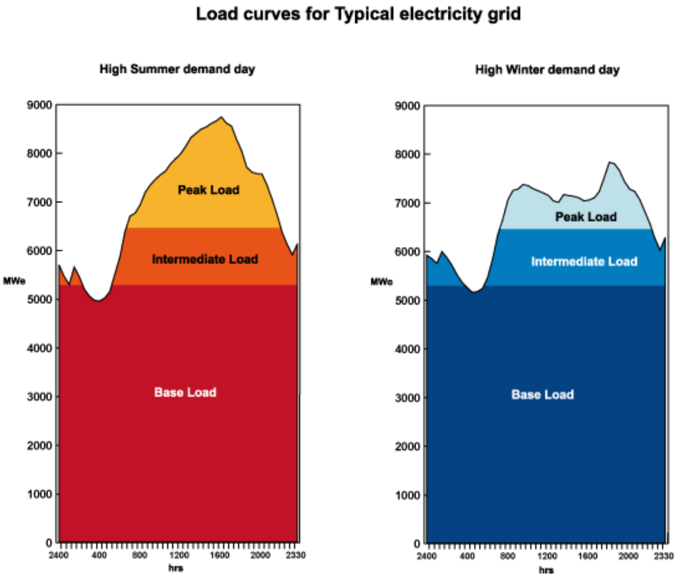


Figure 22 from the World Nuclear Association's (WNA) website shows typical daily system load curves. The horizontal axis represents time during the day, starting and ending at midnight. The vertical axis represents the level of aggregated electricity demand (or load): Low at night, with different daily profiles for winter and summer. The load curve is important because in power systems demand and supply must be in equilibrium at all times.

This chart shows the distinction between baseload and peakload. Baseload means demand that must be served at all times of the day while peakload must be served for just some hours per day. Therefore, peakload power plants must be able to adjust their production rapidly—a flexibility not necessary to serve baseload. For technical and economic reasons, nuclear power plants are among the least flexible and therefore are used predominantly as baseload plants. The next sections show how the large scale deployment of renewables is rapidly eroding the concept of baseload[367], thereby challenging the economics of nuclear power.

The physical behavior of nuclear power plants facing high shares of renewables

Variable renewable energy sources (VRE), like solar and wind, are weather dependent and not fully predictable.[368] In many countries, renewables enjoy priority access to the grid by regulation. However,

---

[366] World Nuclear Association, "World Energy Needs and Nuclear Power", Updated May 2014, see http://www.world-nuclear.org/info/Current-and-Future-Generation/World-Energy-Needs-and-Nuclear-Power/, accessed 17 June 2014.

[367] We use the term "baseload" here as the nuclear industry uses it, namely to refer to loads that in aggregate (even if not individually) appear steady rather than varying over each day and night. Actually, "baseload" has a different, economically based, meaning in utility resource acquisition, where it means the resource of lowest levelized cost per MWh, and in utility operation, where it means the resource of lowest operating cost (so it is dispatched whenever available. "Baseload" is also used by some journalists to refer to large thermal power stations, fossil- or nuclear-fueled, because they were traditionally dispatched whenever available, but now they are no longer the cheapest source of baseload power in this economic sense: nowadays that is the role of renewables, which cost even less to run to because they have no fuel.

[368] Power system operators have always had to deal with strong and not fully predictable variations of demand. Moreover, no electricity generating source is fully predictable, as incidents, accidents or other events can take out any power plant or transmission line at any given point in time. However, VRE substantially increase the level of uncertainty (though not of unpredictability), and thus require additional flexibility in the power system. Following the IEA's terminology, VRE include wind, solar PV, run-of-river, hydropower, wave energy and tidal energy. International Energy Agency, "The Power of Transformation: Wind, Sun and the Economics of Flexible Power Systems, 2014". This study offers an in-depth analysis of the multiple flexibility options that can help integrating large amount of variable renewables into the power system.

even without such rules, variable renewable energies generally have priority simply for economic reasons: with operating costs close to zero, they win nearly all spot market auctions.[369]

Instead of the traditional load curves shown above, in power systems with significant shares of variable renewable energies, the main driver of power system operation is becoming the residual load, or *net load*, i.e. "the hourly total load less the hourly production of wind and solar generating facilities."[370] This concept is illustrated in the following pages.

Recent experience provides empirical evidence of the interaction of a nuclear power plant fleet with large amounts of variable renewable energies. To illustrate this, the operation of the German power system during one week in December 2013 is analyzed hereunder. This example was chosen for several reasons:

First, according to the Nuclear Energy Agency (NEA), Germany has one of the most flexible nuclear fleets in the world: "While (…) nuclear power plants in most OECD countries are operated in a baseload mode, France and Germany, due to different causes, have significant experience with operating their current reactors, both PWRs and BWRs, in a load following mode".[371] Load following means adjusting the production according to the (net) load, i.e. power demand, instead of producing at full capacity, 24/7.[372]

Second, Germany, unlike France, has substantial solar and wind capacities affecting power market prices and system operation.

Finally, the extensive work of the German Fraunhofer Institute for Solar Energy Systems (ISE) provides a good insight into power market operation and prices in Germany.

Figures 23 and 24, produced by ISE for MSC, illustrate the operation of the power system in Germany between 16 and 22 December 2013 and include an episode of high wind production with negative electricity prices.[373] The horizontal axis of both charts represents time, from the early hours of Monday to the end of Sunday. The vertical axis represents the amount of electricity produced and consumed in each hour. Figure 24 also shows the electricity imports or exports.

The upper profile represents the total load curve, with a typical winter weekly pattern: higher demand during day and lower at night, with very steep variations in the morning and in the evening. During the weekend, demand is lower. Due to exceptionally mild temperatures, the general level of demand in this week was significantly lower than the average of this season. Domestic peak demand was around 63 GW, whereas peak demand in cold December weeks can be around 75-80 GW.

---

369 Spot market auctions now exist in many parts of the world. Their functioning is shortly explained in the next section.

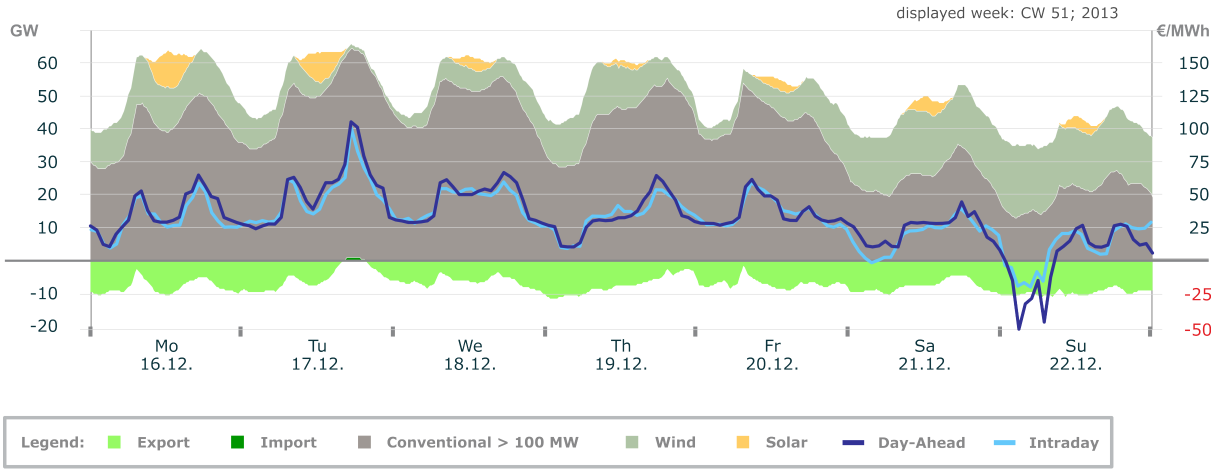
370 California Energy Commission, "Resource Flexibility: Tracking Progress", Updated 12 March 2013, see http://www.energy.ca.gov/renewables/tracking_progress/documents/resource_flexibility.pdf, accessed 13 May 2014.

371 Nuclear Energy Agency, "Nuclear Energy and Renewables – System Effects in Low-Carbon Electricity Systems", OECD 2012, page 67.

372 It is useful to distinguish between frequency control (primary or secondary) and load following. The former refers to very rapid (between seconds and minutes) and relatively small (for instance up to 2.5 percent of reactor power output in Germany, several percent in France) variations of generation, needed to compensate variations of frequency in the power system. In Germany, the regulator allows nuclear power plants to be automatically operated by the grid operators for the purpose of primary frequency control, while in other countries this is not allowed.

373 Similar illustrations for all weeks and days since 2012, and more information on renewable electricity production and wholesale market prices in Germany can be found in Fraunhofer-Institut für Solare Energiesysteme, "Renewable Energy Data", ISE, see http://www.ise.fraunhofer.de/en/renewable-energy-data, accessed 14 May 2014. We thank Prof. Bruno Burger and Johannes N. Mayer of Fraunhofer ISE for their support.

Figure 23: German Power System, Real Data of Week 51 in December 2013.



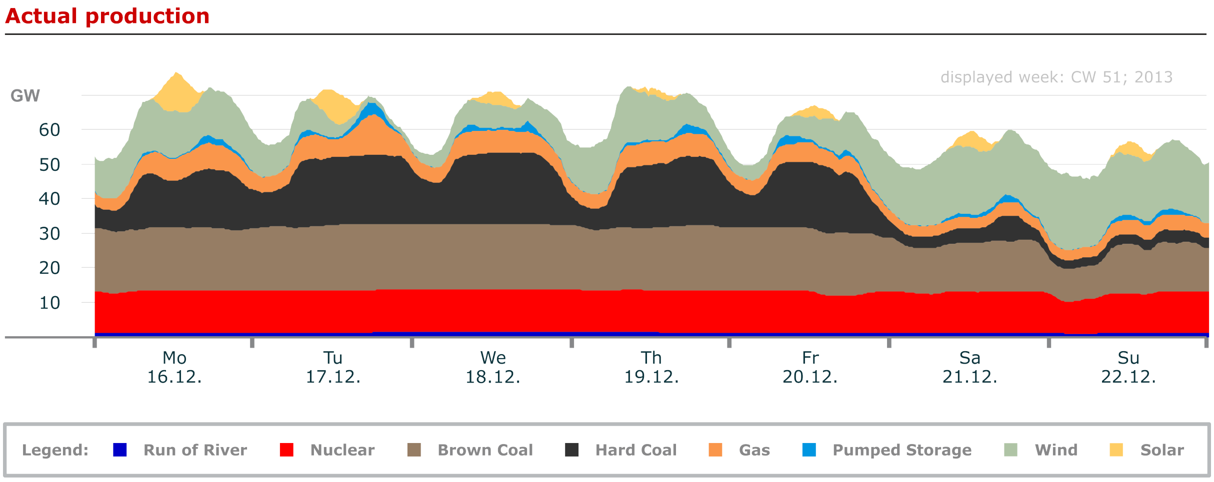
Source: Fraunhofer ISE, based on EEX data, commissioned by MSC, 2014.

The different colors represent the various power generation sources. Notably, even in December, solar (in yellow) was producing up to 9 GW on Monday and Tuesday, but much less during the following cloudy days. The variability of wind (in pale green) is clearly visible, ranging from almost no output on Tuesday evening to almost 25 GW during the weekend. The dark grey area below wind represents the rest of domestic demand, mainly covered by fossil and nuclear power plants (and partly by biomass, geothermal and hydro power). The green area below zero represents net power exports. During this week, Germany was a net importer for only a few hours on Tuesday, and for minimal amounts.

The two blue lines represent the spot electricity market prices, day-ahead and intraday. Figure 24 below shows how nuclear power plants reacted to the episode of negative electricity prices on Sunday 22 December 2013. Producing power when the prices are negative or very low (below operational cost) implies an economic loss, and thus operators try to avoid it.

During the early hours of 22 December 2013, wind was generating up to almost 25 GW, covering around 70 percent of German demand and 55 percent of total German power generation. As this occurred at night, there was no solar production. As a result of the strong wind production and of the exceptionally mild temperatures, the net load, i.e. the demand to be covered by conventional power plants, was lower than expectable dropping to only 14 GW. This significantly eroded the space for baseload power plants, although this pressure was reduced by larger export volumes.[374]

Figure 24: Detailed Generation Mix in Germany, Week 51 in December 2013.



Source: Fraunhofer ISE, based on EEX data, commissioned by MSC, 2014.

Figure 24 distinguishes between the different conventional power sources, providing an insight into their operation during hours of high renewable generation and very low or negative electricity prices,

[374] The German power system operated circa 10 GW for export, roughly equivalent to the combined total power demand of Denmark, Hungary Ireland and Luxembourg during those hours. Data source: ENTSO-E.

forecasted one day ahead. It is immediately apparent that the German nuclear fleet has been the least responsive. Although slightly more responsive than nuclear, brown coal (lignite) power plants also operated significantly during those hours, while hard coal and gas power plants were operating at a minimum, probably in part to meet "must-run" commitments.

Table 8: Reaction of the German Fleets to Forecasted Negative Prices on 22 December 2013

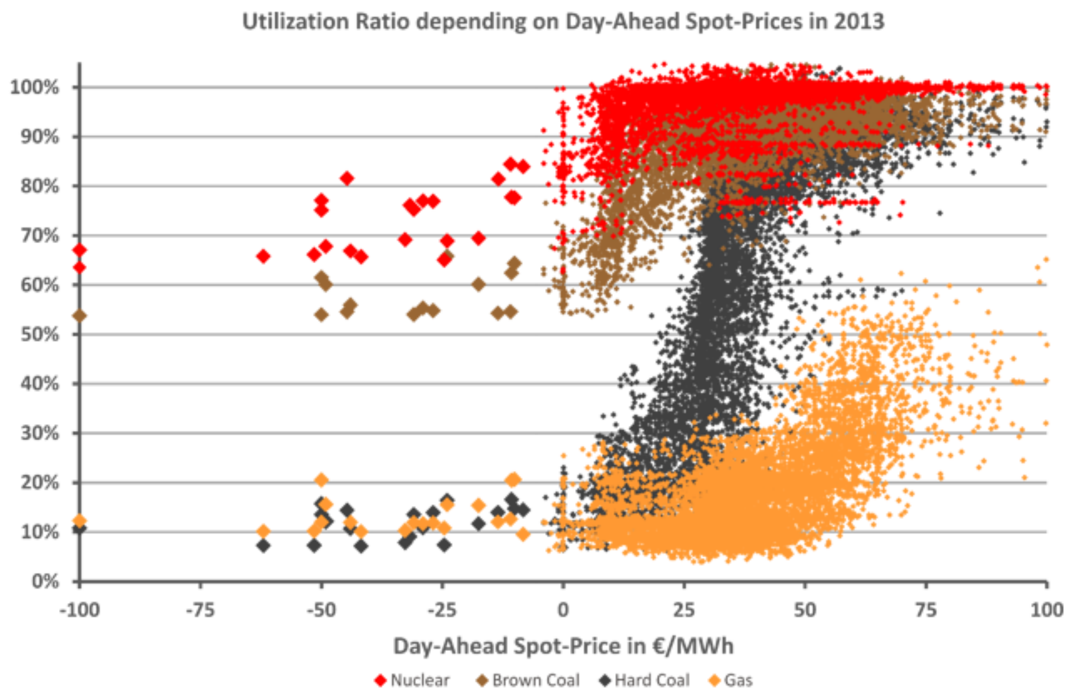
	Nuclear	Brown Coal	Hard Coal	Gas
Maximum generation in that week	12.1 GW	19.1 GW	21.3 GW	11.8 GW
Generation at 2-3 a.m. of 22 December 2013	9.2 GW	9.4 GW	2.6 GW	3 GW
as percent of max generation in that week	*76%*	*45%*	*12%*	*26%*

Source: Fraunhofer ISE, based on EEX data.[375]

Compared with the maximum output during that week, the gas power plant fleet reduced their production by 74 percent, hard coal by 88 percent, brown coal by 55 percent and nuclear by only 24 percent (see Table 8). Considering that in most other countries nuclear power plants operate only as baseload, this flexibility may look high. However, given the requirements of a power system with large shares of variable renewables, this low level flexibility becomes costly for the nuclear power plant operators and for the power system in general.

It is important to assess if these levels of (in)flexibility were an exceptional occurrence of this particular week, or the rule. Figure 25 highlights the extent to which this is a common occurrence, as it represents the utilization ratio of the German conventional power plant fleets during each hour of 2013, comparing it to the price level on the German spot electricity market. Each dot represents the utilization ratio of one of these fleets during a certain hour. For instance, all red points on the top line for 100 percent represent hours during which the German nuclear fleet was operating at 100 percent of its aggregated nominal capacity.

Figure 25: Price Elasticity of Power Plant Operation in Germany in 2013[376]



Source: Fraunhofer ISE, based on EEX data, commissioned by MSC, 2014

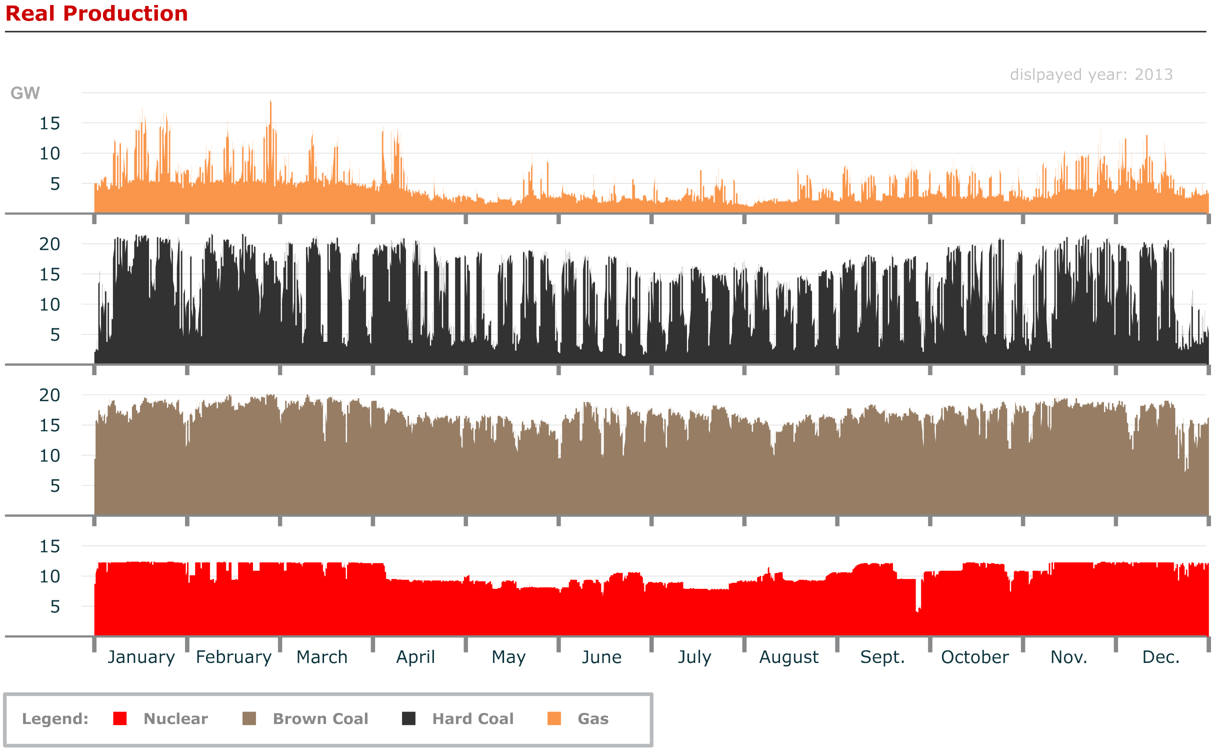
[375] The bottom line of the table refers to the "ex-ante available capacity" declared in advance by the power plant operators.

[376] Data about the last days of 2013 are not yet included. Fraunhofer ISE excerpted evident data mistakes in the EEX database concerning a few dozen hours in the year.

Looking at the hours with prices at zero, the red dots show that the German nuclear power plant fleet was usually operating at between 75 percent and 95 percent of its aggregated nominal capacity. In the same hours, the brown coal power plant fleet was usually operating at around 55 percent to 72 percent, and the hard coal and the gas fleets at between around 8 percent and 22 percent, of their respective aggregated nominal capacities.

The overall picture clearly shows that the gas power plant fleet flexibly responds to spot market price variations, strongly decreasing its production during times of very low or negative prices. Hard coal power plants often follow a peakload mode, frequently switching from (close to) minimum to (close to) maximum capacity. At times of negative prices, the gas and the hard coal power plant fleets typically reduce their aggregated output to 10 percent to 20 percent of their nominal capacity, and they then almost never run above 20 percent.

Figure 26: Generation Profiles of the Power Plant Fleets in Germany in 2013



Source: Fraunhofer ISE, based on EEX data.

The brown coal power plant fleet behaves significantly less flexibly. Even at times of negative or very low prices, it typically operates at about 60 percent to 70 percent of its aggregated nominal capacity, and never below 50 percent. However, the nuclear power plant fleet clearly displays the least flexible behavior. Even in the numerous hours with negative prices, it produced at about 65 percent to 90 percent of its maximum capacity, and it was operating close to its maximum capacity during hundreds of hours with spot prices below its average marginal cost. Typical marginal costs of German nuclear power plants are estimated to be €20/MWh (US$27.3/MWh), including roughly €5/MWh (US$6.8/MWh) for fuel costs and about €15/MWh (US$20.5/MWh) for the nuclear fuel tax in force since 2011.[377]

Another perspective on the comparative flexibility of the German power plant fleet is presented in Figure 26. It shows the aggregated generation level of the conventional German power fleets during each hour of 2013. Large parts of the hard coal fleet typically run during workdays and shut down during weekends. Also day/night patterns are visible.

Aside from interruptions for maintenance of fuel reloading, it is evident that the nuclear fleet runs most of the time at very close to its maximum available capacity**.**

[377] Agora Energiewende, "Negative Strompreise: Ursachen und Wirkungen", June 2014, see http://www.agora-energiewende.de/themen/strommarkt-versorgungssicherheit/detailansicht/article/negative-strompreise-werden-haeufiger/, accessed 11 June 2014. A Hamburg Finance Court in April 2014 declared the fuel tax illegal. However, the tax has been in force since 2011, and it seems reasonable to assume, like Agora Energiewende does, that nuclear power plant operators included the tax in their cost calculations for 2013.

The frequent adjustments for primary or secondary frequency control, i.e. very rapid (between seconds and minutes) and relatively small (for instance up to 2.5% of the reactor power in Germany) variations of generation, are not visible in this chart. In Germany, the regulator allows nuclear power plants to be automatically operated by the grid operators for the purpose of primary frequency control.[378]

Load following refers here to adjustments of production over several hours or whole days, for instance traditionally during one night, or a weekend, and more recently due to periods of high and or solar generation. Major episodes when the nuclear fleet operated in load-following mode are visible in the chart as small oscillations. For instance, the December week discussed above is visible also in this chart. In general, however, such episodes of load following are relatively seldom seen in Germany.[379]

The charts above show that the German nuclear fleet behaved as the most inflexible among the conventional power plants, operating at full capacity during hundreds of hours with prices (far) below its operational costs. Fraunhofer ISE analysis for 2012 produces analogous results.[380] The same findings are confirmed by German think-tank Agora Energiewende, which looked in detail at several episodes of negative spot electricity prices in Germany. During each of these hours, the German nuclear fleet was running at a substantially higher fraction (from around 65 to around 95 percent) of its available capacity than the lignite, hard coal, and gas fleets.[381]

As noted above, the Nuclear Energy Agency of the OECD considers Germany as one of just two countries, the other being France, with significant experience in operating nuclear reactors in a load-following mode. However, even under these exceptionally positive conditions, the nuclear fleet could ensure only very limited levels of flexibility.

A thorough and independent analysis of the French experience with load-following nuclear power plants, including its economic aspects, is so far lacking. A large part of the French nuclear fleet regularly runs in load-following mode, including daily load variations to follow demand reductions at night and during weekends of up to 80% in individual plants. According to one of the presentations given by EDF at a meeting of the IAEA in September 2013,[382] an exceptionally large case of load following occurred on 27 December 2012, when EDF increased the output of its nuclear fleet by around 29 percent (from 40.4 GW to almost 52 GW) within just six hours. By comparison, in the exceptional episode discussed above, the German fleet reduced and then increased its production by about 24 percent within a similar time frame.

In another episode of negative electricity prices, on 16 June 2013, the French nuclear fleet reduced its production by only 13 percent, while the German nuclear fleet during the same hours reduced its output by about 25 percent. Based only on these two episodes, the French nuclear fleet does not seem to offer substantially more flexibility than the German fleet.

According to an analysis by Swedish research institute Elforsk, all EDF reactors operate in flexible power variation mode and can carry out frequency control at +/-2 percent, daily load variation of 50 percent, and load decrease down to zero, i.e. disconnecting the plant from the grid but keeping the ability to rapidly increase load again.[383] Substantial investment has been necessary to achieve this flexibility in operation:

---

[378] Wolfgang Renneberg, "Grenzen und Sicherheitsrisiken des Lastfolgebetriebs von Kernkraftwerken", 2011, see http://www.atomsicherheit.de/studien-und-statements/, accessed 16 June 2014.

[379] The sudden low in nuclear generation visible in late September must be due to an error in the EEX (the German power exchange) database. At least one of the sudden lows in February is probably due to a similar error. In general, however, the data from the EEX database are very consistent and reliable. Private communication from Prof. Bruno Burger, Fraunhofer ISE, May 2014.

[380] J. Mayer et al., "Kohleverstromung zu Zeiten niedriger Börsenstrompreise", Fraunhofer ISE, August 2013, see http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/kohleverstromung-zu-zeiten-niedriger-boersenstrompreise.pdf, accessed 16 June 2014. This article presents the same kind of chart as Figure 24 above, for the six-month periods of 2012 and of 2013, with very similar patterns in both years.

[381] Agora Energiewende, "Negative Strompreise: Ursachen und Wirkungen", June 2014, see http://www.agora-energiewende.de/themen/strommarkt-versorgungssicherheit/detailansicht/article/negative-strompreise-werden-haeufiger/, accessed 11 June 2014.

[382] For more information, see EDF presentations at IAEA, "Technical Meeting on Flexible (non-baseload) Operation Approaches for Nuclear Power Plants", Paris, September 2013, see http://www.iaea.org/NuclearPower/Meetings/2013/2013-09-04-09-06-TM-NPE.html, accessed 11 June 2014.

[383] Elforsk, "Additional Costs for Load-following Nuclear Power Plants, Experiences from Swedish, Finnish, German, and French nuclear power plants", see http://www.elforsk.se/Rapporter/?rid=12_71_, accessed 11 June 2014. Elforsk is a research company set up by the Swedish electrical industry including the nuclear power plant operator Vattenfall.

"EDF tested and modified the systems for about 15 years to reach a validated model of flexible power control that also was accepted by ASN (Autorité de Sûreté Nucléaire) the nuclear safety authority".

According to the same study, however, load-following operation is subject to significant technical restrictions. Flexible operation is excluded during the last phase of the fuel load cycle, usually 60 days out of 12-16 months, and load-following should not be carried out with damaged fuel in the core. A delicate core component of the reactor, the control rod drive mechanism, needs to be adapted, and requires increased maintenance and more frequent replacement. Increased inspection and maintenance is needed also for other components. The volume of liquid radioactive waste increases, in average by 2500m^3/unit/year. Turbine efficiency decreases and the risk for disturbance in operations could increase. Also, "the risk for disturbance in operations could increase (…) [R]egarding the manoeuvrability of PWRs, load variation operation could reduce safety margins of accidental transients, in comparison to base load operation".[384]

A study by the former head of the German nuclear safety authorities mentions further potential safety issues related to load following including unknown impact on material fatigue of a number of safety relevant components, increased potential for human error due to the higher frequency of manual operations, possible damages to the nuclear fuel cladding tube through temperature changes, and an absence of modeling of potential accidents in load-following mode.[385]

The United States NRC does not allow automatic load-following of nuclear power plants.[386] This restrictive approach of the NRC and of other regulators is apparently due to safety concerns. According to the NEA:

> Any variation of reactor power in a nuclear power plant has both immediate and long-term consequences on the reactivity, stability and manoeuvrability of the reactor. Following the power variation, there is a modification of physical conditions in the core, such as fuel temperature, and coolant temperature and density. These changes have a feedback effect, via neutron counter-reactions, on the core reactivity as well as on the neutron flux and power distribution across the core. These effects play an important role in the safety of a nuclear plant and in the nuclear reactor manoeuvrability.[387]

While in certain countries load following by nuclear power plants is restricted by regulation on the ground of safety concerns, its main constraint is linked to economic considerations as emphasized in 2009 by the then Director of Strategy and Research at the World Nuclear Association:

> "One point to note is that France's nuclear reactors comprise 90% of EDF's capacity and hence they are used in load-following mode and are sometimes even closed over weekends. This means that the load or capacity factor is relatively low by world standards, in the high 70s as a percentage. It is generally accepted that this is not an ideal economic situation for nuclear plants."[388]

Very low and negative prices: meaning and impact on nuclear power

"Negative prices in wholesale electricity markets indicate supply inflexibilities"
U.S. DOE Energy Information Administration[389].

The previous section shows how nuclear power plants continue producing at times when power market prices are below their variable costs, and even at times of negative prices. To discuss the implications of this fact, it is necessary to briefly describe the functioning of power markets.

There are power market products for different time units: baseload for a full day (0-24h), peakload (for instance in Germany 08:00-20:00 Monday to Friday), single hours and shorter time units. Some products can be traded as futures, for instance one year ahead. At day-ahead markets, trade closes at noon of the day before "real time", i.e. when electricity is actually produced and consumed. Intra-day markets, where trade is open up to one hour or less before real time, are gaining importance as they

[384] Ibidem.
[385] Wolfgang Renneberg, "Grenzen und Sicherheitsrisiken des Lastfolgebetriebs von Kernkraftwerken", 2011, see http://www.atomsicherheit.de/studien-und-statements/, accessed 16 June 2014.
[386] Nuclear Energy Agency, "Nuclear Energy and Renewables – System Effects in Low-Carbon Electricity Systems", OECD, 2012 (p.68).
[387] Ibidem, page 71.
[388] Steve Kidd, "Nuclear in France – what did they get right?", Nuclear Engineering International, 22 June 2009, see http://www.neimagazine.com/opinion/opinionnuclear-in-france-what-did-they-get-right, accessed 29 May 2014.
[389] U.S.EIA, "Negative prices in wholesale electricity markets indicate supply inflexibilities", 23 February 2012, see http://www.eia.gov/todayinenergy/detail.cfm?id=5110, accessed 14 May 2014.

can benefit from a much higher quality of forecasts concerning wind and solar generation. After market closure, the power system operator guarantees system stability in the very short term.

At the power exchange, producers bid to sell electricity for a certain time and at a specific price. After sorting the bids by price, the power exchange operator declares the strike price for each time unit, i.e. the price of the last bid necessary to meet the forecasted demand, which determines the price level for all buyers and sellers. The bids to sell electricity above the strike price are excluded. All producers who offered lower bids obtain the strike price, even if it is higher than their offer.

Thus, power plant operators have the incentive to bid at a price level just above their short-run marginal cost, which includes the costs of fuel, CO_2 certificates, and any other short-run variable costs. If the strike price turns out to be lower than their bid, they will not produce, thereby avoiding a loss. In case the strike price is higher than their bid, they will in any case earn the full strike price. This additional income is necessary to cover the fixed costs and to provide a return on investment.

In such a system, the power plants with the lowest variable cost always make winning bids and are therefore able to work all the time in baseload mode (24/7), if this suits them. Ideally, a nuclear power plant operator would constantly work at full capacity, gradually reducing the output during the last phase of the nuclear fuel cycle, and interrupting only for fuel recharging and technical modifications. Traditionally, this was the simple business model of most nuclear power plant operators, who generally have (or, increasingly, used to have) lower marginal costs than any fossil-fueled plant.[390]

Given the large size and the inflexibility of nuclear power plants, traders are likely to hedge risks by selling a significant share of their output a long time ahead in futures markets. In many cases, such large volumes may be traded "over-the counter" (OTC), i.e. bilaterally outside the power exchange. In this case, the prices may not be transparent for external observers. Nevertheless, wherever liquid day-ahead markets exist, their (expected) price level is determinant also for the futures and/or bilateral contracts. The reason is that buyers will not accept a price level that is too much higher than the expected price on the day-ahead market, and conversely, sellers will not accept a price far lower than that. Therefore, liquid day-ahead markets are a relevant, although not precise, indicator for the revenues of nuclear power plant operators, even if they sell a significant share of their production in the form of the futures and/or OTC contracts.

When the operator of a flexible power plant faces day-ahead prices lower than the future prices at which it previously sold its output, the operator has the option to fulfill its obligations by buying the equivalent amount of electricity more cheaply at the day-ahead market, instead of producing. Therefore, a flexible power plant will usually not produce at below its marginal costs, unless it has a "must-run" obligation to provide system services, for which it is remunerated in separate markets.

However, the operator of an inflexible power plant may technically not have this option or find it too expensive. Stopping and restarting a nuclear power plant takes time and causes significant costs. Moreover, as seen above, the depth and the frequency of load-following are subject to technical and regulatory constraints.

Negative electricity prices arise if the operators of inflexible power plants are prepared to pay in order to avoid the higher costs of reducing (or stopping), and then increasing (or starting up) their production. According to Agora Energiewende, the other main reason for negative electricity prices in Germany are power plants that may not reduce their production because they have committed to provide "must-run" system services. Agora Energiewende proposes a series of regulatory measures to reduce the amount of contracted conventional "must-run" capacities, among others by adopting rules that enable wind and solar plants to provide the system services they can deliver. If these measures were implemented, some German nuclear power plants—similar to French reactors—might be operated more flexibly in the future, thus producing less at times of negative prices. However, this would at the same time decrease their revenues from the delivery of system services.[391]

[390] Hydro power plants can have lower marginal costs than nuclear. Wind and solar energy always have lower marginal costs than nuclear. Total and variable costs of nuclear power plant operation could be significantly higher if the full costs of decommissioning, waste disposal, of the external effects of the uranium mining and of insuring all risks were fully internalized.

[391] Agora Energiewende, "Negative Strompreise: Ursachen und Wirkungen", June 2014, see http://www.agora-energiewende.de/themen/strommarkt-versorgungssicherheit/detailansicht/article/negative-strompreise-werden-haeufiger/, accessed 11 June 2014. This study mentions a number of other factors that can contribute to negative prices in Germany: the heat driven operation of CHP plants subject to heat supply obligations, the way how the renewable electricity generation supported by the feed-in tariff is marketed by the transmission system operators, internal operational processes within power plant operators that may induce "irrational" market behavior, too early gate closure times, especially before weekends and bank holidays, take-or-pay gas supply contracts and others.

When producing at times of spot market prices below their operational costs, a nuclear plant operator incurs not only opportunity costs, missing the opportunity to earn money by reducing its production. Under current conditions, unless the complete production has been sold in the futures market, the nuclear plant operator that is unable or unwilling to reduce its production *must actually sell it at negative prices*, or in other words to buy the right to continue producing when its electricity is not needed. This risk could be avoided by selling the entire production in futures markets. However, such a strategy could reduce the potential revenues from selling electricity on the spot market during times of high prices, and it exposes the operator to the risk of being forced to buy at higher prices the whole amounts previously sold, in case production must be interrupted for unforeseen reasons. Moreover, the clear trend towards more-frequent very low spot market prices (see Figures 27 and 28) exerts a downward pressure also on prices in the futures market.

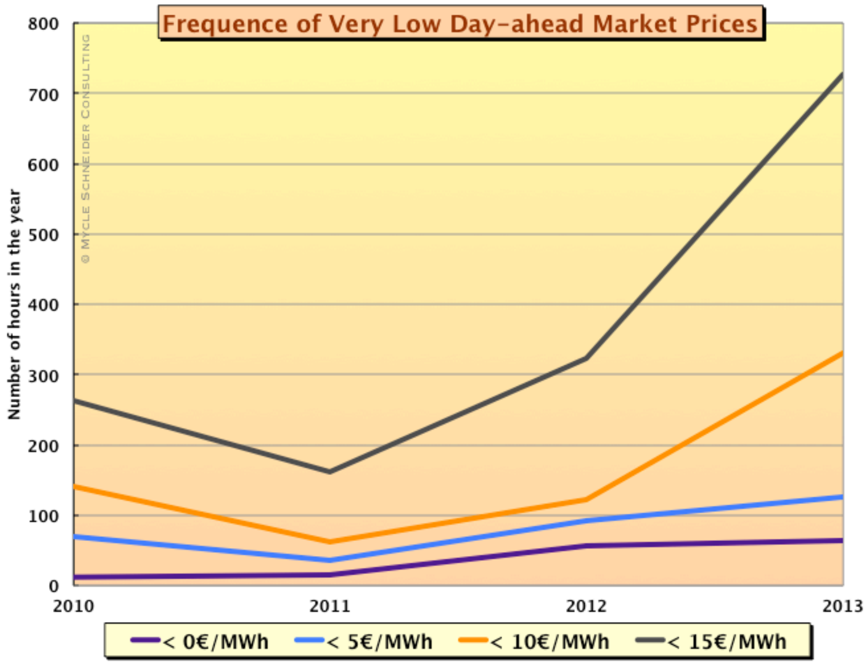
In summary, producing power at times with spot market prices below marginal cost results in reduced revenues, and in many cases in direct losses. On the other hand, frequent load-following can require investments, it causes some direct costs, and above all, it reduces the capacity factor and thus the profitability of a nuclear power plant, spreading dominant fixed costs over lower electricity sales.

Renewables Deployment Entailing Lower Power Prices

The following Figures suggest that nuclear power plant operators are likely to face such problems more frequently, as the deployment of variable renewables continues.

From 2010 to 2013, the combined generation from wind and solar PV in Germany increased by 68 percent, from 49 TWh to 83 TWh. Total renewable generation, including hydro, biomass and geothermal energy, in 2013 was around 152 TWh, 56 percent higher than nuclear generation. However, what is relevant here is the production of variable renewables with marginal costs close to zero, which are driving down the power market prices. These are mainly wind and solar PV.[392] In the same period, nuclear generation decreased, as eight nuclear power plants were permanently shut down in the aftermath of the Fukushima accident.

Figure 27: Frequency of Very Low Power Prices in Germany



Sources: Fraunhofer ISE, based on EEX data; AG Energiebilanz

Figure 28 shows the frequency of hours with very low or negative day-ahead market prices. Assuming all other factors had been equal, the massive withdrawal of nuclear capacities certainly contributed to a reduction of the occurrences of very low prices from 2010 to 2012.[393] Nevertheless, already in 2012, this effect was more than outweighed by the large growth of wind and solar generation. In just two

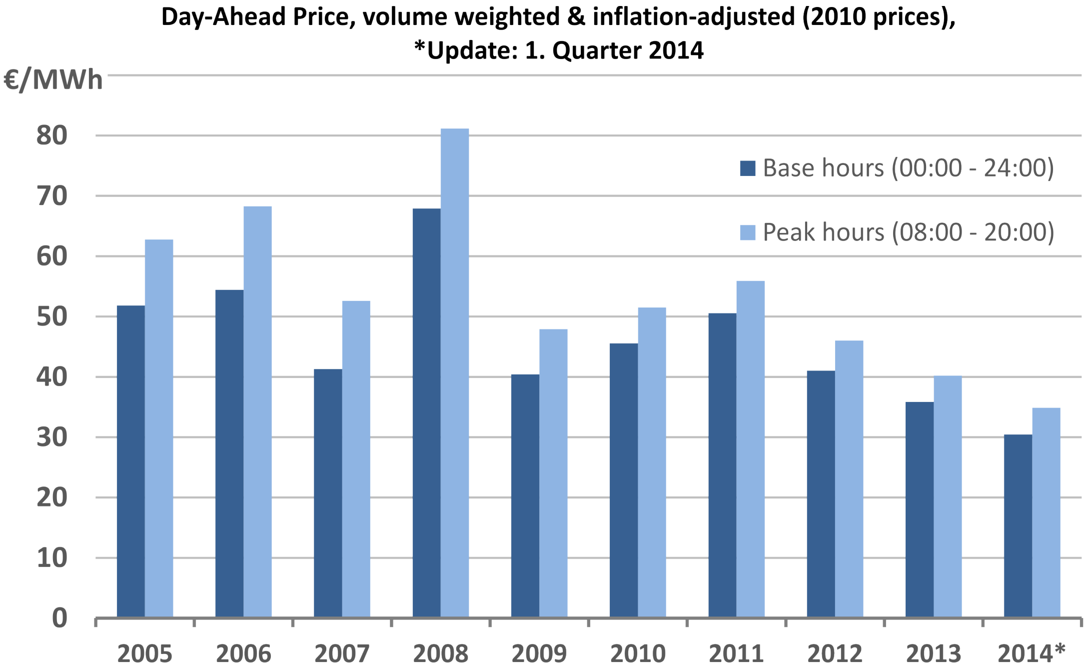
[392] Run-of river hydro power plays a relatively small role in Germany. It is not considered here due to lack of disaggregated data. Wave and tidal energy are not yet used.

[393] As the shutdown nuclear plants still generated some power in 2011, the full impact of their withdrawal is visible only in 2012. From 2012 to 2013, nuclear generation remained fairly stable, with a small reduction of 2 percent.

years, the number of hours with negative prices more than quadrupled, from 15 to 64. The hours with prices below €15/MWh (US$20.5) rose from 161 to 727 (8 percent of the time).

While there are many factors influencing power prices, there is broad agreement that the growth of variable renewables was the main driver for the increasing frequency of very low prices in the German power market.[394]

Figure 28: Decreasing Day-Ahead Electricity Prices in Germany



Source: Fraunhofer ISE, based on EEX data.

Another relevant indicator for the profitability of nuclear power plant operation is the development of average day-ahead prices.

Figure 28 illustrates the declining trend of peakload and baseload spot market prices in Germany since 2011. As discussed above, the main price reference for the revenues of nuclear power plant operators is baseload. From 2011 to the first quarter of 2014, average baseload prices decreased by an astonishing 40 percent. After the shutdown of eight nuclear power plants was announced in March 2011, some critics forecasted price increases and import dependency, but in fact, the opposite occurred.

Looking Ahead: Traditional Baseload Likely to Disappear

"We may not need any [new baseload plant], ever."

Jon Wellinghoff,
then Chairman of the Federal Energy Regulatory Commission (FERC), April 2009[395]

Looking a decade ahead, in several countries baseload could completely disappear at certain times of the year. Figure 29 shows a simulation of a hypothetical April week in the German power system of 2022[396]. The structure is analogous to the charts discussed above. In this week, both solar and wind generation are strong.

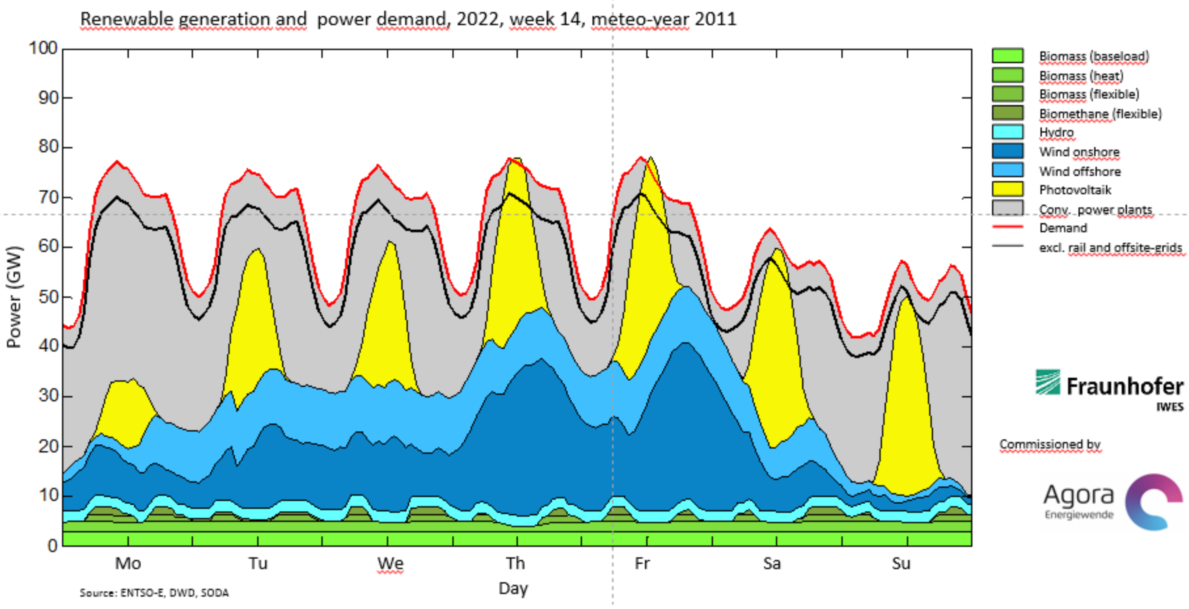
---

[394] The reduction of CO_2 prices was another relevant factor favoring lower prices. However, gas prices increased between 2010 and 2012, and total demand slightly decreased in 2012 and 2013.

[395] New York Times, "Energy Regulatory Chief Says New Coal, Nuclear Plants May Be Unnecessary", 22 April 2009, see http://www.nytimes.com/gwire/2009/04/22/22greenwire-no-need-to-build-new-us-coal-or-nuclear-plants-10630.html, accessed 3 June 2014.

[396] Hourly demand is based on real 2011 data, minus 10% efficiency gains assumed by the authors. Solar and wind generation is based on real 2011 weather data, applied to the capacities officially assumed for 2022 by the main scenario of the Federal government, used by the Federal Network Agency for the 1st German transmission grid

Figure 29: German Power System, Simulation of a Week in April 2022—By Generating Source



Some key features of power systems with high shares of renewables become evident. The conventional power plants serving the net load must cope with very frequent and rapid production ramps, both upwards and downwards. Predictability decreases, as the forecast errors concerning wind and solar generation add up to those concerning demand. Therefore, the conventional power plants must be able to adjust their schedules at short term. The analysis above suggests that the global nuclear power fleet does not have these capabilities.

Baseload disappears completely in this specific week, as well as in numerous other weeks of the year. At other times, baseload still exists, but it is clear that, above a certain share of renewables, the business model of baseload power plants that need high capacity factors to cover (at least a part of) their fixed costs will be rapidly eroded, as more renewables capacities are added. In other words, big thermal plants running whenever they're available are replaced by cheaper-to-run portfolios of renewables, mostly variable renewables, that add up to "virtual baseload" supply—collectively providing reliable electricity from a shifting mix of resources.

This way of operating the grid is analogous to a symphony orchestra (as Rocky Mountain Institute's Clay Stranger puts it): no instrument plays all the time, but with a good score and conductor, beautiful music is continuously produced. This approach is unfamiliar to traditional utilities, but it works. In 2013, four European countries met about half of their total electricity consumption with renewables: Spain 45%, Scotland 46%, Denmark at least 47%, and Portugal 58%. None of them added bulk storage, yet they all sustained excellent reliability, which for the European reliability champions (Denmark and German) was about ten times that of the USA.[397]

development plan. Charts for all weeks of the year, as well as the underlying Excel tables, are available at http://www.agora-energiewende.de/download, accessed 13 May 2014.

[397] A.B. Lovins, "The storage necessity myth: how to choreograph high-renewables electricity systems", 8 July 2014, see https://www.youtube.com/watch?v=MsgrahFln0s&feature=youtu.be&list=UUtMVIFDBDTHbJK8A0HPdNqA, accessed 24 July 2014.

Annexes

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 2014) 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. Load factor figures are drawn from *Nuclear Engineering International*, May 2014, unless otherwise noted.

Africa

South Africa has two French (Framatome/AREVA) built reactors. They are both located at the Koeberg site east of Cape Town, which supplied 13.6 TWh or 5.7 percent of the country's electricity in 2013 (the historical maximum was 7.4 percent in 1989). The reactors are at the only operating nuclear power plant on the African continent.

The state-owned South African utility Eskom launched an effort in 1998 to develop the Pebble Bed Modular Reactor (PBMR), a helium-cooled graphite-moderated reactor based on earlier German designs. What happened then has been summed up by the *Energy Economist* this way: "The project was running about 25 years behind its original schedule, the estimated cost of a demonstration plant had increased 30-fold and a design fit to submit to the regulator had still not been completed."[398] In September 2010, the Government "[dropped the] final curtain on PBMR," a few months after having terminated all public support.[399] Some US$1.3 billion had been invested in the project, with more than 80 percent coming from the South African Government.[400]

The failure of the PBMR led Eskom to consider buying additional large Pressurized Water Reactors (PWR). In the longer term, it planned to build 20 gigawatts (GW) of nuclear plants 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 published a Revised Strategic Plan that still contained a 9.6 GW target, or six units for nuclear power by 2030. Startup would be one unit every 18 months beginning in 2022.[401] While government, little influenced by the events in Fukushima, "still appears gungho for newbuild"[402], other factors lead to delaying the option far into the future. The latest edition of the Integrated Resource Plan for Electricity 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.[403]

Meanwhile, South Africa is developing into a top renewable energy investor. The Renewables 2014 Global Status Report places the country on eighth position in total amount invested (US$4.9 billion) in 2013, excluding small-scale projects, and fourth in terms of renewable energy investment as share of Gross Domestic Product (GDP) in 2012.[404]

---

[398] Energy Economist, "Prospects for nuclear power in 2012", Platts, March 2012.

[399] WNN, "Government Drops Final Curtain on PBMR", 20 September 2010. The company PBMR, which in September 2010 still claimed on its website that "the South-African project is on schedule to be the first commercial scale HTR in the power generation field," later fired all but nine staff, went into "care and maintenance" mode to safeguard intellectual property, and shut down its website for good.

[400] For an independent historical account of the PBMR, see David Fig, "Nuclear Energy Rethink? The Rise and Demise of South-Africa's Pebble Bed Modular Reactor", Pretoria: Institute for Security Studies, ISS Paper 210, April 2010.

[401] DOE, "Revised Strategic Plan – 2011/120-02015/16", February 2012.

[402] NIW, "Newbuild: The Collapse of the Public Technology Tender", 25 April 2014.

[403] DOE, "Integrated Resource Plan for Electricity (IRP) 2010-2030", Update Report 2013, 21 November 2013.

[404] REN21, "Renewables 2014 Global Status Report", June 2014.

The Americas

Argentina operates two nuclear reactors that in 2013 provided 5.7 TWh or 4.4 percent of the country's electricity (down from a maximum of 19.8 percent in 1990). A third unit was connected to the grid on 27 June 2014.

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 two nuclear plants were supplied by foreign reactor builders: Atucha-1, which started operation in 1974, was supplied by Siemens, and the CANDU type reactor at Embalse, which was supplied by the Canadian AECL. After 28 years of operation, the Embalse plant is supposed to get a major overhaul, including the replacement of hundreds of pressure tubes, to operate for potentially 25 more years.[405] Reportedly, contracts worth US$440 million were signed in August 2011 and main work was to start by November 2013.[406] The project could take up to five years and cost about US$1.5 billion.[407] However, as of the middle of 2014, there were no reports of any work getting underway. Trade journal *Nuclear Engineering International* comments: "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."[408]

Atucha-2 was officially listed as "under construction" since 1981. In 2004, the IAEA estimated that the start-up of Atucha-2 would occur in 2005. Since then, the IAEA kept adjusting the expected "first grid connection" date. In June 2013, the Argentinian Government announced that the project would be completed within two months.[409] That date came and went. Finally, on 3 June 2014, the first criticality of the reactor was announced and grid connection was established on 27 June 2014.

The presidents of Argentina and Brazil, Fernández de Kirchner and Lula da Silva—whose countries had long been potential military nuclear rivals—met in February 2008 and agreed to "develop a program of peaceful nuclear cooperation that will serve as [an] example in this world."[410] In early May 2009, Julio de Vido, Argentina's Minister of Planning and Public Works, stated that planning for a fourth nuclear reactor would be under way and that construction could start as early as within one year.[411] It did not. Neither a siting decision, nor a call for tender, has been reported to date.

After repeated delays construction of a prototype 27 MWe PWR, the domestically designed and built CAREM25 (a type of pressurized-water Small Modular Reactor with the steam generators inside the pressure vessel) was scheduled to begin near the Atucha site in the first half of 2013, but was delayed to February 2014, with startup planned for 2018.

Brazil operates two nuclear reactors that provided the country with 13.8 TWh (down 9 percent from the 2012 historic maximum) or 2.8 percent of its electricity in 2012 (down from a maximum of 4.3 percent in 2001). The load factor decreased from the record 91 percent to 79 percent, due to a two-month outage at Angra-1 for vessel head replacement.

As early as 1970, the first contract for the construction of a nuclear power plant, Angra-1, was awarded to Westinghouse. The reactor went critical in 1981. In 1975, Brazil signed with Germany what remains probably the largest single contract in the history of the world nuclear industry for the construction of eight 1.3 GW reactors over a 15-year period. However, 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 covered by the program, 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 indicated that a

---

405 PowerGenWorldwide.com, "Argentina's Embalse Nuclear Plant to Get 25-year Extension", 5 August 2010.
406 Research and Markets, "Nuclear Power Market in Argentina", May 2012.
407 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 29 June 2014.
408 Ibidem.
409 iEco, "Prometen que en dos meses inaugurarán Atucha II", 27 June 2013.
410 WNN, "Argentina and Brazil Team Up for Nuclear", 25 February 2008. Both countries have a long way to go to make their programs exemplary. Their industrial as well as their non-proliferation record has been far from convincing.
411 Marketwire.com, "Argentina to Reinforce Nuclear Energy by Adding 700 MW and Building Fourth Nuclear Plant", 7 May 2009.

"new" construction start occurred on 1 June 2010. In early 2011, the Brazilian national development bank BNDES approved 6.1 billion Reias (US$3.6 billion) for work on the reactor.[412] Reportedly, in November 2013, Eletrobras Eletronuclear signed a US$1.67 billion contract with French builder AREVA for the completion of the plant.[413] Planned commissioning dates vary from 2015 to May 2018, depending on sources. Considering that the plant is said to be only about half complete, at least the 2015 date appears highly unrealistic.

In early May 2012, a top-level Brazilian Government official announced that the country will not proceed with the previously stated plans to launch up to eight new nuclear power plants. "The last plan, which runs through 2020, does not envisage any [new] nuclear power station because there is no need for it", the energy ministry's executive secretary stated. "Demand is met with hydro-electrical power and complementary energy sources such as wind, thermal and natural gas."[414] In December 2013, a new Decennial Energy Plan 2022 was released. It includes only the three Angra plants without any further program extension.[415] No significant support is to be expected from the current Brazilian President Dilma Rousseff, "who has been opposed to nuclear power since her time as minister of mines and energy (2003–2005) and who is conscious of the negative public views on nuclear energy", according to an independent research report.[416]

Canada operates 19 reactors, all of which are CANDU (CANadian Deuterium Uranium), providing 94 TWh—an increase of almost 6 percent over the previous year—or 16 percent of the country's electricity in 2013 (down from a maximum of 19.1 percent in 1994). Two reactors, Bruce-1 and -2, had been restarted in 2012 after 15- and 17-year shutdown periods.

There have been significant delays in restarting six of originally eight reactors in long-term-shutdown (LTS). In December 2012, the LTS status of the two 40-year old Pickering-2 and -3 was "retroactively changed to Permanent Shutdown", as of May 2007 and October 2008 respectively. In January 2010, operator Ontario Power Generation (OPG, Ex-Ontario Hydro) requested a five-year license renewal for the four Pickering-1 to -4[417] reactors, but in July 2010 the Canadian Nuclear Safety Commission (CNSC) decided to limit the license to three years. For all remaining six Pickering units, the licenses expired on 30 June 2013.[418] However, these licenses were extended in late June 2013 for two months to August 2013[419], and in August 2013 for a five-year period to 31 August 2018[420]. The Ministry for Energy stated that the remaining two Pickering reactors are "expected to be in service until 2020" 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".[421] Greenpeace Canada considers that "declining electricity demand, however, has eliminated the need for

---

412 However, it is surprising to note that AREVA's 400-page Reference Document 2012 does not even contain the word "Angra".

413 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", see http://www.world-nuclear-news.org/C-Areva-contracted-to-complete-Angra-3-081134.html; both accessed 30 June 2014.

414 WNISR, "Brazil Abandons New Build Plans", 11 May 2012, see http://www.worldnuclearreport.org/Brazil-Abandons-New-Build-Plans, accessed 17 July 2014.

415 Ministério de Minas e Energia, "Plano decenal de expansão de energia 2022", December 2013.

416 Togzhan Kassenova, "Brazil's Nuclear Kaleidoscope", Carnegie Endowment for International Peace, (CEIP), March 2014, see http://carnegieendowment.org/files/brazil_nuclear_kaleidoscope_lo_res.pdf, accessed 30 June 2014.

417 Also called Pickering A reactors.

418 NEI, "Pickering A Gets 3-year Licence Extension", 2 July 2010, see http://www.neimagazine.com/news/newspickering-a-gets-3-year-licence-extension, accessed 3 August 2014.

419 CNSC, "CNSC Extends Operating Licences for Pickering A and B Nuclear Generating Stations", 24 June 2013, see http://www.suretenucleaire.gc.ca/eng/mediacentre/releases/news_release.cfm?news_release_id=462, accessed 24 June 2013.

420 CNSC, "CNSC Renews Pickering Nuclear Generating Station Operating Licence", 9 August 2013, see http://www.suretenucleaire.gc.ca/eng/resources/news-room/news-releases/index.cfm?news_release_id=469, accessed 30 June 2014.

421 Ministry of Energy, "Achieving Balance—Ontario's Long-Term Energy Plan", December 2013, see http://www.energy.gov.on.ca/docs/LTEP_2013_English_WEB.pdf, accessed 1 July 2014.

new reactors *and* Pickering".[422] A recent 13-fold increase in liability from CAD75 million to CAD1 billion in case of a major accident, will not make it any easier for nuclear operators.[423]

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 Licence" for the Darlington project, "a first in over a quarter century".[424] But before the project could go into the next stage, in October 2013, the Ontario Government pulled the plug and "decided against spending upwards of CAD10 billion to buy two new nuclear reactors".[425] Ontario's Long-Term Energy Plan, released in December 2013, confirms the decision: "Ontario will not proceed at this time with the construction of two new nuclear reactors at the Darlington Generating Station."[426]

Under the new Plan, Ontario will complete its phase-out of coal in electricity generation in 2014, stipulates a Conservation First policy, and aims to "balance the following five principles: cost-effectiveness, reliability, clean energy, community engagement and an emphasis on conservation and demand management before building new generation".[427] The Plan received a rather positive response, including from some environmentalists. The Pembina Institute considers that "in many ways it offers a reasonable approach", with "nuclear's share of the electricity mix falls from 59 percent in 2013 to 42 percent by 2025" and "nearly half of Ontario's power is projected to come from renewables by 2025. That's up from 28 percent today."[428]

In **Mexico,** two General Electric 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 2013, nuclear power produced a record 11.4 TWh—3 TWh (+36 percent) more than in 2012—or 4.6 percent of the country's electricity (down from a maximum of 6.5 percent in 1995). An uprating project boosted the nameplate capacity of both units by 20 percent to 765 MW each. Work continued until February 2013 while the plant remained officially in operation, so the average load-factor of the two reactors plunged from 84 percent in 2011 to 64 percent in 2012 before recovering to pre-uprating levels in 2013. The power plant is owned and operated by the Federal Electricity Commission (Comisión Federal de Electricidad).

Energy Minister Pedro Joaquín Coldwell 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.[429] Currently, fossil fuel plants account for four-fifths of the installed capacity and nuclear for the remaining 3 percent.

[422] Greenpeace Canada, "Time to Shut Down the Pickering Nuclear Station", 19 November 2013, see http://www.greenpeace.org/canada/en/Blog/time-to-shut-down-the-pickering-nuclear-stati/blog/47446/, accessed 1 July 2014.
[423] NucNet, "Canada Increases Absolute Liability Limit Of Operators To CAD1 Billion", 3 February 2014, see http://www.nucnet.org/all-the-news/2014/02/03/canada-increases-absolute-liability-limit-of-operators-to-cad-1-billion, accessed 1 July 2014.
[424] OPG, "Joint Review Panel issues Licence to Prepare Site", 17 August 2012, see http://www.opg.com/nb/index3.asp, accessed 8 May 2013.
[425] 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 WNISR, "The End of New Build in Canada?", 11 October 2014, see http://www.worldnuclearreport.org/The-End-of-New-Build-in-Canada.html; both accessed 30 June 2014.
[426] Ministry of Energy, "Achieving Balance—Ontario's Long-Term Energy Plan", December 2013, see http://www.energy.gov.on.ca/docs/LTEP_2013_English_WEB.pdf, accessed 1 July 2014.
[427] Ibidem.
[428] Tim Weis, "Recognizing progress in Ontario's new long-term energy plan", Pembina Institute, 19 December 2013, see http://www.pembina.org/blog/767, accessed 17 July 2014.
[429] 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/current/2014/kw21/mexico-sets-goal-for-renewables-to-grow-to-33-of-installed-capacity.html, accessed 1 July 2014.

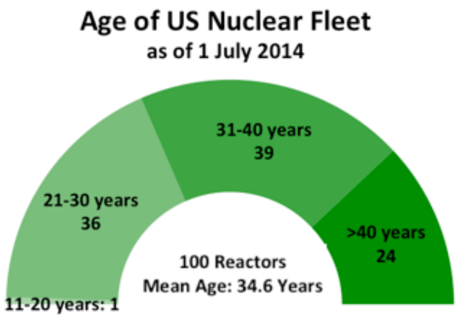
United States Focus

The United States has more nuclear power plants than any other country in the world, with 100 commercial reactors currently operating. This is the lowest number of operating reactors since the Chernobyl accident in 1986. The highest number of operating units, 108, was reached in 1990. Four units were officially closed in the first half of 2013, the first time reactors shut down were announced since 1998. In addition, in August 2013, Entergy announced that it would retire its Vermont Yankee plant in late 2014.[430]

The U.S. reactor fleet provided 790 TWh in 2013, a 2.5 percent increase over the previous year, but still 2.2 percent less than in the record year 2010. The load factor increased by an impressive 4.6 percentage points in 2013 over the previous year. Nuclear plants provided 19.4 percent of U.S. electricity in 2013 (down from a maximum of 22.5 percent in 1995).

With only five reactors under construction (one of them since 1972) and no new reactor started up in 18 years, the U.S. reactor fleet continues to age, with an average of 34.6 years, amongst the highest in the world: 24 units—every fourth reactor—have operated for more than 40 years and up to 44 years (see Figure 30). Projects are being developed and implemented to allow reactors to operate for potentially up to 60 years. As of June 2014, 72 of the 100 operating U.S. units have received a license extension.[431]

Figure 30: Age of U.S. Nuclear Fleet



Not all these lifetime extension options are taken up. Common factors cited for early reactor closure decisions and the wider challenge to the nuclear industries existing nuclear fleet are low gas prices, cheap wind power in the Midwest, and flat electricity demand. But another key challenge is the cost of maintaining aging nuclear reactors. Rising operating and maintenance costs during 2002–2012 have been significant, particularly for the 26 single-unit reactors which on industry figures for 2012 are more than 50% higher compared to the nuclear power plant sites with multiple reactors.[432] Analysis from Mark Cooper showed how rising costs of an aging nuclear reactor fleet and the availability of lower cost alternatives are likely to persist over the next decades, the relevant time frame for making decisions about the fate of aging reactors.[433] The decision by Entergy to close the Vermont Yankee reactor in 2014 was justified on the basis of low gas prices but also due to the high costs of maintaining the single unit plant.[434] Another reason, critical in forcing the decision, was the major legal and political opposition to continued operation of the plant from within Vermont and New Hampshire. In the past decade, public pressure had led the State of Vermont legislature and Governor to challenge continued operation of the plant, leading to numerous court hearings and major

[430] New York Times, "Vermont Yankee Plant to Close Next Year as the Nuclear Industry Retrenches", 27 August 2013, see http://www.nytimes.com/2013/08/28/science/entergy-announces-closing-of-vermont-nuclear-plant.html?_r=0, accessed 2 July 2014.

[431] U.S.NRC, "Status of License Renewal Applications and Industry Activities", see www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 2 June 2014.

[432] Electric Cost Utility Group (https://www.eucg.org/committees/nuclear.cfm#guidance) as cited by Nuclear Energy Institute, "Status and Outlook—Annual Briefing for the Financial Community", 13 February 2014, see http://www.nei.org/CorporateSite/media/filefolder/Policy/Wall%20Street/WallStreetBrief2014slides.pdf?ext=.pdf, accessed 31 May 2014.

[433] Mark Cooper, Senior Fellow For Economic Analysis, "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 31 May 2014.

[434] Entergy, "Entergy to Close, Decommission Vermont Yankee", Frequently Asked Questions section, see http://www.entergy.com/vy/, accessed 2 July 2014.

uncertainty in the future of the plant, even with the NRC granting a 20 year life extension to the plant in 2011.[435]

One sign of the uncertainty in the prospects for continuing operation of aging nuclear reactors was the decision made in 2013 to cancel planned power up-rates. Exelon Corporation abandoned plans to increase power by a total of 423 MW at four of its reactors two at LaSalle in Illinois and two at Limerick in Pennsylvania, due to "a lack of significant improvement in long-term [electricity] pricing and [the] large size and long payback period of the investments."[436]

The U.S. Energy Information Administration Office (EIA) in its 2014 *Annual Energy Outlook* to 2040 reported that wholesale electricity prices have reduced quark spreads (the difference between electricity prices and the cost of nuclear fuel – the latter being a small fraction of annual costs) for all nuclear power plants, especially those with increasing operations and maintenance (O&M) costs or capital addition costs.[437] As the Electric Utility Cost Group has reported, O&M costs for U.S. nuclear plants rose at an average annual rate of 3.5 percent during 2008-12 period.[438] On the basis of these figures the EIA assumes under its Accelerated Nuclear Retirements case O&M costs for nuclear power plants will grow by 3% per year through 2040; that all nuclear plants not retired for economic reasons are retired after 60 years of operation; and that no additional nuclear power plants are built after the 5.5 GW of capacity currently under construction is completed. As the EIA concluded, "this case reflects uncertainty regarding actions and costs associated with continued operation of the existing nuclear fleet."[439]

In May 2014, three nuclear power plants owned by Exelon failed to secure contracts to provide power to the electrical grid at an annual PJM auction. PJM is a regional transmission organization that coordinates the movement of wholesale electricity for 61 million people in 13 States on the East coast, South east and Midwest plus the District of Columbia.[440] The PJM auction determines the cost to customers of providing electricity during the highest-demand times of the year, and covers the period three years in advance from June 2017 to May 2018. PJM's priority is to ensure reliable delivery of power when it's needed most, and the grid operator certified that Byron and Quad Cities are not required.[441] The two reactors at Byron and two at Quad Cities reactors in Illinois were priced out of the auction by competing power providers, in particular new natural gas fired generation, placing the future of those assets in question according to Exelon. The two units at Byron are licensed until 2024 and 2026, the two Quad Cities reactors are both licensed until 2032.[442] This was the first time they were rejected in the auction in the 12 years since those plants became part of the PJM Interconnection regional power grid. Exelon's Oyster Creek reactor in New Jersey, which is slated to close in 2019, also didn't clear the auction.

[435] NRC, "Vermont Yankee Nuclear Power Station – License Renewal Application—Renewed License Issued on 03/21/2011", see http://www.nrc.gov/reactors/operating/licensing/renewal/applications/vermont-yankee.html, accessed 2 July 2014.
[436] NW, "New US nuclear plant orders uncertain, but licensing continues", 11 July 2013.
[437] U.S. Energy Information Administration Office of Integrated and International Energy Analysis, "Annual Energy Outlook 2014 With Projections to 2040", U.S. Department of Energy, April 2014, see http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf, accessed 30 May 2014.
[438] Electric Utility Cost Group (https://www.eucg.org/committees/nuclear.cfm#guidance) as cited by Nuclear Energy Institute, Nuclear Energy 2014, "Status and Outlook–Annual Briefing for the Financial Community", 13 February 2014, see http://www.nei.org/CorporateSite/media/filefolder/Policy/Wall%20Street/WallStreetBrief2014slides.pdf?ext=.pdf, accessed 31 May 2014.
[439] U.S. Energy Information Administration Office of Integrated and International Energy Analysis, "Annual Energy Outlook 2014 With Projections to 2040", U.S. Department of Energy, April 2014, see http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf, accessed 30 May 2014.
[440] Chicago Tribune, "Auction results place Exelon power plants in jeopardy", 27 May 2014, see http://www.chicagotribune.com/business/breaking/chi-exelon-plants-auction-20140527,0,7654081.story, accessed 1 June 2014.
[441] Chicago Business, "Financial outlook craters for two Exelon nukes in Illinois", 27 May 2014, see http://www.chicagobusiness.com/article/20140527/NEWS11/140529822/financial-outlook-craters-for-two-exelon-nukes-in-illinois, accessed 2 July 2014.
[442] WNN, "Exelon plants in question", 28 May 2014, see http://www.world-nuclear-news.org/C-Exelon-plants-in-question-2805141.html, accessed 31 May 2014.

The NRC is currently considering plant life extension applications for 19 nuclear reactors (one more than a year ago), beyond the 72 license extensions already granted.[443] No final decision on the new applications can be granted until the NRC completes a new "waste confidence rule", which relates to long term management of nuclear waste, including commercial reactor spent fuel. This follows a decision of the Court of Appeals for the District of Columbia in 2012, which invalidated the NRC's then "waste confidence rule". The court ruled that the NRC had failed to consider the environmental effects of not securing a permanent waste disposal facility in the United States, or the environmental risks from storage of spent fuel stored at reactor sites for six decades.[444] A Generic Environmental Impact Statement (GEIS) from the NRC is scheduled to be issued in October 2014, but the NRC is contended to have failed to address the range of issues contained in the Court of Appeal ruling and in the law as required under National Environmental Policy Act (NEPA).[445] Consequently there is considerable uncertainty when the NRC will be able to resume issuance of both life extension and construction licenses.

New Reactor Projects—Suspended and Cancelled

In June 2013, the Tennessee Valley Authority (TVA) indefinitely suspended plans to complete reactor construction at the Bellefonte plant in Hollywood Alabama. Construction on two reactors at the site was begun in the early 1970s.[446] Having halted the project in 1988, work on the US$4.9 billion plant restarted in late 2011, but stalled again early in 2012, when TVA said that it would not start working on completion of the Bellefonte units until after the initial fuel loading at Watts Bar 2, under construction since 1972. The federally owned corporate agency said it would focus instead on completing its Watts Bar Unit 2 in a "quality manner, on time and within budget." Watts Bar is scheduled for operation in late 2015. But according to TVA's senior vice president for Nuclear Construction, Mike Skaggs, "Protecting the Bellefonte asset is also at the top of our 'must and will do' list."[447] The decision also sets back any plans for the construction of an AP1000 reactor at the Bellafonte site, originally planned for two units but reduced to one in 2009[448]).

Construction has continued of three AP1000 reactors, unit-3 and unit-4 Vogtle in Georgia and VC Summer unit-2 in South Carolina. In the case of Vogtle, a report for the Georgia Public Service Commission (PSC) in June 2014 warned that projected startup of unit-3 has slipped from April 2016 to January 2018, and that the project faces many challenges to meet those deadlines. The PSC report revealed that a detailed work schedule exists only through December 2015 and that—since the construction companies have a poor track record of meeting deadlines—it remains unclear how construction will be compressed into the remaining timeframe if it is to meet the revised schedule.[449]

Construction of VC Summer unit-3 began in November 2013.[450] In February 2014, the U.S. Department of Energy confirmed that the owners of plant Vogtle, Georgia Power and Oglethorpe Power, will receive a combined US$6.5 billion in federal loan guarantees to complete their 2,200-MW nuclear plant expansion.[451] No other loan guarantees for commercial power reactors have been announced and many of the projects that applied for the guarantees are now on hold. The loan

---

443 NRC, "Status of License Renewal Applications and Industry Activities", Updated 1 July 2014, see http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 2 July 2014.
444 United States Court of Appeals, "On Petitions for Review of Orders of the Nuclear Regulatory Commission, State of New York et al, petitioners Vs NRC, respondents", decided 8 June 2012, see http://www.ct.gov/ag/lib/ag/press_releases/2012/20120608nrc_decision.pdf, accessed 30 May 2014.
445 Geoffrey H. Fettus, Senior Attorney, "Briefing On Waste Confidence Rulemaking — Presentation Before The Full Commission Nuclear Regulatory Commission", Natural Resources Defense Council (NRDC), 21 March 2014, see http://www.nrc.gov/reading-rm/doc-collections/commission/slides/2014/20140321/fettus-slides-20140321.pdf, accessed 30 May 2014.
446 Powermag, "TVA Indefinitely Delays Bellefonte Nuclear Project", 20 June 2013, see http://www.powermag.com/tva-indefinitely-delays-bellefonte-nuclear-project/, accessed 30 May 2014.
447 Ibidem.
448 Seattle Times, "TVA plan for Ala. nuclear plant drops to 1 reactor", 7 August 2009; TVA originally filed a COLA with the NRC for two AP1000s, subsequently reduced to one in 2009; see http://seattletimes.com/html/businesstechnology/2009619802_apustvanuclear.html?syndication=rss, accessed 30 May 2014.
449 Athens Banner Herald, "Monitor warns of delays building Plant Vogtle", 23 June 2014, see http:/m.onlineathens.com/local-news/2014-06-23/monitor-warns-delays-building-plant-vogtle, accessed 17 July 2014.
450 WNN, "Second Summer AP1000 under construction", 6 November 2013, see http://www.world-nuclear-news.org/NN-Second-Summer-AP1000-under-construction-0611134.html, accessed 31 May 2014.
451 Platts, "Georgia Power, Oglethorpe to receive nuclear loan guarantees totaling $6.5 bil", 19 February 2014, see http://www.platts.com/latest-news/electric-power/washington/georgia-power-oglethorpe-to-receive-nuclear-loan-21240192, accessed 31 May 2014.

guarantees include a credit rate, as required by law, subsidy fee—a charge to recipient companies to repay the government for the risk of extending the loan. Documents released in April 2014 revealed that the DOE had set a zero subsidy rate for the loans,[452] —effectively assuming that the risk of loan default is zero. Weaknesses in the loan guarantee program were detailed in a Government Accountability Office (GAO) report to Congress in 2012,[453] including the warning "that risks inherent to the program make it difficult for DOE to estimate credit subsidy costs it charges to borrowers. If DOE underestimates these costs, taxpayers will ultimately bear the costs of defaults or other shortfalls not covered by the borrowers' payments".[454] Under the Federal Credit Reform Act of 1990, the credit subsidy cost for any guaranteed loan must be provided prior to a loan guarantee commitment. South Carolina Electric & Gas and Santee Cooper are also building two AP1000 reactors at their Summer station. These utilities applied for a loan guarantee but DOE has not awarded them a conditional commitment.

On 30 May 2014, South Carolina Electric & Gas Co applied for an electricity price increase to cover US$70 million in construction costs at VC Summer in 2013.[455] If granted by the Public Service Commission, it will be the seventh price increase since 2009. Under the South Carolina Base Load Review Act, utilities are permitted to increase electricity prices for current customers to pay for construction of nuclear plants before they go into operation. Many other State Utility Commissions prohibit any construction cost related price increases prior to power production. Between a portfolio of Federal subsidies (not just the loan guarantee) and the special Georgia and South Carolina laws ostensibly transferred all costs and risks to federal taxpayers and state utility customers, while any potential upside goes to utility investors. These arrangements seem unlikely to be repeated in other states, and in due course may not offer utilities the degree of protection from cost overruns that they intended. If cost overruns and price increases cause political stress, regulators may not be the same people or have the same attitudes that they did when the projects began, and no matter what the state law says, regulators have many ways to penalize utilities that they think performed poorly.

Pending Combined Operating License Applications (COL)

As of May 2014, 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. Eight were subsequently suspended indefinitely or cancelled and 16 have been delayed. Four COLs were granted for the AP1000 reactors at Vogtle 3&4 and VC Summer 2&3.

Of the 12 reactors listed by as under review by the NRC[456], six are AP1000 designs, though none of the utilities have committed to building them. For the remaining six reactors—two Evolutionary Power Reactors (EPR)[457], two Economic Simplified Boiling-Water Reactors (ESBWR), and two Advanced Boiling Water Reactors (ABWR)—the NRC must certify the designs before issuing COLs. Major uncertainties remain as to how many if any of these will actually be built. The design certification process has been delayed by requirements established by the NRC in response to the 2011 Fukushima-Daiichi accident.

While no applicant for a reactor license has said it will definitely build a new unit, utilities are persisting with their applications for a range of reasons including hedging against growth in electricity demand, a rise in natural gas prices or restrictions on carbon emissions, according to the Nuclear Energy Institute (NEI).[458] However, the U.S. Energy Information Administration (EIA) projected in 2014 that rising nuclear reactor operating costs, lower natural gas prices and stagnant growth in

---

[452] Clean Energy, "New Documents Confirm Utility Giant Southern Company Gets Sweetheart Deal from Energy Department for Multi-Billion Nuclear Loan Guarantees for Vogtle Reactors", 21 April 2014, see http://www.cleanenergy.org/new-documents-confirm-utility-giant-southern-company-gets-sweetheart-deal-from-energy-department-for-multi-billion-nuclear-loan-guarantees-for-vogtle-reactors/, accessed 1 June 2014.

[453] Government Accountability Office, "Report to Congressional Committees—DOE Loan Guarantees—Further Actions Are Needed to Improve Tracking and Review of Applications", March 2012, see http://www.gao.gov/assets/590/589210.pdf, accessed 31 May 2014.

[454] Ibidem.

[455] The State, "SCE&G customers facing seventh rate increase for nuclear project", 30 May 2014, see http://www.thestate.com/2014/05/30/3477727/sceg-customers-facing-seventh.html, accessed 1 June 2014.

[456] NRC, "Combined License Applications for New Reactors", 1 July 2014, see http://www.nrc.gov/reactors/new-reactors/col.html, accessed 2 July 2014.

[457] Outside the United States, EPR stands for European Pressurized Water Reactor.

[458] NW, "New US nuclear plant orders uncertain, but licensing continues", 11 July 2013, see http://www.platts.com/IM.Platts.Content/ProductsServices/Products/nucleonicsweek.pdf, accessed 3 July 2014.

electric demand (which peaked nationwide in 2007 and has fallen in four of the past five years), will lead to the closure of 10,800 megawatts of U.S. nuclear generation, or around 10 percent of total capacity, by the end of the decade.[459] The EIA reported that 6,000 MW of nuclear capacity will shut by 2020, in addition to six reactors totaling 4,800 MW that have already shut or plan to shut in that time period. The actual number of reactors vulnerable to closure could be considerably higher.

In December 2013, the U.S. NRC issued an exemption to PPL Bell Bend, LLC (PPL), which has a pending license application for one EPR at Luzerne County, Pennsylvania.[460] PPL had requested an exemption from certain regulatory requirements that require them to submit updates to the Final Safety Analysis Report (FSAR) included in their COL application. PPL must submit an FSAR to the NRC by 31 December 2014. Currently PPL has no construction timetable for the EPR at Bell Bend, which they state is dependent on the issuance of an NRC license, loan guarantees, and securing project partners.[461]

Five years after filing a Combined Operating Licensed Application with the NRC for two additional reactors at Comanche Peak[462], on 8 November 2013 Luminant, a subsidiary of Dallas-based Energy Future Holdings, suspended its application. In 2011, Luminant had restated its intention to proceed with Comanche Peak units 3&4, with the aim of securing license approval at the end of 2013, with commercial operation dates of 2021/2022.[463] The partner in the two Advanced Pressurized Water Reactors project, Mitsubishi Heavy Industries (MHI), stated that it was focusing its efforts on the restart of nuclear reactors in Japan and from 2014 focusing on its services and components business for reactors already in operation in the U.S. MHI "has informed us that they will materially slow the development of their design control document for their new reactor design by several years. In addition, both [Mitsubishi] and Luminant understand the current economic reality of low Texas power prices driven in large part by the boom in natural gas," read a statement from Luminant (not to mention Texas's national leadership in even cheaper wind power).[464] It also stated to the NRC that "it does not make sense to continue to expend Luminant and NRC resources on the COL application review" and that they will "develop a mutually agreeable plan" to suspend it.[465] The company anticipated all review activities to be suspended by the end of March 2014. Luminant is not withdrawing its application to the NRC entirely, leaving open the possibility that it might eventually expand, but with low gas and wind power costs reducing electricity prices any prospect in the near term is unlikely.

In August 2013, the NRC informed Duke Energy that there could be a three year delay before a decision is made on its COL application for its two AP1000 reactors William States Lee III, Units 1 and 2, in Levy County, Florida.[466] The delay was due to changes in the site location of the two reactors, as well as further seismic data required by the NRC following the Fukushima-Daiichi accident. In 2008 Progress Energy and Duke had raised the cost estimate for the two reactors to US$11 billion, twice the original cost estimate from only three years earlier.[467] In July 2013, Duke

---

[459] U.S. Energy Information Administration Office of Integrated and International Energy Analysis, "Annual Energy Outlook 2014 With Projections to 2040", U.S. Department of Energy, April 2014, see http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf, accessed 30 May 2014.

[460] Federal Register, "PPL Bell Bend, LLC; Bell Bend Nuclear Power Plant; Exemption From the Requirement To Submit an Annual Update to the Final Safety Analysis Report Included in a Combined License Application", filed 23 December 2013, see https://www.federalregister.gov/articles/2013/12/24/2013-30752/ppl-bell-bend-llc-bell-bend-nuclear-power-plant-exemption-from-the-requirement-to-submit-an-annual, accessed 25 May 2014.

[461] Bellbend, "PPL Factsheet", see http://www.bellbend.com/faqs.html, accessed 25 May 2014.

[462] Associated Federal Register Notice, "Acknowledgment Of Receipt Of The Combined License Application For Comanche Peak Nuclear Power Plant, Units 3 and 4", 3 November 2008, see http://pbadupws.nrc.gov/docs/ML0824/ML082420365.pdf, accessed 25 May 2014.

[463] Luminant, "Luminant Statement Regarding Comanche Peak Development", 14 March 2011, see http://www.luminant.com/news/newsrel/detail.aspx?prid=1197, accessed 25 May 2014.

[464] Dallas News, "Expansion of Comanche Peak nuclear power plant suspended", 8 November 2013, see http://www.dallasnews.com/business/energy/20131108-expansion-of-comanche-peak-nuclear-power-plant-suspended.ece?nclick_check=1, accessed 25 May 2014.

[465] WNN, "Mitsubishi delays certification of APWR", 12 November 2013, see http://www.world-nuclear-news.org/NN-Mitsubishi-delays-certification-of-APWR-1211134.html, accessed 25 May 2014.

[466] WNN, "Three-year delay in Lee licensing", 1 August 2013, see http://www.world-nuclear-news.org/nn-delay_in_lee_licence_review-0108134.html, accessed 31 May 2014.

[467] WNN, "Duke raises cost estimate for Lee plant", 7 November 2008, see http://www.world-nuclear-news.org/NN-Duke_raises_cost_estimate_for_Lee_plant-0711084.html, accessed 31 May 2014.

officials said that they may bring the Levy reactors on line sometime in the 2020s[468], but on 1 August 2013, they announced that it had cancelled the plans, having seen the price estimate for the AP1000 reactors increase by 400% to US$24.7 billion.

Under Florida's controversial "Construction Work in Progress" (CWIP) law, also known as the "advance fee law", Progress, and then its successor Duke, was able to charge customers on their electricity bills for the construction of Levy County nuclear power plant. The Florida Legislature passed the 2006 law that allowed utilities to collect money from customers in advance to help build nuclear plants, justifying it on the basis that it would allow utilities to build the plants cheaper and faster. Under the law, Duke customers will still have to pay up to US$1.5 billion, while shareholders will retain US$150 million. In 2009, economist Mark Cooper had advised[469] the Florida Public Service Commission (PSC) to cancel the project as imprudent. Having described the CWIP law "as crony capitalism", in 2014 he noted that if the PSC had taken his advice four years ago, they would have saved 1.3 billion."[470] In April 2014 it emerged that Westinghouse is suing Duke for canceling the Levy project, with a claim of US$512 million for engineering and design work.[471] Litigation is pending in federal courts in North Carolina and Pennsylvania. If Westinghouse is successful, Florida ratepayers could be charged under CWIP. Duke intends to continue the licensing process with the NRC.

Despite the controversy over the Levy project, on 14 May 2014, the Florida Public Utility Commission approved Florida Power & Light Company's (FPL) request to build two AP1000 reactors at Turkey Point unit 5 and unit 6, near Miami.[472]

The Detroit Edison Company, which filed in September 2008 for a Combined Operating Licensed Application for the Fermi-3 ESBWR on Lake Erie, Michigan, has indicated that it is likely to indefinitely suspend plans to build the reactor.[473] Citing declining demand for energy in the state, DTE executives indicated a preference for a new gas plant, but not for five years. The NRC is scheduled to complete its design certification for the ESBWR in September 2014.[474]

Électricité de France (EDF) announced 30 July 2013 that it was ending its ambitions for nuclear plant operations and construction in the United States[475], having failed to secure a new partner for its planned EPR at Calvert Cliffs in 2012 following the withdrawal of Constellation Energy.

The Dominion utility announced in April 2013 that while it is proceeding with its license application with the NRC, it has not yet committed to building a new reactor unit at North Anna, Louisa County, Virginia.[476] A decision could be made in 2016, Dominion stated in July 2013.[477]

Review of Foreign Ownership Restriction (FOCD)

---

[468] NW, "New US nuclear plant orders uncertain, but licensing continues", 11 July 2013, see http://www.platts.com/IM.Platts.Content/ProductsServices/Products/nucleonicsweek.pdf, accessed 3 July 2014.

[469] NRC, "Direct Testimony Of Dr. Mark Cooper On Behalf Of Southern Alliance For Clean Energy (SACE), Before The Florida Public Service Commission, Nuclear Plant Cost Recovery Clause", Filed 15 July 2009, see http://pbadupws.nrc.gov/docs/ml1023/ml102300614.pdf, accessed 31 May 2014.

[470] Tampa Bay Times, "Duke Energy to cancel proposed Levy County nuclear plant", 1 August 2013, see http://www.tampabay.com/news/business/energy/duke-energy-to-cancel-proposed-levy-county-nuclear-plant-fasano-says/2134287, accessed 30 May 2014.

[471] Tampa Bay Times, "Duke Energy's customers face a potential $500 million bill", 4 April 2014, see http://www.tampabay.com/news/business/energy/duke-energys-customers-face-a-potential-500-million-bill/2173654, accessed 1 June 2014.

[472] Penn Energy, "FPL wins initial approval for new nuclear reactors at Turkey Point", 14 May 2014, see http://www.pennenergy.com/articles/pennenergy/2014/05/fpl-wins-initial-approval-for-new-nuclear-reactors-at-turkey-point.html, accessed 1 June 1014.

[473] Toledo Blade, "Natural gas boom takes toll on nuke power plants — Fracking shapes DTE's plans for Monroe area", 5 November 2013, see http://www.toledoblade.com/Energy/2013/11/06/Natural-gas-boom-takes-toll-on-nuke-power-plants.html, accessed 31 May 2014.

[474] NRC, "ESBWR Application Review Schedule", see http://www.nrc.gov/reactors/new-reactors/design-cert/esbwr/review-schedule.html, accessed 30 May 2014.

[475] Reuters, "EDF exits U.S. nuclear, ups earnings outlook", 30 July 2013, see http://www.reuters.com/article/2013/07/30/edf-results-idUSL6N0G00MZ20130730, accessed 31 May 2014.

[476] WNN, "ESBWR back as proposed North Anna unit", 26 April 2013, see http://www.world-nuclear-news.org/NN-ESBWR_back_on_for_proposed_North_Anna_unit-2604134.html, accessed 31 May 2014.

[477] NW, "New US nuclear plant orders uncertain, but licensing continues", 11 July 2013, see http://www.platts.com/IM.Platts.Content/ProductsServices/Products/nucleonicsweek.pdf, accessed 3 July 2014.

In March 2013 and under pressure from the nuclear power utilities, the NRC launched a generic review of the prohibition on foreign ownership, control or domination or FOCD of nuclear power plants.[478] The review is looking at the record of application of Section 103d of the Atomic Energy Act of 1954, as amended (AEA) which rules that ownership, control or domination of a nuclear power plant by a foreign entity is illegal.[479] The NRC has emphasized that it "has not proposed, nor is it currently conducting, rule making regarding FOCD", and that upon completion of the review, a voting paper is due to the Commission no later than 31 December 2013, which will "include recommendations on the path forward, recognizing that the Commission would provide formal notice and opportunity for public comment should it propose to endorse or make significant changes in policy."[480] As of May 2014 the NRC staff have yet to complete their review.

One nuclear project that has in recent years been at the center of dispute over its foreign ownership status is a pair of Advanced Boiling Water Reactors planned for construction at the South Texas Plant (STP). The project company established to develop the project, Nuclear Innovation North America (NINA), was originally a joint venture between the Toshiba American Nuclear Energy Corporation (TANE) and NRG Energy. NRG, the majority shareholder in NINA, announced in April 2011 that it was withdrawing from the project, writing down a US$481 million investment, and excluding any further investment.[481] However, after NRG pulled out of the project and according to an NRC letter to NINA "although TANE owns about 10 percent of NINA, its overwhelming financial contributions give it significantly more power than is reflected by this ownership stake".[482] According to Brett Jarmer, an attorney for a coalition of groups opposing the license, "federal law is clear that foreign controlled corporations are not eligible to apply for a license to build and operate nuclear power plants.[483]

In May 2013, NRC staff turned down the application to proceed with the South Texas project on the basis that it fell foul of the FOCD.[484] However, the issue was further reviewed by the NRC's Atomic Safety and Licensing Board (ASLB), which in April 2014 issued a Partial Initial Decision (PID).[485] This found that NINA's revised license application for the two South Texas Project Advanced Boiling Water Reactors does not contravene Section 103(d) of the Atomic Energy Act (AEA), 42 U.S.C. § 2133(d), or 10 C.F.R. § 50.38, and that Toshiba's indirect foreign ownership of NINA does not, in and

---

[478] NRC, "Webinar Conducted By the U.S. Nuclear Regulatory Commission to discuss foreign ownership, control, or domination requirements", 10 September 2013, see http://pbadupws.nrc.gov/docs/ML1324/ML13248A261.pdf, accessed 25 May 2014. Industry have stated their view that foreign financing does not equal control over the facilities and that there should be changes to the FOCD. See NEI, "Comments of the Nuclear Energy Institute on Requirements related to foreign ownership, or domination of commercial nuclear power plants", 2 August 2013, see http://www.nei.org/CorporateSite/media/filefolder/Federal-State-Local-Policy/Legal-Documents/NEI-FOCD-Comments-FILED-August-2-2013-Compressed.pdf?ext=.pdf, accessed 25 May 2014. Opponents have stated that any proposed changes, such as implementing potentially new programs to monitor mitigation measures would be time consuming and a waste of resources. In addition, members of the public also stated that the NRC should not be considering allowing additional foreign ownership so that new reactors can be built. See letter of Honorable Edward J Markey to NRC, Chair Alison MacFarlane, 2 August 2013, see http://www.nirs.org/nukerelapse/calvert/2013-08-02_markey_nrc.pdf, accessed 25 May 2014.

[479] NRC, "Foreign Ownership, Control, or Domination (FOCD) of Commercial Nuclear Power Plants", see http://www.nrc.gov/reactors/focd.html, accessed 25 May 2014.

[480] NRC, "NRC to Honorable Edward J. Markey United States Senate", 19 September 2013, see http://www.nrc.gov/reading-rm/doc-collections/congress-docs/correspondence/2013/markey-09-19-2013.pdf, accessed 25 May 2014.

[481] WNN, "NRG Withdraws From Texan Project", 20 April 2011, see http://www.world-nuclear-news.org/NN-NRG_withdraws_from_Texan_project-2004114.html, accessed 2 July 2014.

[482] WNN, "NINA falls foul of foreign ownership law", 1 May 2013, see http://www.world-nuclear- news.org/NN-NINA_falls_foul_of_foreign_ownership_law-0105137.html, accessed 6 July 2014.

[483] PR Newswire, "Foreign Ownership Could Halt Licensing Of South Texas Project Nuclear Reactors; NRC Says NINA Doesn't Meet Their Requirements", 1 May 2013, see http://www.prnewswire.com/news-releases/foreign-ownership-could-halt-licensing-of-south-texas-project-nuclear-reactors-nrc-says-nina-doesnt-meet-their-requirements-205654341.html, accessed 4 July 2014.

[484] NRC, "Evaluation by the Office of Nuclear Reactor Regulation on behalf of the Office of New Reactors South Texas Project, units 3 and 4 — Docket nos. 52-012 and 52-013", see http://pbadupws.nrc.gov/docs/ml1315/ml13150a284.pdf, accessed 25 May 2014.

[485] NRC, "United States Of America Nuclear Regulatory Commission Atomic Safety And Licensing Board, Docket Nos. 52-12-Col And 52-13-Col, Nuclear Innovation North America ASLBP No. 09-885-08-Col-Bd01 Llc, Third Partial Initial Decision (Ruling On Contention Fc-1)", 10 April 2014, see http://pbadupws.nrc.gov/docs/ml1414/ml14143a323.pdf, accessed 30 May 2014.

of itself, indicate that NINA is subject to FOCD.[486] This decision has also now been challenged by groups opposed to the licensing of the South Texas reactors.[487]

Whatever the outcome of the final ruling and the NRC review of FOCD, the prospects for the South Texas Project look poor. In May 2014, the Toshiba Corporation posted losses of US$305 million on the asset value of NINA.[488] While Toshiba stated that it remains positive on the feasibility of the project, it has yet to secure a U.S. based source of funding.[489]

Asia

China Focus

China started construction of its first commercial reactor in 1985, but its nuclear sector is developing rapidly, with 28 reactors under construction—42 percent of the world's total. China currently has 21 reactors (17 GW) in operation, which in 2013 provided a record 105 TWh or 2.1 percent of the country's electricity, the lowest nuclear share of any country operating more than one commercial nuclear plant. In 2013, wind-generated electricity provided 135 TWh, 29 percent more than the power generated by nuclear plants.[490] All renewables combined, including hydropower, accounted for more than 20% (> 1,000 TWh) of China's electricity generation. For the first time, in 2013, China added more new renewable power capacity than new fossil and nuclear capacity. The country added almost ten times more solar photovoltaic capacity (at least 11.3 GW) than in the previous year.[491]

During the past year, unprecedented evidence has emerged of challenges to China's planned nuclear power program. These include delays in construction and cost increases for the Westinghouse AP1000 reactors and AREVA EPRs, continuing doubts over the siting of reactors in provinces inland, and questions over safety and regulatory oversight.

Current status

All of the nuclear units under construction in China are scheduled to come online before 2020 and would bring the total to 49 reactors. To put this into perspective, in 2013 China installed 12 GW of solar, a threefold increase over 2012.[492] Announcing plans for 2014, China's National Energy Administration (CNEA) stated that it will add 56.6 GW of non-fossil fueled generating capacity, comprising 20 GW of hydro, 18 GW of wind, 10 GW of solar, and 8.6 GW of nuclear power.[493] The new target for nuclear capacity installation assumes seven units with a capacity of 1,000 MW each will be brought into operation this year, corresponding to 40 percent of the total current installed capacity. As of the middle of the year, only one reactor (Ningde-2) had begun operation. This is one of the Generation II CPR-1000s, which has been the focus of concerns over their vintage design with resultant safety implications. There are currently 17 CPR-1000 reactors under construction.

Three new reactor construction projects began in the 18 months to the middle of 2014. Construction began on Yangjiang-5 and -6, both Advanced CPR-1000 (ACPR) design, and located in Guangdong Province. The ACPR-1000 is a so-called enhanced version of the CPR-1000, reportedly with higher seismic standards, double containment, and a reactor core catcher. In designating the Yangjiang units 5 and 6 as Generation III, reactor vendor CNECC appears to be in compliance with the terms of the

---

486 Ibidem.

487 NRC, "Intervenors' Petition For Review Of Licensing Board Memorandum And Order lbp-14-03, In The Matter Of South Texas Project Nuclear Operating Co. Application For The South Texas Project Units 3 And 4 Combined Operating License", 5 May 2014, see http://pbadupws.nrc.gov/docs/ml1412/ml14126a693.pdf, accessed 30 May 2014.

488 Reuters, "Toshiba writes down value of stake in Texas nuclear project", 7 May 2014 see http://www.reuters.com/article/2014/05/07/toshiba-nuclear-writedown-idUSL3N0NT2CZ20140507, accessed 30 May 2014.

489 WNN, "Toshiba writes down NINA losses", 7 May 2014, see http://www.world-nuclear-news.org/C-Toshiba-writes-down-NINA-losses-0705148.html, accessed 30 May 2014.

490 CleanTechnica, "Wind Leaves Nuclear Behind In China", 13 March 2014, see http://cleantechnica.com/2014/03/13/wind-leaves-nuclear-behind-china/#PJRsIHPkjukKwMAR.99, accessed 31 May 2014.

491 REN21, "Renewables 2014 Global Status Report", June 2014, see http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf, accessed 4 July 2014.

492 Bloomberg, "China Installed a Record 12 Gigawatts of Solar in 2013", 23 January 2014, see http://www.bloomberg.com/news/2014-01-23/china-installed-a-record-12-gigawatts-of-solar-in-2013.html, accessed 31 May 2014.

493 NW, "China regulator sets 2014 nuclear installation target of 8.64 GW", 30 January 2014.

State Council Nuclear Power Safety Plan announced in October 2012.[494] These revised plans, following the March 2011 Fukushima nuclear disaster, specified that all new commercial reactor projects approved for construction in China would be of Generation III design. However, the majority of reactors currently under construction in China are Generation II CPR-1000 reactors.

Chinese nuclear officials defending the design of the ACPR-1000 have cited measures to reduce the risk of vessel melt-through, to limit the risk of loss of coolant accidents, and to increase the capacity to cope with hydrogen formation under containment, as well as the back-fit of digital instrumentation & control system.[495] Questions remain as to the safety revisions incorporated into the ACPR-1000 and the overall qualification of the design by Chinese regulators following the Fukushima-Daiichi accident.[496] Design work on the ACPR-1000 began in 2009, prior to the Fukushima accident. In mid-November 2011, the operator of Yangjiang, China Guangdong Nuclear Power, now China General Nuclear Power Group, revealed the basic design of the ACPR-1000, including the claim that it had taken into account the lessons of the Fukushima accident. That affirmation appears barely credible given that it was pronounced less than six months after the events in Japan. Further, the ACPR-1000 is reported to be in compliance with the latest domestic Code of Safety of Nuclear Power Plant Design (HAF102), which itself dates from 2004. The IAEA was requested to conduct a Generic Reactor Safety Review (GRSR) for the design concept for the ACPR-1000. This was completed in May 2013. The results have not been made public.[497]

Construction has also begun on the Tianwan reactor unit-4, a VVER-1000 (AES-91)[498] and designed by Gidropress and supplied by Rosatom. International safety reviews of the VVER design have led to stated improvements, but according to reports by independent experts, it is unclear, which of all of the recommended passive safety systems were finally incorporated into the design by the plant operator, China National Nuclear Corporation (CNNC).[499] Questions remain over the quality of Russian-made components following a corruption scandal involving one of Tianwan's suppliers, with reports of thousands of individual complaints from CNNC on the low quality of material supplied to the earlier Tianwan reactors.[500] In a survey of local public opinion in 2012, a majority (54%) expressed opposition to building nuclear reactors at Tianwan due to safety concerns—an issue that Chinese authorities are increasingly aware of and which they recognize needs urgently to be addressed.[501]

Delays in nuclear projects confirmed for the first time

During the past year details have emerged of construction delays of between 18–30 months in the case of the AP1000 reactors, and of 13–15 months with the two EPR reactors. In the case of the four AP1000 reactors at Sanmen and Haiyang, escalating costs, late design changes, and component failures were confirmed by Chinese officials.[502] In addition, concerns about a lack of commissioning

[494] Xinhua, "China passes energy development, nuclear power plans", 24 October 2012, see http://news.xinhuanet.com/english/china/2012-10/24/c_131927898.htm, accessed 31 May 2014.
[495] WANG Yuhong, "IAEA-CN-205-T1-02 Reinforcement of Defence-in-Depth: Modification Practice after Fukushima Nuclear Accident", China Nuclear Power Design Co., Ltd China Nuclear Power Engineering CO., Ltd, International Conference on Topical Issues in Nuclear Installation Safety, 21 – 24 October 2013, see http://www-pub.iaea.org/iaeameetings/cn205p/Monday/Wang.pdf, accessed 31 May 2014.
[496] NNSA, et al., "Comprehensive Safety Inspection Report on Civilian Nuclear Facilities", 2012, (in Chinese), see http://www.mep.gov.cn/zjyj/201206/W020120615619308262677.pdf, accessed 5 March 2014; as cited in Hui Zhang and Tuosheng Zhang, "Securing China's Nuclear Future ", The Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard University, March 2014, see http://belfercenter.ksg.harvard.edu/files/securingchinasnuclearfutureenglish.pdf, accessed 19 May 2014.
[497] Most GRSRs are proprietary and not made public, see IAEA/GSAN, "Design Safety Review (DSR)/Generic Safety Review (GRSR), see http://nucleus.iaea.org/sites/gsan/services/Pages/DSRS.aspx, accessed 19 May 2014.
[498] Rosatom, "The celebration ceremony of the first concrete installation took place at Tianvan NPP unit 4", 27 September 2013, see http://www.rosatom.ru/en/presscentre/news/b64c2400414006efbe20be4f5b177cea, accessed 31 May 2014.
[499] Antonia Wenisch, "AES-92 for Belene: The Mystery Reactor", Austrian Institute of Ecology, Vienna, February 2007, see http://www.ecology.at/files/pr529_1.pdf, accessed 31 May 2014.
[500] Bellona, "Rosatom-owned company accused of selling shoddy equipment to reactors at home and abroad, pocketing profits", 28 February 2012, see http://bellona.org/news/nuclear-issues/nuclear-russia/2012-02-rosatom-owned-company-accused-of-selling-shoddy-equipment-to-reactors-at-home-and-abroad-pocketing-profits, accessed 31 May 2014.
[501] Ningle Yu, et al., "Knowledge of and Attitude to Nuclear Power among Residents around Tianwan Nuclear Power Plant in Jiangsu of China", International Journal of Medical Sciences, 2012, see http://www.medsci.org/v09p0361.html, accessed 31 May 2014.
[502] NW, "Design changes, parts issues slow Chinese AP1000 projects: regulator", 20 March 2014.

test procedures are an additional challenge, according to Li Jigen, director of AP1000 nuclear plant regulation for the National Nuclear Safety Administration (NNSA). According to Li, the changes and repairs have delayed the operation of the AP1000 units by as much as 30 months. Originally scheduled for commercial operation in 2013, the units are now expected to be operational in late 2015 at the earliest.[503] Only in September 2013, the start up date for both the AP1000 reactors at Sanmen-1 and Haiyang-2 had been given as December 2014, according to the chairman of SNPTC. "There are some major nonconformities during part of the equipment manufacturing process [in which] rework and repair are needed. Delivery time is delayed again and again," Li said.[504]

SNPTC, which was designated by the State Council in 2008 as the lead company for the deployment of China's large capacity PWR, is working with Westinghouse to develop the scaled-up AP1000, designated CAP1400. The success of the AP1000 project "paves a solid foundation for China to build the CAP1400 demonstration nuclear plants", according to SNPTC.[505]

More details of the problems at Sanmen and serious criticism of the performance of both Westinghouse and SNPTC were provided in February 2014. Significant design changes, quality assurance failings, and lack of support between design teams had resulted in delays and cost increases for the Sanmen AP1000 unit one reactor, according a Shan Sun, a senior official at China's National Energy Administration, in a presentation made to the IAEA.[506]

According to Shan Sun, the construction of Sanmen-unit 1, which had begun in March 2009, was at least 24 months behind schedule and 20% over budget by the end of 2013. Consequently, the electricity price for the unit had been raised from 6.9 US$ cents to 8.3 US$ cents. There had been "18,000 design changes by end of 2013". Rather than taking the average of one month for regular design changes, it took four to six months. The delays in completing the engineering stage are said to be caused by Westinghouse's unfamiliarity with Chinese regulations, with the design team's not having sufficient authority to handle basic design changes and insufficient support for regulatory review from "the offshore team". The relationship between SNPTC and its Sanmen project subsidiary, the State Nuclear Power Engineering Corporation, was described as confused. Shan also highlighted quality assurance issues, which "need to be reinforced after decades of inactivity," and "ineffective quality assurance" oversight with the subcontractors.

Despite the delays in the first two units at Haiyang site, in April 2014, China's Ministry of Environmental Protection approved an environment impact assessment for two additional AP1000s at the site.[507] The Ministry is also seeking public comments on plans for six AP1000 reactors to be built at Xudabao, in Liaoning province. Construction at unit 1 is planned to start in 2014, with work starting on unit 2, ten months later, and startup scheduled for 2019 and 2020 respectively. Westinghouse in April 2014 stated that it was in negotiation with Chinese power companies for the purchase of eight additional AP1000 reactors, to be built at Sanmen and Haiyang.[508]

AREVA EPR delay

A 13–15-month delay in the first EPR project was confirmed in early 2014. Safety concrete was first poured at the Taishan-1 EPR in November 2009, with AREVA predicting that fuel would be loaded in July 2013, and with test performances completed in December 2013. However, in February 2014, Shan Sun revealed that while both Taishan units were initially planned to be completed within 52 months, with Taishan-1 coming on line in March 2014, that unit is now expected online in June 2015; unit 2 is slated to follow in September 2016. AREVA refused to explain the cause of the delays. One of the reasons cited for delays at Taishan is the knock-on effects from the major delays in the AREVA EPR projects at Olkiluoto in Finland and Flamanville in France.[509] The NNSA has not been able to rely on testing and qualification results from the EPR European projects. In addition, malfunctions with equipment suppliers at Taishan have been cited as typical of first of a kind reactor projects. One consequence of the problems at the Taishan project, a joint-venture project owned 70%

---

[503] Reuters, "China says first Westinghouse reactor delayed until at least end of 2015", 18 July 2014, see http://reuters.com/article/idlNL4N0PT0T820140718?irpc=932&irpc=932, accessed 18 July 2014.
[504] Ibidem.
[505] NW, "China has localized AP1000 technology, says SNPT", 27 February 2014.
[506] 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.
[507] NW, "Chinese ministry approves siting two more AP1000 units at Haiyang", 3 April 2014.
[508] Reuters, "China seen buying Westinghouse reactors for $24 billion nuclear energy projects", 21 April 2014, see http://in.reuters.com/article/2014/04/21/china-nuclear-idINL3N0ND1GS20140421, accessed 19 May 2014.
[509] NIW, "Taishan's Delays Hinder Further Areva EPR Sales", 21 March 2014.

by China General Nuclear (CGN) and 30% by EDF, is that CGN will delay before committing to additional EPR projects.

Evidence of regulatory oversight and quality control challenges emerged in June 2014. Stephane Pailler, head of international relations at France's Nuclear Safety Agency (ASN), described how it was not easy to know what is happening at the Taishan site in contrast to the European EPR projects.[510] The concerns in France over their EPR projects surfaced in February 2014, when in testimony to the National Assembly, ASN Commissioner Philippe Jamet warned that "collaboration isn't at the level we would wish it to be" and that "one of the explanations for the difficulties is that the Chinese safety authorities lack means. They are overwhelmed."[511]

Interior provinces project doubts

Further doubts about the pace of China's nuclear program emerged during the past year, specifically plans for construction of reactors in interior provinces. To date all of China's commercial reactors have been located on its coastline.

In October 2012, the State Council lifted the suspension in new reactor projects (imposed in the aftermath of the Fukushima-Daiichi accident) but delayed the start of construction of reactors planned for the nation's inland provinces. All operating nuclear reactors and those under construction have until now been located on the China's coastal plains. One of the safety issues in light of the 2011 Fukushima-Daiichi accident was the ability to secure reactor core cooling function in the event of a major accident at sites dependent upon river water. Construction was postponed at the first such site in Taohuajing, Henan province, until the end of the 12th five-year national development plan in 2015, with construction scheduled to begin in 2016.[512]

The Henan Province in recent years has suffered severe drought conditions on the four inflow branch rivers of the Yangtze River, including a 46 percent water volume decrease in 2011, leading to drinking water shortages for nearly a million people.[513] The Taohuajing site plans are for the construction of up to four AP1000 reactors.[514] However, in early 2014, diverging views inside the Chinese nuclear establishment emerged on the wisdom of proceeding with inland projects in general, and Taohuajing in particular. While officially Chinese policy remains unchanged, sensitivity over long-term water supply and pollution in the inland provinces, as well general safety and economics, appears to be questioning the inclusion of such projects in the 13th five year plan (2016–2020). A former Chinese official to the IAEA, has warned that nuclear power facilities in the drainage area of the Yangtze could deal a fatal blow to the densely populated region in the event of a major earthquake or radiation leak.[515] Countering these warnings, a former vice-minister of energy has restated that inland nuclear reactor projects can proceed, citing as evidence the fact that 44 of the 58 reactors in operation in France are inland facilities, including 26 along the banks of the Rhine and Rhone rivers[516]. It should be noted that the water crisis in China's inland provinces is of a different order of magnitude compared to that of France[517]. Whatever the reality of the debate, it is obvious that there remain major unresolved issues with reactor construction plans for China's interior provinces.

---

[510] Bloomberg, "Nuclear Regulators 'Overwhelmed' as China Races to Launch World's Most Powerful Reactor", 19 June 2014, see http://www.bloomberg.com/news/2014-06-18/french-nuclear-regulator-says-china-cooperation-lacking.html, accessed 17 July 2014.

[511] Ibidem.

[512] Sizhi Guo, "Trends in Major Emerging Nuclear Country: China", Faculty of Economics, Teikyo University, 47th Japan Atomic Industrial Forum Annual Conference, 15-16 April 2014, see http://www.jaif.or.jp/english/annual/47th/47-s2_guo-e.pdf, accessed 19 May 2014.

[513] China.org, "Drought affects rice production", 21 March 2011, see http://www.china.org.cn/environment/2011-05/21/content_22610643.html, accessed 31 May 2014.

[514] WNN, "China's first inland cooling contract", 21 April 2010, see http://www.world-nuclear-news.org/C_First_inland_cooling_contract_2104101.html, accessed 19 May 2014.

[515] WantChinaTimes, "Experts disagree on China's plans for inland nuclear plants", 6 May 2014, see http://www.wantchinatimes.com/news-subclass-cnt.aspx?id=20140506000061&cid=1105, accessed 19 May 2014.

[516] Ibidem.

[517] However, water shortage has led to operational restrictions in France in the past.

2020 projections

A further reduction in the projected number of nuclear reactors to be installed and under construction by 2020 was announced by Zhang Huazhu, head of the China Nuclear Energy Association (CNEA). In April 2014 Zhang said that both installed capacity and reactor units under construction would total 88 GW by 2020, 58 GW of which would be in operation.[518] If accurate, this would be a reduction of 12 GW from the target recommended by the State Council Research Office (SCRO) in 2011 and a very significant reduction in the 130 GW forecast by officials in 2010.

A revision to the National Nuclear Power Middle and Long Term Development Plan 2005–2020 was under consideration in 2010, when some officials predicted that a likely target for 2020 would be 80 GW in operation, together with a further 50 GW under construction.[519] However, in January 2011, SCRO, which makes independent policy recommendations to the State Council, suggested that the 2020 target should be restricted to 70 GW of nuclear power in operation, with another 30 GW under construction, so as to ensure quality control in the supply chain. The 2014 disclosures of delays in AP1000 and EPR constructions and on going questioning of inland construction projects could further affect the projected installed capacity in 2020.

Meanwhile, China leads the ranking in 12 out of 25 global renewable energy categories, including investment and total installed renewable power capacity.[520]

India operates 20 nuclear power reactors with a total capacity of 5.2 GW; the majority of these have a capacity of 220 MW per unit. In 2013, nuclear power provided a record 30 TWh that covered just 3.5 percent of India's electricity, slightly below the record level of 3.7 percent already achieved in 2001/02 when nuclear generation was only around 17 TWh.

One reactor, Rajasthan-1 has not generated any power since 2004 and according to the new criteria, it was moved to the LTO category. Kudankulam-1 started up in October 2013 after 11 years of construction, numerous delays, and significant opposition.[521]

India lists six units as under construction with a total of 3.9 GW. Most currently operating reactors have experienced construction delays, and operational targets have rarely been achieved. India's lifetime nuclear load factor is only 60.5 percent as of the end of 2013, the lowest of any country operating more than two units.

India's 1974 nuclear weapons test triggered the end of most official foreign nuclear cooperation, including invaluable Canadian assistance. The nuclear weapons tests in 1998 came as a shock to the international community and triggered a new phase of instability in the region, including a subsequent nuclear test series by Pakistan. Various (and different) international sanctions were imposed on the two countries.

This state of affairs started to change under U.S. Bush administration's announcement in 2005 of what became known as the U.S.-India deal. Following intense lobbying by the United States, supported by France and Russia, the IAEA approved a "safeguards agreement" with India in August 2008, and on 6 September 2008 the Nuclear Suppliers Group (NSG), a 45-country group regulating international commerce to prevent the proliferation of nuclear weapons, granted an exception to its own rules. Thus, although India is a non-signatory of the NPT, has developed and maintains a nuclear weapons program, and refuses full-scope safeguards,[522] it is still permitted to receive nuclear assistance and to carry out nuclear commerce with other nations. The reasons for this deviation from the previous nonproliferation consensus appear to be geopolitical and commercial.

In June 2014, India ratified an Additional Protocol to its Safeguards Agreement with the IAEA under which a total of 14 civilian reactors will be put under safeguards. However, the Additional Protocol is

---

[518] Xinhua, "China's nuclear power installed capacity to reach 88 GW by 2020", 20 April 2014, see http://english.people.com.cn/business/8603754.html, accessed 31 May 2014.

[519] Yang Bo, "China Nuclear Energy Development", China Nuclear Energy Association, 13 June 2012, see http://wenku.baidu.com/view/d1b05455f46527d3240ce078.html, accessed 2 July 2014.

[520] REN21, "Renewables 2014 Global Status Report", June 2014, see http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf, accessed 4 July 2014.

[521] For details, see WNISR, "Controversial Reactor Starts Operation at Kudankulam in India", 24 October 2013, see http://www.worldnuclearreport.org/Controversial-Reactor-Starts.html, accessed 14 July 2014.

[522] Comprehensive inspection and verification that all nuclear materials and all nuclear facilities have been used for declared purposes only.

considered particularly lax and a number of reactors serving military purposes will remain outside of the international inspection regime.[523]

In December 2010, the Nuclear Power Corporation of India Ltd. (NPCIL) and AREVA signed an agreement—though not yet a commercial contract—for the construction of two EPRs (and potentially four more) for a site in Jaitapur and a fuel supply for 25 years.[524] The contract reportedly would be worth some €7 billion (US$10 billion) for *two* EPRs[525], a surprisingly low figure considering that the cost estimate for the French and Finnish EPRs has escalated to €8.5 billion (US$11.6 billion) *each*. The financial challenge gets further exacerbated by the fact that the Indian Rupee has dropped by more than 30 percent against key international currencies since the deal was first discussed in 2009. India's 2010 Civil Liability for Nuclear Damage Act that holds suppliers liable to some degree in case of accident remains a further major stumbling block to the project. Nevertheless, the Indian Parliament was told in December 2013 that "infrastructure works at the site are in progress", while no commercial contract has been signed yet.[526]

Even before the 2010 NPCIL-AREVA agreement was signed, as on other sites, opposition against the Jaitapur project was significant. The Fukushima events triggered a further increase in opposition. Two Russian-built reactors at Kudankulam were mostly completed before 3/11, "since when the sudden growth of a powerful local protest movement has effectively brought commissioning to a standstill".[527] In May 2013, India's Supreme Court paved the way for the commissioning of the reactors, which had been legally challenged by citizens' groups, arguing that the plant is "in the largest interest of the nation particularly the State of Tamil Nadu".[528] Meanwhile the state of West Bengal has scrapped another project for up to six Russian reactors at the coastal site of Haripur.[529]

The current five year plan counts on doubling the currently installed capacity and starting construction of a further 19 units. Princeton University's M.V. Ramana concludes a milestone historical assessment of the Indian program with a question and answer:

> Is a rapid and large-scale expansion of nuclear power in India, along the lines projected by the Department of Atomic Energy (DAE), feasible? The answer that emerges in the course of our excursion through the history of how the nuclear project has materialized in the country is that it is very unlikely and probably impossible. The principal reasons, among many, for this conclusion are the technical implausibility of the DAE's plans, its inability as an organization to learn lessons from its earlier failures, and local opposition.[530]

Trade journal *Nuclear Intelligence Weekly* put it more bluntly: "There's no reason to believe that the country can keep this schedule, of course." Indeed, Indian nuclear planning has been always overly optimistic, not to say unrealistic.[531]

In contrast, Indian entrepreneurs—largely in the vibrant private sector rather than large state-owned enterprises and agencies—have proven adept at rapidly scaling competitive, modular, short-lead-time, renewable technologies. India ranks in the world's Top 5 in net wind, concentrating solar (CSP), and solar water heating capacity added in 2013, and in cumulative installed wind, CSP, and total renewable power capacity (excluding hydro).[532]

---

523 M.V. Ramana, "India ratifies an additional protocol and will safeguard two more nuclear power reactors", International Panel on Fissile Materials (IPFM), 1 July 2014, see http://fissilematerials.org/blog/2014/07/india_ratifies_an_additio.html, accessed 2 July 2014.

524 AREVA, "India: Agreements Between AREVA and NPCIL for the Supply of Two EPR Reactors and Fuel for 25 Years", Press Release, 6 December 2010.

525 Bloomberg.com, "India Signs $9.3 Billion Deal for Areva to Build Two Nuclear Power Plants", 6 December 2010.

526 WNN, "Jaitapur clears bureaucratic hurdles", 31 December 2013, see http://www.world-nuclear-news.org/NN-Jaitapur-clears-beaurocratic-hurdles-3112131.html, accessed 2 July 2014.

527 WNN, "Cabinet clears way for Kudankulam", 19 March 2012, see http://www.world-nuclear-news.org/NN-Cabinet_clears_way_for_Kudankulam-1903127.html, accessed 30 May 2012.

528 WNN, "Kudankulam's public interest ruling", 7 May 2013, see http://www.world-nuclear-news.org/NN-Kundankulams_public_interest_ruling_0705137.html, accessed 14 May 2013.

529 Nucleonics Week, "West Bengal eliminates Haripur as second VVER site: reports", 25 August 2011.

530 M.V. Ramana, "The Power of Promise – Examining Nuclear Energy in India", Penguin-Viking, 2012, 366 pages.

531 See WNISR 2013, Table 7, "Nuclear Power in India: Planning, Projection or Fantasy?", 30 July 2013, see http://www.worldnuclearreport.org/World-Nuclear-Report-2013.html#asia, accessed 14 July 2014.

532 REN21, "Renewables 2014 Global Status Report", June 2014.

Japan Focus

Nuclear power in 2013 provided Japan 13.6 TWh or 1.6 percent of total electricity compared with 2 percent in 2012, 18 percent in 2011, 29 percent in 2010, and the historic maximum of 36 percent in 1998. From July 2012, only two reactors at Ohi in Fukui Prefecture operated in Japan. Since 15 September 2013, when Ohi Unit-4 was shut down, no commercial nuclear reactor has been in operation as of 1 July 2014. The expectation is that no nuclear reactor will resume operation before September 2014 at the earliest, which would, under IAEA classification, determine that all of Japan's nuclear reactor fleet is considered in Long Term Shutdown (LTS).[533] All but the two Ohi units are in WNISR's new "Long-term Outage" (LTO) category.[534]

The Fukushima-Daiichi accident, which began on 11 March 2011, has led to the shutdown of all 50 nuclear reactors and the destruction of four at the Fukushima-Daiichi site. It is no exaggeration to say that the tragic events of March 2011 have had a profound effect on the society and economy of Japan. A consistent majority of Japanese citizens when polled have opposed continued reliance on nuclear power, including plans for restarting shutdown nuclear reactors.[535]

On 11 April 2014, the Abe government approved a new energy plan, reversing the previous government's position announced in September 2012 that called for a zero nuclear power future by the 2030s.[536] The Fourth Strategic Energy Plan, originally due to be completed in mid-2012 and after further delays, was the first formal energy policy issued since the Fukushima-Daiichi accident and described nuclear power as "low-carbon and quasi-domestic energy" and a "base-load" power source that should be used for continuous, around-the-clock power generation.[537] While the plan called for a lowering of dependence on nuclear power, it deliberately excluded targets for the percentage of electricity, which in future would be nuclear generated; such a target would be set following the restart of nuclear reactors, Abe told the Japanese Parliament (Diet).[538] The setting of no nuclear target was seen as an attempt to deflect the 90 percent of public views submitted during the comment period in December 2013, which were opposed to nuclear power operations.[539] It also, however, reflects the reality that the Government does not know how many or when some of the stranded reactors will be restarted. On 18 December 2013, TEPCO formally applied to METI for the decommissioning of Fukushima-Daiichi Units 5 and 6, reducing the number of reactors (in theory) available for restart from 50 to 48.[540] In addition, the Fourth Strategic Energy Plan also reiterates the 2010 renewable energy target of 13.5 percent for 2020 and 20 percent for 2030, further questioning the prospects for nuclear power. On the other hand, the new energy plan also maintains a long-standing government policy of promoting spent nuclear fuel reprocessing, as well as plutonium mixed oxide fuel (MOX) use in commercial reactors. Projects to develop fast breeder reactors, which also use plutonium as nuclear fuel, will also be reexamined.[541]

---

533 IAEA, "Glossary of Terms in PRIS Reports", IAEA PRIS, see http://www.iaea.org/pris/Glossary.aspx, accessed 6 June 2014.

534 As explained elsewhere in this report, reactors fall under the LTO category if they have not generated any electricity the previous year and the six first months of the current year.

535 Asahi Shimbun, "Asahi Poll: 59 percent oppose restart of nuclear reactors", 18 March 2014, see http://ajw.asahi.com/article/0311disaster/fukushima/AJ201403180058, accessed 6 June 2014.

536 Energy and Environment Council, "Innovative Strategy for Energy and the Environment", Government of Japan, 14 September 2012.

537 METI, "Strategic Energy Plan", April 2014, (provisional translation), see http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf, accessed 6 June 2014; and Makoto Yagi, "Cabinet Approval of the New Basic Energy Plan", Federation of Electric Power Companies (FEPCO), 11 April 2014, see http://www.fepc.or.jp/english/news/message/__icsFiles/afieldfile/2014/04/15/press_e_20140411.pdf, accessed 3 June 2014.

538 NHK, "Government to set ratio for nuclear power", 11 April 2014, see http://www3.nhk.or.jp/nhkworld/english/news/20140411_47.html, accessed 12 April 2014.

539 Asahi Shimbun, "Abe administration ignored massive public opposition to nuclear power", 25 May 2014, see http://ajw.asahi.com/article/behind_news/politics/AJ201405250023, accessed 5 June 2014.

540 Japan Atomic Industrial Forum (JAIF), "TEPCO Applies to METI to Decommission Two Fukushima Reactors", 24 December 2013, see http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1387879431P.pdf, accessed 6 June 2014.

541 The plan removed the term prototype to describe the Monju fast breeder reactor, stating instead that it would be the basis for "a base for international research" on managing nuclear waste. The Monju reactor has been disqualified from operating since 30 May 2013; see Japan Times, "Monju must remain idled, NRA to order", 30 May 2013, see http://www.japantimes.co.jp/news/2013/05/30/national/monju-must-remain-idled-nra-to-order/, accessed 6 June 2014.

In justifying its support for the restart of the nation's shutdown nuclear reactors, the government emphasized the nation's growing fiscal trade deficit caused in part by the importation of ¥3.6 trillion (US$36 billion) worth of replacement fossil fuel.[542] This has raised doubts about the calculation formula among experts.[543] Of nine nuclear power utilities, that had released their outlook for fiscal year 2014, six (Hokkaido, Chubu, Kansai, Chugoku, Shikoku and Kyushu Electric) projected losses, with five companies expecting it to be their third consecutive year of losses.[544] During both 2012 and 2013, utilities have increased electricity prices for domestic and commercial customers throughout Japan; in addition, at least two utilities have reached agreement with the state-owned Development Bank of Japan for capital injections.[545]

As of 10 June 2014, nine nuclear power companies have applied to the Nuclear Regulation Authority (NRA) for safety assessments of 19 nuclear reactors.[546] Compliance with the post-Fukushima Guidelines, which came into force in July 2013[547], is the first step for utilities in their plans for reactor restart, which would be followed by "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[548], fire protection, and the management of the reactor in the event of a loss of offsite electrical power, cooling function, and accident management[549], including prevention of hydrogen explosion, and the containment or filtered venting of radioactive into the environment. In the case of seismic assessment, reactors that are found to be 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 safety countermeasures in place. Emergency evacuation plans are also required to be agreed with local communities within a radius of 30 km of the nuclear plant. Upon completion of the preliminary approval of the safety case, the NRA is to hold a series of local public information meetings, and 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 be participants.

Pressurized Water Reactors (PWR) are the most advanced in the review process, based on the regulators analysis that it is easier to secure PWRs against seismic events than it is Boiling Water Reactors (BWR). Reactors at Sendai, Tomari, Ikata and Genkai emerged in late 2013 as front-runners for passing NRA guidelines and therefore restart; in March 2014, the NRA announced that the two Sendai reactors in Kyushu would be a priority for safety screening.[550] Just over one year after filing its application for review, the NRA Commissioners, on 16 July 2014, approved a draft assessment of Kyushu Electric's Sendai nuclear reactors confirming compliance with the revised Guidelines.[551]

---

542 Nikkei Asian Review, "Japan logs record trade deficit of 13.75 tril. yen in FY 2013", 21 April 2014, see http://asia.nikkei.com/Politics-Economy/Economy/Japan-logs-record-trade-deficit-of-13.75-tril.-yen-in-FY-2013, accessed 9 June 2014. The fossil fuel share of US$ 35 billion, or 25% of the total deficit, should be seen in the context of deliberate government policy on of the pillars of 'Abeconomics' with the devaluation of the yen aimed at boosting exports, but which also has the effect of increasing the cost of imports.

543 Asahi Shimbun, "Editorial: New basic energy plan offers no convincing vision for Japan's future", 12 April 2014, see http://ajw.asahi.com/article/views/editorial/AJ201404120044, accessed 1 June 2014.

544 FEPCO, "Financial assessment of utilities", Summary of Press Conference, Federation of Electric Power Companies, 14 March 2014, see http://www.fepc.or.jp/english/news/conference/__icsFiles/afieldfile/2014/03/19/kaiken_e_20140314.pdf, accessed 1 April 2014.

545 Bloomberg, "Japan Utilities Seek Government Lender's Help on Fuel Costs", 2 April 2014, see http://www.bloomberg.com/news/2014-04-02/kyushu-electric-drops-after-report-on-capital-boost-tokyo-mover.html, accessed 6 June 2014.

546 JAIF, "Nuclear Power Plants in Japan (In operation and under construction)", 10 June 2014, see http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS02_1402531967P.pdf, accessed 11 June 2014; also, Reuters, "Factbox-outlook for japan nuclear reactor re-starts", 2 April 2014, see http://in.reuters.com/article/2014/04/01/japan-nuclear-restarts-idinl4n0mt0k020140401, accessed 6 June 2014.

547 NRA, "New Regulatory Requirements for Light-Water Nuclear Power Plants – Outline", August 2013, see http://www.nsr.go.jp/english/e_news/data/13/0912.pdf, accessed 6 June 2014.

548 NRA, "Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Earthquakes and Tsunamis)", 3 April 2013, see http://www.nsr.go.jp/english/data/new_regulatory_requirements2.pdf, accessed 6 June 2014.

549 NRA, "Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Severe Accident Measures)", 3 April 2013, see http://www.nsr.go.jp/english/data/new_regulatory_requirements3.pdf, accessed 6 June 2014.

550 Asahi Shimbun, "NRA to designate nuclear plants for priority safety screenings", 20 February 2014, see http://ajw.asahi.com/article/0311disaster/fukushima/AJ201402200032, accessed 6 June 2014.

551 Nuclear Regulatory Authority, 17th Commission meeting, 16 July 2014, (in Japanese), see http://www.nsr.go.jp/committee/kisei/h26fy/20140716.html, accessed 19 July 2014.

Critics contend that multiple outstanding issues remain unresolved at Sendai, including vulnerability to an active volcano and incomplete and inadequate emergency evacuation plans.[552] Further review of Kyushu Electric documentation will take place during August 2014, as well as a public comment period of one month. The NRA is expected to issue a final approval not before September 2014. At that point the decision on restart falls for the Governor of Kagoshima Prefecture and the mayor of the nearest local community to the reactors, Satsumasenda. The other 17 reactors under consideration by the NRA are at a range of stages in the process with most likely not to be completed until 2015.

The Abe government is committed to the earliest possible restart of reactors in Japan, and the fact that not one reactor has resumed operations, has led to considerable pressure being applied to the NRA to speed up the process. On occasions the NRA has deemed documentation submitted by a utility to be inadequate, incomplete, or not credible, followed by requests for more analysis and information or modifications at the site. However a trend in the NRA approach to safety assessments is emerging with initial objections being over time resolved and in some cases a reversal of previous positions. One of the clearest examples of this was the Kansai Electric Oi reactors. Having previously concluded in 2012 that there were active faults at the site in Fukui Prefecture, which under the NRA guidelines means no reactor operation was permitted, the NRA Commissioners in September 2013 revised this position and concluded that the fault was not active.[553] However, outside the NRA process, there are important external factors that will also determine how many nuclear reactors will eventually resume operations; these include:

- Citizen-led lawsuits;
- Economic factors, including a cost-benefit analysis by the utility on the implications of restart or decommissioning;
- Local political and public opposition;
- Impact of electricity deregulation.

In the case of the two Ohi reactors for example, a citizens initiated legal action led to a landmark Fukui District Court ruling that instructed KEPCO not to restart the reactor units 3 and 4.[554] The judgement covered a range of technical issues. The court rejected KEPCO's seismic safety assessments stating that there was a greater seismic risk at the plant; the ruling concluded that it was inherently impossible to determine on scientific grounds the scale of future seismic events. Assessing future maximum seismic events is the determinant for the utility and regulator agreeing on the Design Base Ground Motion (DBGM) for all nuclear power plants in Japan. The court also demanded absolute safety, citing fundamental personal rights protected under the constitution. Significantly, by accepting the plaintiffs' case against KEPCO, the court was acknowledging the risk posed to personal safety within 250 km of the nuclear plant (plaintiffs were from throughout the wider Kansai region). While KEPCO immediately filed an appeal to overturn the ruling, it stated that it intended to restart the reactors upon successful completion of the NRA review.[555] The Government reiterated this position. However, the impact of the ruling is both of local and national significance. "We'll make a decision based on the safety reviews, putting the security of the prefecture's residents first,"[556] stated Fukui Governor Issei Nishikawa. But the court decision has strengthened local opposition, which will make it more difficult to win consent from residents in Fukui, and therefore restart prior to the conclusion of the appeal process will not be straightforward. The court of appeal will probably not finish its deliberations before mid-to-late 2015. And the Fukui decision may affect other courts' sentiment.

---

[552] Asahi Shimbun, "Too many vital questions need answering before restarting reactors", 17 July, 2014, see http://ajw.asahi.com/article/views/editorial/AJ201407170031, accessed 19 July 2014.

[553] Wall Street Journal, "Fukushima Watch: Active or Not? The Battle Over the Oi Nuclear Plant's Seismic Fault", 5 November 2012, see http://blogs.wsj.com/japanrealtime/2012/11/05/fukushima-watch-active-or-not-the-battle-over-the-oi-nuclear-plants-seismic-fault/; and Japan Daily Press, "Nuclear regulator says there's no active fault under Oi power plant", via Jiji Press, 3 September 2013, see http://japandailypress.com/nuclear-regulator-says-theres-no-active-fault-under-oi-power-plant-0335212/; both accessed 6 June 2014.

[554] Financial Times, "Japanese court blocks plan to restart nuclear plant, disrupt an already complicated and politically charged effort to restart", 21 May 2014, see http://www.ft.com/intl/cms/s/0/838d1532-e0c8-11e3-a934-00144feabdc0.html#axzz342oVrApW, accessed 6 June 2014.

[555] Japan Times, "Kepco could defy courts and restart Oi reactors despite legal block", 28 April 2014, see http://www.japantimes.co.jp/news/2014/05/28/national/kepco-defy-courts-restart-oi-reactors-despite-legal-block/#.U5YLFCiyRHw, accessed 9 June 2014.

[556] Nikkei, "Court throws wrench into Japan's nuclear restart", 22 May 2014, see http://asia.nikkei.com/Politics-Economy/Policy-Politics/Court-throws-wrench-into-Japan-s-nuclear-restart, accessed 23 May 2014.

Providing a precise analysis through extrapolation from the current situation to predict the timeframe for restart of nuclear plants, the total number that will be restarted, and therefore the number that will be permanently shut down is impossible at this stage. As noted, there are multiple variables in addition to the ongoing NRA review process. However, on the assumption that the two reactors at Sendai complete their NRA review, overcome public acceptance and legal challenges, and are restarted during the last quarter of 2014, it is likely that with the exception of these reactors and the two that have operated in 2013, all of Japan's commercial nuclear plants will in effect be in Long Term Outage during the remainder of 2014 and beyond.

The utilities have deliberately prioritized NRA assessment of reactors that have operated for the fewest years, with an average age of 20 years. However, some utilities have had little choice, and they have sought safety review for five reactors that are 29 or 30 years old. This is slightly less than the average age for the remaining 29 reactors (31 years), which have yet to apply for NRA safety review, reflecting the rapid aging of the Japanese nuclear fleet. One effect of this is to create further uncertainty as to the actual risks and costs of reactor back-fitting to bring them into compliance with revised standards, the actual effectiveness of these measures in raising reactor safety standards, and what this means in financial terms to indebted utilities faced with the prospects of electricity market reform within the next few years.

At the same time, pressure to resume operations to generate electricity and income is clearly mounting. It is possible to speculate that reactors over 40 years are unlikely to resume operations, and that given the length of time the NRA review process is taking, it is possible that the 12 reactors whose current age is more than 35 years, out of the current 48, will not restart. It has already been conceded by utilities that they will consider the decommissioning of two reactors (39 and 40 years respectively) a significant admission in itself.[557]

Again, it is by no means certain that reactors will not operate beyond 40 years. Under existing policy, utilities can apply for plant life extension for an additional 20 years beyond their original 40-year limit.[558] A great deal will depend on how the current batch of safety reviews proceeds during the next 12 months. The replacement of two NRA Commissioners in September 2014, in particular the removal of Kunihiko Shimazaki, a seismologist, considered by the utilities as an obstacle to early completion of safety reviews, and his replacement by Satoru Tanaka, a proponent of continued nuclear power operation[559] with close ties to the utilities[560], demonstrate the Abe government's determination to speed reactor restart.

It also cannot be assumed that all 19 reactors applications currently outstanding with the NRA will restart, with questions and disagreements over seismic issues (including active fault status), and many plants far back in the review and screening process. Even with final approval, and given other unresolved safety issues, there will be as many legal challenges to overcome as there are nuclear power plants, while the majority of public opinion three years after the start of the Fukushima-Daiichi accident remains strongly opposed to nuclear reactor operation. Prime Minister Abe's four predecessors, two from his own party (and one of those his popular mentor), publicly oppose his energy policy, and came together in an unprecedented meeting in July 2014 around this issue.

Two reactors, Shimane-3 and Ohma, had been officially under construction since 2007 and 2010 respectively. Construction had been interrupted after 3/11 but reportedly resumed in Ohma (also spelled Oma) in October 2012. Construction status at Shimane-3 is unclear, but no work resumption has been reported. In 2012, WNISR deleted both reactor projects from its construction list as completion appears unlikely.

---

557 Japan Times, "Retiring Shimane reactor 'an option'", 28 March 2014, see http://www.japantimes.co.jp/news/2014/03/28/national/retiring-shimane-reactor-an-option/#.U5R60SiyRHx, accessed 6 June 2014; and Asahi Weekly, "Kyushu Electric Power president "decision by the fall on Genkai nuclear power plant"", 23-28 April 2014, (in Japanese), see http://www.asahi.com/articles/ASG4L6KP3G4LTIPE02L.html, accessed 6 June 2013.

558 Japan Times, "Risky nuclear loophole", 21 January 2012, see http://www.japantimes.co.jp/opinion/2012/01/21/editorials/risky-nuclear-loophole/#.U0Qq2Y6yT5o, accessed 20 April 2014.

559 Japan Times, "New NRA names revealed", 27 May 2014, see http://www.japantimes.co.jp/news/2014/05/27/national/politics-diplomacy/new-nra-names-revealed/#.U4SrtyiyRHw, accessed 9 June 2014.

560 Asahi Shimbun, "Experts on nuclear panel got funds from power industry", 6 February 2012, see http://ajw.asahi.com/article/behind_news/social_affairs/AJ201202060056, accessed 9 June 2014.

In an unprecedented move, the municipal government of Hakodate, close to the Ohma site in Aomori Prefecture, sued operator J-Power and the central government over the building project. Never before has a Japanese municipality taken legal action to prevent the building of a nuclear power plant. The trial opened on 3 July 2014.[561]

In conclusion, it cannot be predicted with any certainty what the future percentage of electricity in Japan will be nuclear generated. Even with all 19 reactors currently under NRA review restarting within the next two years, the total restored nuclear capacity would be only about 18 GW, a reduction by more than 58 percent compared to four years ago when it was 42.5 GW and 29 percent of Japan's electricity was nuclear generated. Additional reactors are likely to apply for safety review in the coming year, but even returning to a 20 percent share of electricity, given the multiple external factors remains a major challenge.

Pakistan operates three reactors that provided 4.4 TWh and 4.4 percent of the country's electricity in 2013, a slight decline from the historic maxima of the previous year. The load factor—based on Chasnupp-1 and Kanupp—dropped from close to 89 percent to 74 percent. The third unit, Chasnupp-2 supplied by China, came on line only three days after 3/11.

During Chinese Prime Minister Wen Jiabao's visit to Pakistan in December 2010, it was reported that China might build another two 650 MWe reactors in the country.[562] The Pakistan Atomic Energy Commission (PAEC) indicated a target capacity of 8.8 GW with 10 installed units by 2030.[563] Construction of two 315 MWe units started in 2011 at the Chasnupp site with the engagement of China Zhongyuan Engineering as the general contractor and China Nuclear Industry No. 5 as the installer, with finance also coming from China.

The first unit at the Karachi site, KANUPP, a 125 MW CANDU heavy water reactor, was first connected to the grid in October 1971 and is one of the oldest operating reactors in the world. A groundbreaking ceremony was held on 26 November 2013 for the construction of two additional units of 1100 MW each, first of a kind ACP1000 reactors, to be supplied by China National Nuclear Corporation on a turnkey basis.[564] The project has drawn unusually open and direct opposition from political leaders, local officials and independent scientists, in particular because of the untested nature of the technology.[565] The Karachi site is also part of one of the world's most densely populated areas, with 20 million people living in Karachi city, that would make mass evacuation in case of a major accident virtually impossible. Three physicists, well known international experts, have challenged the safety case of the project in a detailed high-profile contribution to *Newsweek Pakistan*.[566]

In the 1980s, Pakistan developed a complex system to illegally access various components for its weapons program on the international black market, including from diverse European sources.[567] Immediately following India's nuclear weapons tests in 1998, Pakistan also exploded several nuclear devices. International nuclear assistance has been practically impossible, given that Pakistan, like India, has not signed the NPT and does not accept full-scope safeguards, and is therefore currently unlikely to be granted the same exception as India to the NSG's export rules. Some Pakistani experts bitterly complain about the "simply unfair" differential treatment under the international non-proliferation regime and consider that "participation in the NSG is essential if Pakistan is to be able to acquire the equipment and expertise needed to build the nuclear plants that will fill this power gap".[568]

On the other hand, according to Pakistan's Alternative Energy Development Board, the country has vast potential resources in wind energy, estimated at 350 GW. In 2013, Pakistan doubled its installed capacity to a still modest 100 MW. In January 2013, the Korean Solar Energy Company launched a large 1 GW solar project in Balochistan that is supposed to help ease power shortages in the region.

---

561 Asahi Shimbun, "Court hears first arguments in Oma nuclear plant lawsuit", 4 July 2014, see http://ajw.asahi.com/article/0311disaster/fukushima/AJ201407040041, accessed 4 July 2014.
562 Spero News, "Nuclear Energy on Agenda as Chinese Premier Visits Pakistan", 17 December 2010.
563 Dawn.com, "Ten Nuclear Power Plants Planned", 12 January 2011.
564 WNN, "Pakistan breaks ground for coastal units", 3 December 2013, see http://www.world-nuclear-news.org/NN-Pakistan_breaks_ground_for_coastal_units-0312134.html, accessed 2 July 2014.
565 NIW, "Opposition Emerges to Karachi Newbuild", 7 February 2014.
566 Pervez Hoodbhoy, et al., "The nuclear shadow over Karachi", Newsweek Pakistan, 17 March 2014.
567 Mycle Schneider, "Nucléaire: Paris, plaque tournante du trafic pakistanais", Politis (Paris), 1989.
568 Zahir Kazmi, "Letter from Pakistan : How an unfair non-proliferation regime undermines nuclear security", Bulletin of the Atomic Scientists, 30 August 2012, see http://www.thebulletin.org/web-edition/op-eds/letter-pakistan-how-unfair-non-proliferation-regime-undermines-nuclear-security, accessed 15 May 2013.

On the Korean Peninsula, the **Republic of Korea** (South Korea) operates 22 reactors that provided 132.5 TWh, (8 percent less than in 2012) or 27.6 percent of the country's electricity in 2013 (down from a maximum of 53.3 percent in 1987). One reactor, Wolsong-1, has not generated any power since 2012 and, according to the new criteria, it was moved to the LTO category. In addition, five reactors are listed as under construction, of which three are scheduled for startup in 2014. South Korea's reactors have shown excellent performance in the past. However, due to persisting component and quality control issues, the annual load factor dropped by 8.6 percent in 2013 to a disappointing 72.1 percent, the level of India.

Less than a month after 3/11, the Korea Electric Power Corporation (KEPCO) presented plans to double installed nuclear capacity to close to 43 GW by 2030 and bring the nuclear share in the power generation to 59 percent.[569] However, observers see a "dramatic political shift against nuclear power in the year since Fukushima".[570] Park Won Soon, Mayor of Seoul, for example, initiated a program entitled "One Less Nuclear Power Plant" with the official target to "save away" through energy efficiency and renewable energy roll-out the equivalent amount of energy generated by a nuclear reactor. After his overwhelming re-election in June 2014, Mayor Park is also a prime candidate for the next presidential elections. In 2013, the Seoul Metropolitan Government appointed a high-level Seoul International Energy Advisory Council (SIEAC), composed of leading international energy experts, to assist in the design of innovative clean energy policy.[571]

Opposition to nuclear power continued to grow during 2013 amongst the general population, with 63 percent of people polled opposing nuclear power.[572]

The Korean Government under President Park Geun-hye, who came into office in December 2012, attempted to support the nuclear industry and to restore public trust after a series of scandals. In 2012, the CEO of Korea Hydro & Nuclear Power (KHNP) was forced to resign over the cover-up of a station blackout at Kori-1 and another diesel generator failure at Yonggwang-2. But this scandal was dwarfed by the subsequent revelations in late 2012 that detailed massive quality control falsification over tens of thousands of items at the nation's nuclear plants.

In January 2013, the Nuclear Safety and Security Commission (NSSC) announced that over the past 10 years, 13,794 units of 561 items with falsified quality certificates have been supplied to KHNP, and 6,949 units of 341 items were found installed in nuclear power plants.[573] Almost all 5,258 safety-related items supplied with falsified documents were replaced under the witness of site investigators. A total of 20 suppliers and 215 cases of quality record falsification had been identified. In May 2013, the scandal widened into safety-class control-command cables. After an anonymous report had tipped off the NSSC, it was confirmed that test reports had been forged and that the test in fact failed under loss-off-coolant-accident 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.[574] 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 (Loss of Coolant Accident) test".[575] Shin-Wolsong-2 was authorized for restart on 25 June 2013[576], 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.[577] Shin-Kori-3 and -4 as well as

[569] Ki Hak Kim, "Fueling the Sustainable Future", 6 April 2011.

[570] NIW, "South Korea: Growing Nuclear Skepticism", 23 March 2012.

[571] SIEAC Members include famous energy analyst Amory B. Lovins, Rocky Mountain Institute and Allan Jones, who has shaped energy policy in London, U.K. and Sydney, Australia. SIEAC is coordinated by Mycle Schneider.

[572] Bloomberg, "South Korea Targets 29 Percent Nuclear Power Reliance by 2035", 10 December 2013, see http://www.bloomberg.com/news/2013-12-10/south-korea-targets-29-percent-nuclear-power-reliance-by-2035.html, accessed 18 June 2014.

[573] NSSC, "NSSC to Announce Investigation Results and Preventive Action Plans", 9 January 2013, see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=3884&pager.offset=30&board_no=501, accessed 18 June 2014.

[574] WNA, "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 2014.

[575] NSCC, "NSSC Approved The Resumption of Shinkori Unit 1.2 and ShinwolsongUnit 1", 2 January 2014, see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=6240&pager.offset=10&board_no=501, accessed 18 June 2014.

[576] WNA, "Another Korean reactor cleared for restart", 27 June 2013, see http://www.world-nuclear-news.org/RS-Another_Korean_reactor_cleared_for_restart-2706135.html, accessed 18 June 2014.

[577] 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 2014.

Shin-Wolsong-2, all under construction, also had falsified quality-control documents and needed to replace the incriminated cables.[578] 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.

The political consequences of these scandals led to a government appointed study group recommending in October 2013 a reduction in projected nuclear electricity share of between 22–29 percent by 2035.[579] 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."[580]

In the end, the government draft energy paper released in December 2013 opted for the higher 29 percent option by 2035, which compares with the 30 percent achieved in 2012 and the previous long term plan of 2008 that had stated the intention to supply 41 percent of electricity from nuclear power by that time.[581] However, the government remained committed to 43 GW by 2035, an increase from the 36 GW expected to have been installed by 2024. The increase in capacity is premised on projections for continuous growth of electricity demand during the coming years with an average annual increase of 1.9 percent.[582] The energy plan did not change the 2008 renewable energy target of 11 percent by 2035.

In late January 2014, the Government approved the allocation of US$7 billion for the construction of two additional APR1400 reactors, the first approved since 3/11.[583] The announcement came after the U.S. NRC had decided in December 2013 to reject KHNP's design license certification application for the APR1400, two of which are under construction at Shin Kori-3 and-4 in Korea (as well as two reactors at Barakah in the UAE).[584] The reason cited by the NRC was insufficient information in key areas including "software common cause failures of non-safety related control systems" and critical characteristics of the safety I&C system platform. It also lacked sufficient detail for some specific technical issues, including reactor coolant pump design, potential corrosion of some internal reactor parts, radioactive waste management and radiation protection."[585] The NRC also noted that KHNP had failed to submit technical reports in four areas, including fuel seismic response evaluation and spent fuel criticality analysis. Negotiations had been underway since 2010 on the application.

Despite the government's commitment to continuing nuclear power growth, public opposition has also continued. For example, all political candidates in the recent June elections in Pusan called for the closure of the Kori unit 1 reactor, which has been plagued with safety failures, and whose license expires in 2017.[586]

Taiwan operates six reactors at three sites Chinshan, Kuosheng and Maanshan, which provided 39.8 TWh in 2013 after generation peaked at 40.4 TWh in 2011. Nuclear generated electricity provided 19.1 percent of the country's electricity in 2013 (compared with its maximum share of 41 percent in 1988).

---

[578] NSSC, "NSSC Confirms Fake Test Reports of Safety-Class Control Cables", 29 May 2013, see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=3884, accessed 18 June 2014.

[579] 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 2014.

[580] Ibidem.

[581] 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-idUSBREA0D06G201401, accessed 18 June 2014.

[582] IEA, "International Energy Outlook 2013", 25 July 2013, see http://www.eia.gov/forecasts/ieo/electricity.cfm, accessed 19 June 2014.

[583] Wall St Journal, "South Korea Approves $7 Billion Nuclear Project Move Comes Despite Public Pressure to Curb Use of Nuclear Energy", 29 January 2014, see http://online.wsj.com/news/articles/SB10001424052702303519404579350171389658490, accessed 19 June 2014.

[584] NRC, "Korea Hydro And Nuclear Power Co., Ltd., And Korea Electric Power Corporation – Non-Acceptance Of The Application For Standard Design Certification Of The APR1400", 19 December 2013, see http://pbadupws.nrc.gov/docs/ML1335/ML13351A417.pdf, accessed 19 June 2014.

[585] Nuclear Engineering International, "NRC decides not to start review of Korean APR-1400 design", 2 January 2014, see http://www.neimagazine.com/news/newsnrc-decides-not-to-start-review-of-korean-apr-1400-design-4154413, accessed 5 April 2014.

[586] 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 3 June 2014.

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 and still present unresolved safety concerns.[587] According to the Atomic Energy Council, as of end of March 2014, Unit 1 of Lungmen construction was 97.7 percent complete,[588] while Unit 2 was 91 percent complete. The plant is estimated to have cost US$9.9 billion so far.[589] In December 2013, the Taipei high court ruled against Taipower's position and ruled that changes made to the design of structures, components equipment and systems at the Lungmen plant were related to safety.[590] The court upheld a fine imposed on Lungmen owner, Taipower, by the Atomic Energy Council after finding the utility violated the country's atomic law as the changes were made without consultation with General Electric (GE). Design changes to the reactors were agreed between Taipower and GE after a three year dispute over construction delay costs during 2007–2010.

After multiple delays, rising costs, and large-scale public and political opposition, on 28 April 2014, Premier Jiang Yi-huah announced that Lungmen Unit 1 will be mothballed after the completion of safety checks, while work on the second unit at the site will stop. Jiang said that the government would hold a "National Energy Conference" before September 2014 to formulate policies to ensure future electricity supplies. Jiang refused to state directly that the project had been "halted." However, with the official freeze of construction, WNISR took the units off the listing.

Taipower, according to the government, would terminate existing contracts that involve Lungmen Unit 2 and preserve documents concerned with its design, engineering, construction and quality.[591] The Chinese Nationalist Party (KMT), the ruling party in Taiwan, still wishes to retain the option of starting the Lungmen plant. The estimated costs of "sealing" Lungmen was given as between T$1 and T$2 billion (US$ 33–66 million), which would be needed to maintain the reactors, not including cost of completing the reactors or restart.

The future of the Lungmen plant could be determined by a national referendum announced by the government but with no date. There are, however, doubts over the conditions required for referenda. The referendum act of 2003 requires more than 50 percent of all eligible voters to take part and that over half of the votes agree to the proposition. None of the six past national referenda has passed, causing the political opposition and anti-nuclear groups to suspect that putting Lungmen to a referendum is a means of proceeding to operation. In the last year, opinion polls have shown that over half the population does not believe Lungmen is safe, while the KMT mayors of New Taipei and Taipei cities, as well as KMT lawmakers, have openly expressed reservations.[592] Particular concerns at Lungmen relate to vulnerability to earthquakes and tsunamis. The opposition Democratic Progressive Party (DPP) has called for a change in the terms of a referendum to requiring a simple majority,[593] and an assessment on the feasibility of converting the reactors to LNG.[594]

It is unclear what the impact of the Lungmen delays, or possible final cancellation will have on the future of the Chinshan nuclear plant. In November 2011, the Ministry of Economic Affairs' Bureau of Energy announced that the two reactors at Chinshan (or Jinshan), Taiwan's oldest (grid connection 1977 and 1978), would be shut down as soon as the Lungmen reactors came online, with no extension to their 40-year lifetime.[595] That would mean the shutdown of the operating units between 2016 and 2025. In 2011, the Government had presented a new energy strategy to "steadily reduce nuclear dependency, create a low-carbon green energy environment and gradually move towards a nuclear-free homeland".

---

587 Asia Pulse, "Minister Casts Doubt on Viability of 4th Taiwan Nuclear Plant", PennEnergy, 15 March 2012.

588 Planning Department Atomic Energy Council, "Status and Challenges of Nuclear Power in Taiwan", April 2014, see http://www.aec.gov.tw/english/whatsnew/files/20140506-5.pdf, accessed 15 June 2014.

589 WNA, "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 15 June 2014.

590 Nucnet, "Lungmen Design Changes Did Not Affect Safety, Taipower Says", 24 January 2014, see http://www.nucnet.org/all-the-news/2014/01/24/lungmen-design-changes-did-not-affect-safety-taipower-says, accessed 15 June 2014.

591 Nucleonics Week, "Taiwan lawmakers seeks answers on plans to 'seal' Lungmen-1", 8 May 2014.

592 Taiwan Today, "Getting Lungmen referendum right", 27 February 2013, see http://www.taiwantoday.tw/ct.asp?xitem=202544&CtNode=426, accessed 15 June 2014.

593 WNA, "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 15 June 2014.

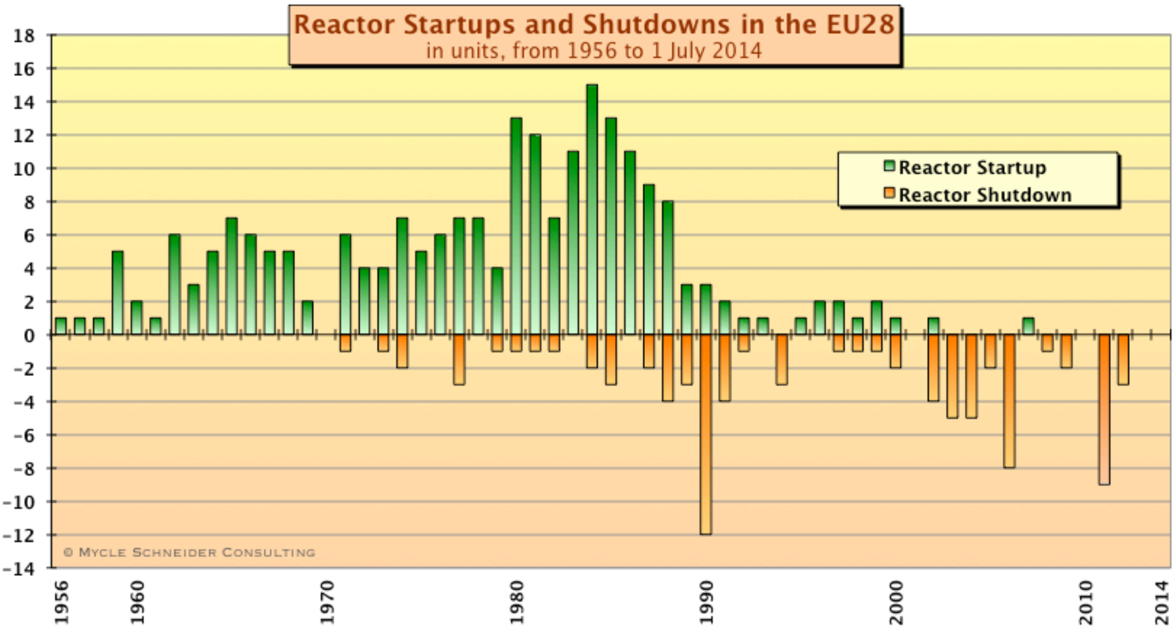
594 Nucleonics Week, "Taiwan lawmakers seeks answers on plans to 'seal' Lungmen-1", 8 May 2014.

595 Bureau of Energy, "Ensure Nuclear Security—Steadily Reduce Nuclear Dependency—Create a Low-carbon Green Energy Environment & Gradually Move Towards a Nuclear-free Homeland", Ministry of Economic Affairs, 3 November 2011.

European Union (EU28) and Switzerland

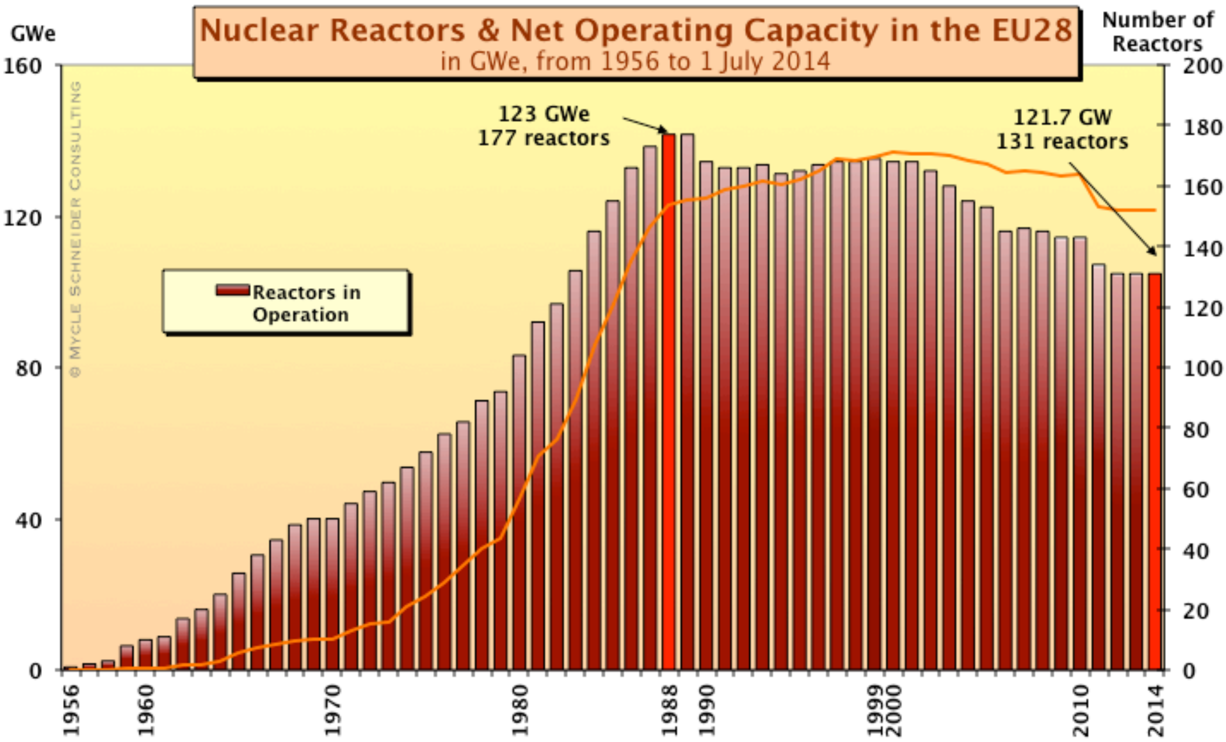
The European Union 28 member states (EU28)[596] have gone through three nuclear construction waves, two small ones in the 1960s and the 1970s and a larger one in the 1980s (mainly in France). The region has not had any significant building activity since the 1990s. (See Figure 31.)

Figure 31: Nuclear Reactors Startups and Shutdowns in the EU28, 1956–2014



Source: IAEA-PRIS, MSC, July 2014

Figure 32: Nuclear Reactors and Net Operating Capacity in the EU28, 1956–2014



Source: IAEA-PRIS, MSC, June 2014

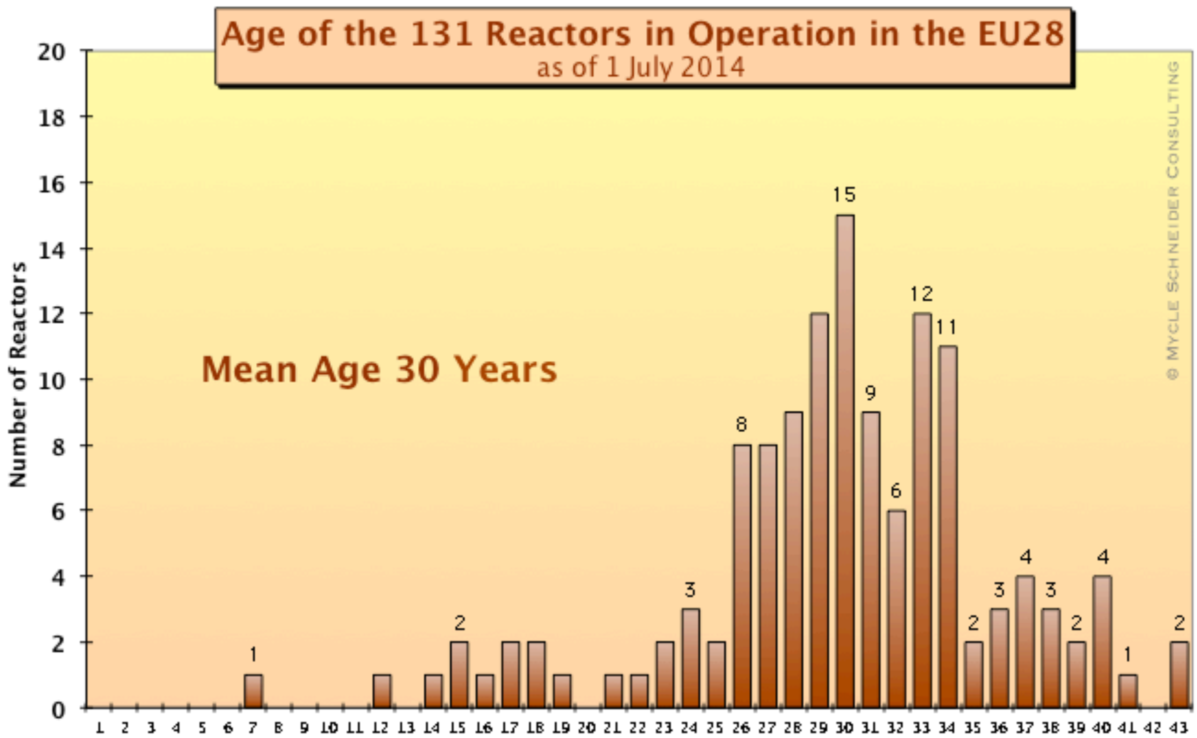
[596] Croatia has joined the EU on 1 July 2013. Since Croatia does not operate nuclear power plants, this changes statistically very little in this context.

In July 2014, half of the 28 countries in the enlarged EU operated 131 reactors—about one-third of the world total—12 fewer than before the Fukushima events and one-quarter below the historic maximum of 177 units in 1989. (See Figure 32.) The vast majority of the facilities, 112 or 85.5 percent, are located in eight of the western countries, and only 19 are in the six newer member states with nuclear power.

In 2013, nuclear power produced 27 percent of the commercial electricity[597], identical to 2012 and down from 31 percent in 2003.[598] Nearly half (49 percent) of the nuclear electricity in the EU was generated by one country, France.

With the lack of new reactor construction, the average age of the EU's reactors now stands at 30 years (see Figure 33).

Figure 33: Age Pyramid of the 131 Nuclear Reactors Operated in the EU28



Sources: IAEA-PRIS, MSC, July 2013

Western Europe

In Western Europe (EU15), as elsewhere, the significance of electricity in the overall energy picture, as well as the role of nuclear power, is often over-estimated. In 2012, electricity accounted for only about 22 percent of the EU15's commercial primary energy consumption.

As of July 2014, the EU15 was home to 112 operating nuclear power reactors, or 45 units fewer than in the peak years of 1988/89.

Two reactors are currently under construction in the older member states EU15, one in Finland (Olkiluoto-3) and one in France (Flamanville-3). Both projects are years behind schedule and billions over budget (details are discussed elsewhere in the report). These are the first construction starts in the region since building began on the French Civaux-2 unit in 1991. 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.

The following section provides a short overview by country (in alphabetical order).

[597] Eurostat, "Electricity Statistics 2013", April 2014, see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Electricity_Statistics_2013.xls, accessed 14 June 2014.

[598] EURELECTRIC, "Key Statistics – Edition 2013", 7 June 2013.

Belgium operates seven reactors and has the world's second highest share of nuclear in its power mix, at 52.1 percent in 2013 (down from a maximum of 67.2 percent in 1986). The nuclear plants achieved their highest generating level of 46.7 TWh in 1999 compared to 40.6 TWh in 2013. In 2002, the country passed nuclear phase-out legislation that required the shutdown of the nuclear plants after 40 years, meaning that (based on their start-up dates) plants would be shut down between 2015 and 2025. On 13 October 2009, the then Government issued a 10-page general policy statement that included one reference to nuclear power: "The government has decided to postpone by 10 years the first sequence of the phase-out of nuclear power."[599] However, that government was voted out in June 2010, just prior to voting on supporting legislation to delay the phase-out. Following Fukushima and the establishment of a new Government, the phase-out legislation was left in place, even if the operator GDF-Suez was lobbying hard to postpone it via an extension of "at least 10 years".[600]

In December 2013, the phase-out legislation was finally amended,[601] which resulted in the operator's being granted a 10-year extension of its Tihange-1 reactor, while an additional operating tax was introduced that effectively removed about 70 percent of its profit.[602] The other shutdown dates were confirmed (see Table 9) and the Art. 9, in the existing legislation, that enabled continual operation as a result of security of supply concerns, was deleted.

Table 9: Closure Dates for Belgian Nuclear Reactors 2015-2025

Reactor Name (type, net capacity)	Owner/Operator	First Grid Connection	End of license (latest closure date)
Doel-1 (PWR, 433 MW)	Electrabel/GDF-Suez	1974	15 February 2015
Doel-2 (PWR, 433 MW)	Electrabel/GDF-Suez	1975	1 December 2015
Doel-3 (PWR, 1006 MW)	Electrabel/GDF-Suez	1982	1 October 2022
Tihange-2 (PWR, 1008 MW)	Electrabel/GDF-Suez	1982	1 February 2023
Doel-4 (PWR, 1039 MW)	Electrabel/GDF-Suez	1985	1 July 2025
Tihange-3 (PWR, 1046 MW)	Electrabel/GDF-Suez	1985	1 September 2025
Tihange-1 (PWR, 962 MW)	Electrabel/GDF-Suez	1975	1 October 2025

Note: PWR=Pressurized Water Reactor

Sources: Belgian Law of 18 December 2013; Electrabel/GDF-Suez, 2014[603].

In the summer of 2012, the operator identified an unprecedented numbers of 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 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".[604]

An independent assessment[605] concluded that "FANC should obtain—before authorizing the restart of the affected reactors—absolute certainty that the flaws will not lead to the failure of the reactor pressure vessel. This is obviously not the case at present and will not be the case even if the

[599] Prime Minister of Belgium, "Déclaration du gouvernement relative à sa politique générale", 13 October 2009, see http://archive.vanrompuy.belgium.be/files/Statepremier.pdf, accessed 19 July 2014.
[600] Gérard Mestrallet, et al., "Nuclear in Belgium: recent developments", GDF Suez, 4 November 2011.
[601] 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.
[602] Melchior Wathelet, Energy Minister, "Avec la réserve stratégique, Melchior Wathelet finalise l'exécution de son plan", 16 December 2013, see http://wathelet.belgium.be/fr/2013/12/16/avec-la-reserve-strategique-melchior-wathelet-finalise-lexecution-de-son-plan/, accessed 3 July 2014.
[603] Electrabel/GDF-Suez, "News from the nuclear plants", see https://www.electrabel.com/en/corporate/nuclear-power-plant-belgium/doel-tihange/news, accessed 3 July 2014.
[604] AIB-Vinçotte, "Synthesis Report Doel165", 28 January 2013.
[605] Ilse Tweer, "Flawed Reactor Pressure Vessels in Belgian Nuclear Plants Doel-3 and Tihange-2", Materials Scientist, 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 1 June 2013.

complementary tests should prove positive". However, on 17 May 2013, FANC issued a statement saying that it "considers it safe to restart the Doel-3 and Tihange-2 reactor units".[606] The units restarted in spite of the serious concerns by a range of scientists, and reached full capacity respectively on 9 and 11 June 2013.

On 25 March 2014, Electrabel/GDF-Suez announced the immediate shutdown of the Doel-3 and Tihange-2 reactors, declared as "anticipating planned outages", respectively over one and two months ahead of schedule.[607] 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". Additional results were expected by 15 June 2014 but on 1 July 2014, 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.[608]

The fate of Doel-3/Tihange-2 is uncertain and has potentially serious generic implications for the aging of nuclear power plants.

Finland currently operates four units that supplied a record 22.7 TWh or 33.3 percent of its electricity in 2013 (down from a maximum of 38.4 percent in 1986). The country also achieved the world's second highest annual load factor for 2013 (93.8 percent) and holds the same position for the lifetime load factor (87.3 percent), both behind Romania. Finland is one of the few countries that has adopted different nuclear technologies and suppliers, as two of its reactors are PWRs built by Russian contractors, at Loviisa, while two are BWRs built by ABB 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 comprising 66 percent AREVA and 34 percent Siemens[609], is building a 1.6 GW EPR under a fixed-price turn-key contract with the utility TVO—an arrangement that AREVA top managers have admitted in private talks they would "never do again". The project was financed essentially on the balance sheets of the country'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 "fixed price" but "take-or-pay contract".

Construction started in August 2005 at Olkiluoto on the west coast. The project (Olkiluoto-3 or OL3) is about nine years behind schedule and is now 280 percent over budget (see also Economics Chapter). According to media reports—there is no recent TVO estimate (see hereunder)—the plant is currently expected to start up in 2018 or later[610] and the cost estimate has been raised to €8.5 billion (US$11.6 billion). It remains unclear who will cover the additional cost: the vendors and TVO blame each other and are in litigation. "TVO is not pleased with the situation and repeating challenges with the project scheduling" and admits that "the plant completion may be further delayed".[611] 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 several dozen nationalities made communication and oversight extremely complex.

The repeated construction delays of OL3 are a blow not only to power planning by the utility and to the 60 large customers involved in the project consortium, but also to the Finnish Government. OL3 was also part of the government's strategy to achieve its target of a zero-percent increase of 1990 emissions under the Kyoto Protocol. The lack of an operational OL3 has forced Finland to use emissions trading to compensate for the GHGs produced in the country. And of course TVO has had to arrange for replacement power at prevailing prices to cover the late unit's delivery shortfall.

---

[606] 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 1 June 2013.
[607] Electrabel/GDF-Suez, "Anticipating planned outages of Doel 3 and Tihange 2 reactors", 25 March 2014, see https://www.electrabel.com/en/corporate/article?article=14-03-25-anticipating-planned-outages-doel3-tihange2-reactors, accessed 3 July 2014.
[608] 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 3 July 2014.
[609] Siemens quit the consortium in March 2011 and announced in September 2011 that it was abandoning the nuclear sector entirely.
[610] Esmerk, "Finland: OL3 construction site quieting down is normal at this stage, TVO says", 28 February 2014.
[611] TVO, "Information about the start-up of Olkiluoto 3 nuclear power plant unit", Press Release, 11 February 2013, see http://www.tvo.fi/news/32, accessed 1 June 2013.

In late February 2013, TVO's Board of Directors proposed a new shareholder loan commitment of €300 million (US$410 million) to its shareholders in order to cope with financing costs and maintain a minimum 25 percent share of shareholders' capital or loan.[612] The 2013 Annual Report highlights the extent of the deterioration of the relationship between TVO and AREVA and the technical problems that remain when it stated:[613]

> In February 2014 TVO announced that it had not received the overall schedule update of the OL3 project from the Supplier. Therefore TVO does not provide an estimate of the start-up time of the plant unit at the moment. TVO had required the Supplier, who is in charge of the project schedule, to update the overall schedule and to provide a clarification of the measures needed to ensure proper progress to complete the plant unit. Information about the start-up date of electricity production of the OL3 plant unit is pending the finalization of the Supplier's schedule clarification.

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".[614] The decision was ratified by the Finnish Parliament on 1 July 2010. But already significant delays have emerged. In late March 2012, TVO invited five reactor vendors—AREVA, GE Hitachi (GEH), Korea Hydro and Nuclear Power (KHNP), Mitsubishi, and Toshiba—to submit bids, which were transmitted in January 2013. Then, 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".[615] The Government has said that it hopes to be able to give its view to this request in early autumn 2014 and that any extension will not be as long as the originally approved five years.[616]

In parallel, Fortum Power is 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—which was fnarrowed 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.[617] In August 2012, a group of minority stakeholders left the Fennovoima consortium, followed by E.ON, which sold its 34 percent share in April 2013 to Voimaosakeyhtiö SF, a consortium of 60 companies and municipalities that already held the remaining 66 percent. Fennovoima ended the formal tender process in February 2013, inviting Toshiba to direct negotiations over a 1300 MW ABWR design and effectively dropping the EPR from the competition. In addition, 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".[618] However, while Toshiba and AREVA were explicitly mentioned in government and parliament planning authorizations, Rosatom was not. Despite this, in March 2014 Rosatom, through a subsidiary company ROAS Voima Oy, completed the purchase of 34% of Fennovoima, the price of which was not disclosed[619], and then in April 2014 a "binding decision to construct" an AES-2006 reactor was announced. It is said that the Ministry of Employment and the Economy of Finland is now preparing a proposal for Fennovoima's application to supplement the Decision-in-Principle. If the Government approves the supplement, the application will proceed to Parliamentary ratification.[620]

[612] TVO, "TVO Board of Directors proposes new shareholder loan commitment to its shareholders", 27 February 2013, see http://www.tvo.fi/news/39, accessed 1 June 2013.
[613] TVO, "Annual Report 2013", 2014, see http://www.tvo.fi/uploads/Verkkovuosikertomus2013/pdfjulkaisut/TVO_Annual_Report_2013.pdf, accessed 19 July 2014.
[614] TVO, "Construction of a Nuclear Power Plant Unit at Olkiluoto – General Description – OL4", August 2008, see www.tvo.fi/www/page/2840/.
[615] TVO, "TVO applies for an extension to submit construction license application of Olkiluoto 4 plant unit", Press Release, 20 May 2014.
[616] Ministry of Employment and the Economy, "Minister Vapaavuori: TVO must demonstrate sufficient certainty of implementation for OL4 project", Press Release, 20 May 2014, see https://www.tem.fi/en/energy/press_releases_energy?89521_m=115226, accessed 19 July 2014.
[617] Fennovoima, "Fennovoima received bids for nuclear power plant", Press Release, 31 January 2012.
[618] Rosatom, "Fennovoima invites ROSATOM to direct negotiations", Press Release, 5 April 2013, see http://www.rosatom.ru/en/presscentre/news/2df4ec804f260b62bd2afd2c0ad82648, accessed 1 June 2013.
[619] Fennovoima, "Rosatom acquired 34% of Fennovoima", Press Release, 27 March 2014.
[620] Fennovoima, "Owners made final commitment to Fennovoima", Press Release, 15 April 2014.

France Focus

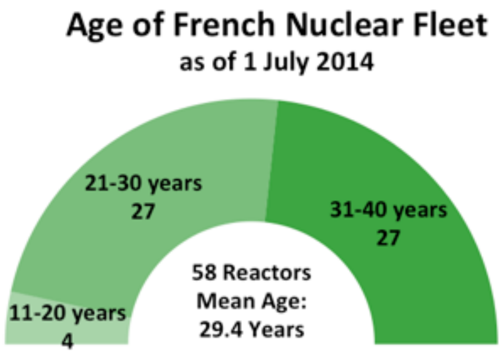
France's nuclear industry is seen to be a world leader and is exceptional in many ways. In 1974, the Government launched the world's largest public nuclear power program in response to the oil crisis in 1973. But after four decades of continual support for nuclear power, the Government under President François Hollande has initiated a significant shift in energy policy.

In 2013, France's 58 reactors[621] produced 406 TWh or 73.3 percent of the country's electricity, both declining for the second consecutive year. In contrast, in 2005, 431.2 TWh of nuclear electricity was produced providing 78.5 percent of the total. The 2013 annual load factor dropped almost another point to 72.7 percent, about the same level as India (72.1 percent), and well below the global average of 80 percent (excluding Japan).

France has a significant base load overcapacity, primarily nuclear power plants, that has led to the "dumping" of electricity on neighboring countries and has encouraged the development of highly inefficient thermal applications of electricity— such as electric heating. This has resulted in a high winter peak load of over 100 GW (102 GW in February 2012), compared to a total installed capacity of 128 GW[622]. While France remains a net electricity exporter, contrary to expectations, it has been a significant net *importer* of power from Germany, 9.8 TWh in 2013, for a number of years.

The average age of the reactors is now about 30 years (29.4 years in mid-2014, see Figure 34), which raises questions about the investment needed to enable them to continue operating, as aging reactors increasingly need parts to be replaced. According to an independent assessment,[623] lifetime extension beyond 40 years will probably be very expensive (between €1 billion and €4 billion (US$1.4–5.5 billion) per reactor, depending on the safety level to be achieved).

Figure 34. Age Distribution of French Nuclear Fleet (by Decade)



Sources: IAEA-PRIS, MSC, 2014

These investments for lifetime extensions will need to be balanced against factors such as: the already excessive nuclear share in the power mix; the shutdown of the EURODIF gaseous diffusion uranium enrichment plant and the subsequent significant reduction in demand (by two to three reactor equivalents); and energy efficiency and renewable energy production targets on both EU and French level. 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. (See also the section on Lifetime Extension in the Economics chapter).

If the French Government and state controlled utility Électricité de France (EDF) opted to proceed with the construction of a new unit, then this is not due to lack of capacity but because the industry faces a serious problem of maintaining nuclear experience and competence. In December 2007, EDF started construction of Flamanville-3 (FL3). The FL3 site has encountered quality-control problems with basic concrete and welding similar to those at the OL3 project in Finland, which started two-and-a-half years earlier. The French project is now at least four years late and not expected to start commercial operation before 2016. The cost has more than doubled since construction started to

[621] All pressurized water reactors, 34 x 900 MW, 20 x 1300 MW, and 4 x 1400 MW.

[622] RTE, "Bilan électrique 2013", January 2014.

[623] Yves Marignac, "L'échéance des 40 ans pour le parc nucléaire français : Processus de décision, options de renforcement et coûts associés à une éventuelle prolongation d'exploitation au-delà de 40 ans des réacteurs d'EDF", WISE-Paris, report commissioned by Greenpeace France, February 2014, 169 p., see http://www.greenpeace.org/france/PageFiles/266521/greenpeace-rapport-echeance-40-ans.pdf, accessed 7 June 2014.

€8.5 billion (US$11.6 billion) in December 2012, €2 billion (US$2.7 billion) more than in 2011—"terrible publicity", as trade journal *Usine Nouvelle* noted.[624]

In addition, there have been major difficulties with large investment projects—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 €35.5 billion (US$49 billion) debt, as of the end of 2013, and increasing operational costs, estimated by the national Energy Regulatory Commission (CRE) to be increasing 4.5 percent annually since 2007. In 2012, electricity tariffs did not cover the costs, which created a loss of €1.5 billion (US$2 billion).[625] In fact, the French Court of Accounts concluded that the average nuclear generating cost, which in 2010 stood at €49.5/MWh (US$67.5/MWh) has increased to €59.8/MWh (US$81.7/MWh) in 2013, a 20.6 percent increase in just three years (16 percent increase in constant $€_{2010}$).[626] That does not include upgrading for planned life time extensions and additional post-3/11 (post-Fukushima) safety improvements requested by the Nuclear Safety Authority. While power prices increase, which are expected to reach around 30 percent between 2012 and 2017, will help fund the necessary investments, alternative energy suppliers and resources will thereby become more competitive.[627]

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 over a five-year period up to 2017. 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".[628]

AREVA, probably the largest nuclear builder in the world, filed losses for the third year in a row, with €2.5 billion (US$3.4 billion) losses in 2011, €100 million (US$137 million) in 2012 and €500 million (US$683 million) in 2013. In December 2011, Standard & Poor's downgraded AREVA to "BBB-" rating as well as its stand-alone credit profile of bbb-".[629] It has not changed since. AREVA's share price had plunged in 2012 by 88 percent of its peak 2007 value, while EDF shares had lost up to 85 percent of their value over the same period, hitting bottom in January 2013. Both sets of share values have risen since, but remain far below the performance of the national indicator CAC40 that gives the average development of the 40 largest French companies listed on the stock market. In December 2012, Moody's downgraded EDF's perspective from stable to negative. Fitch Ratings placed EDF on negative outlook on 1 July 2013, "as the electricity tariff rises were considered too low to maintain a level of indebtedness consistent with an A+ rating".[630]

France also operates many other nuclear facilities, including uranium conversion and enrichment, fuel fabrication, and plutonium facilities. France and the United Kingdom are the only countries in the EU that engage in reprocessing, or separating plutonium from spent fuel. The U.K. has announced it will abandon reprocessing in the near future. France's two La Hague facilities are licensed to process 1,700 tons of fuel per year; however, all significant contracts with foreign clients have finished. The La Hague operator AREVA NC therefore depends entirely on the domestic client EDF for future business, yet reprocessing's high cost burdens the already financially stressed EDF. Consequently, the two majority state-owned companies EDF and AREVA continue to fight over several strategic issues:

[624] 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 1 June 2013.

[625] Commission de Régulation de l'Énergie, "Analyse des coûts de production et de commercialisation d'EDF dans le cadre des tarifs réglementés de vente d'électricité", 4 June 2014.

[626] Cour des comptes, "Le coût de production de l'électricité nucléaire—Actualisation 2014", Communication à la Commission d'Enquête de l'Assemblée Nationale, May 2014.

[627] In 2017, Enercoop, a 100-percent renewable power provider that used to be the most expensive distributor in France but which has never increased its tariffs, will sell power at a lower price than nuclear EDF. While the current Energy Minister has so far refused to grant any significant rate increase in 2014, the measure is only on-hold, since it is illegal for EDF to sell electricity at rates that does not cover its costs.

[628] EDF, "Les grands chantiers du nucléaire civil – Le 'grand carénage' du parc nucléaire de production d'EDF", 14 January 2014.

[629] According to Standard & Poor's (S&P) credit rating categories, BBB- is the lowest S&P investment grade. If S&P did downgrade AREVA by one additional notch, it would slip into the junk bond category. S&P points out that AREVA's current rating incorporates three notches of uplift above the company's SACP [Stand-Alone Credit Profile] for "extraordinary state support". In other words, AREVA's SACP of bb- is already "junk" and just one notch off "highly speculative".

[630] EDF, "Reference Document 2012", 5 April 2013, see http://press.edf.com/fichiers/fckeditor/Commun/Finance/Publications/Annee/2014/ddr2013/EDF_DDR2013_va.pdf, accessed 4 July 2014.

follow-up agreements on reprocessed uranium conversion, uranium enrichment, reprocessing, and plutonium fuel fabrication, as well as the overall industrial strategy.

The report of a National Assembly Enquiry Committee on the "Past, Present and Future Costs of Nuclear Power", in its final recommendations, raised "concerns about the development of the costs of nuclear power", called on the government to define a clear energy policy framework and requested a pluralistic assessment of the scenarios providing the basis for planning of the future electricity generation mix.[631]

The current Government under President Hollande proposes a radical change in direction on nuclear power from not only the previous administration under Nicolas Sarkozy, but also with all recent Governments. For the first time since 1974, a French Administration is drafting legislation that is breaking with the four-decades-old "tout électrique—tout nucléaire" dogma. The 189-page draft Energy Bill is expected to be adopted by the Council of Ministers before the end of July 2014 and then voted on before the end of the year[632]. It proposes:

- The capping of the installed nuclear capacity at the current level. This means that before the reactor under construction in Flamanville can start up, an equivalent capacity has to be shut down (probably the two Fessenheim units, the oldest reactors in France).
- The reduction of the nuclear energy share in electricity generation to 50 percent by 2025 (from about 75 percent now).
- The increase of the renewable energy share in electricity generation to 40 percent by 2030 (from 18.6 percent now, of which two thirds are large-scale hydro).

Post-3/11 international attention has focused very much on the German nuclear phase-out decision and its ambitious *Energiewende*. The new French targets—if they get voted into law—would constitute a much more radical change from past strategies than the German "turnaround".

Four days after 3/11, **Germany**'s conservative and pro-nuclear Government decided to shut down eight of its fleet of 17 reactors. Originally for a three-month period, the closure of almost half of the German reactors turned out to be permanent. Nuclear power plants still generated 92.1 TWh net in 2013—31 percent less than in the pre-3/11 year 2010—and provided 15.4 percent of the electricity (gross)[633] in the country (down from the historic maximum of 30.8 percent in 1997). Renewables provided 25.3 percent of national electricity *consumption*. Nuclear power contributed 7.6 percent of primary energy consumption in Germany, vs. 11.5 percent for renewables in 2013.[634]

On 14 March 2011, Chancellor Angela Merkel abruptly announced putting plant life extension plans on hold, and initiated a major re-shift of the country's nuclear policy. On 6 June 2011 the Government passed far-reaching energy transition legislation, which passed the Bundestag on 31 July 2011 almost by consensus, and came into force on 6 August 2011. Key characteristics include:

- The operating licenses will expires once the production credit is used up and at the latest according to Table 10. 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, whether new or existing. Economy and Energy Minister Sigmar Gabriel declared:

[631] François Brottes (Président), Denis Baupin (Rapporteur), "Rapport fait au nom de la Commission d'Enquête relative aux coûts passés, présents et futurs de la filière nucléaire (…)", 5 June 2014, see http://www.assemblee-nationale.fr/14/pdf/rap-enq/r2007-tI.pdf, accessed 4 July 2014.

[632] Ministère de l'écologie, du développement durable et de l'énergie, "Projet de loi de programmation pour un nouveau modèle énergétique français", 22 June 2014.

[633] Compared to 25.5% lignite, 24.1% renewables, 19.4% coal, 10.6% natural gas, 1% oil, see AGEB, "Bruttostromerzeugung in Deutschland von 1990 bis 2013 nach Energieträgern", June 2014, see http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=20140207_brd_stromerzeugung1990-2013.pdf, accessed 5 July 2014.

[634] Compared to 33.4% for oil, 22.3% natural gas, 12.8% coal, 11.7% lignite and 11.5% renewables, see AGEB, "Witterung treibt Energieverbrauch", 18 March 2014.

> Germany said goodbye to nuclear energy because it is intrinsically linked to considerable, non-controllable risks. These risks exist in foreign countries the same way. Therefore, it is logical that we do not support nuclear power plants in foreign countries in the future via Hermes guarantees.[635]

In March 2014, utility E.ON announced its intention to shut down its Grafenrheinfeld plant in May 2015, seven months earlier than required by law. Because of "lacking profitability", the premature closure would be "unavoidable, also in the interest of the shareholders of the company"; E.ON argued that the particular weight of the German nuclear fuel tax was unbearable considering the short remaining lifetime of the reactor.[636]

Table 10: 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[637]	1976	
Isar-1 (BWR, 878 MW)	E.ON	1977	
Krümmel (BWR, 1346 MW)	KKW Krümmel[638]	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
Gundremmingen-B (BWR, 1284 MW)	KKW Gundremmingen[639]	1984	31 December 2017
Philippsburg-2 (PWR, 1402 MW)	EnBW	1984	31 December 2019
Brokdorf (PWR, 1410 MW)	E.ON/Vattenfall[640]	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[641]	1988	
Neckarwestheim-2 (PWR, 1310 MW)	EnBW	1989	

Notes: PWR=Pressurized Water Reactor; BWR=Boiling Water Reactor

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

The German nuclear phase-out decision has generated widespread interest from other countries and has led to a number of unfounded claims, such as that 'Germany would have to replace nuclear electricity through increased coal consumption or nuclear power imports from France'. In fact, Germany made notable progress in energy efficiency, and gross electricity consumption decreased by 2.9 percent between 2010 and 2013, while renewable energy generation increased by 45 percent over

[635] Bundesministerium für Wirtschaft und Energie, "Gabriel: Keine Hermesdeckungen mehr für Nuklearanlagen im Ausland", 12 June 2014, see http://www.bmwi.de/DE/Presse/pressemitteilungen,did=642020.html, accessed 5 July 2014.
[636] E.ON, "E.ON nimmt Kernkraftwerk Frafenrheinfeld vor Ende der Laufzeit außer Betrieb", 29 March 2014, see http://www.eon.com/de/presse/news/pressemitteilungen/2014/3/28/eon-nimmt-kernkraftwerk-grafenrheinfeld-vor-ende-der-laufzeit-ausser-betrieb.html, accessed 5 July 2014.
[637] Vattenfall 66,67%, E.ON 33,33%.
[638] Vattenfall 50%, E.ON 50%.
[639] RWE 75%, E.ON 25%.
[640] E.ON 80%, Vattenfall 20%.
[641] RWE 87,5%, E.ON 12,5%.

the same period and in 2013 represented 24.1 percent in the power generation mix and covered 25.3 percent of national electricity consumption.[642]

However, as in other countries, cheap coal prices on the world market (mainly because efficiency, gas, and renewables displaced so much coal from the U.S. market), coinciding with spiking natural-gas prices and a collapsed EU carbon market, led to perverse effects: while German power production from natural gas plants dropped by 25 percent during 2010–2013, lignite plants boosted production by 10 percent over the same period and coal plants by 4 percent. These effects, however, are expected to be brief and temporary. And the coal uptick, particularly in 2013, was not driven by domestic demand, since efficiency and renewables were both rising; rather, it was entirely to serve record German power exports, chiefly to Holland and France.

The key driver behind the increase in hard coal and lignite burning is thus the price signal on the European power exchange market, *not* the nuclear phase-out. Europe has a large structural overcapacity, so in the absence of a significant carbon price, there has been an increasing incentive to operate existing lignite and coal fired power plants. Germany does not have any capacity problems, on the contrary, the country never exported more than in 2013 with 72.2 TWh or 33.8 TWh net, a 46 percent increase in net exports over the previous year, and due to its highly competitive wholesale prices, (which renewable power has sharply reduced in the past few years), Germany is the only country that consistently is a net exporter of electricity to France.

The **Netherlands** operates a single, 40-year-old 480 MW PWR that provided 2.8 TWh or 2.7 percent of the country's power in 2013 (down from a maximum of 6.2 percent in 1986) and approximately half that produced by wind power in the same year.[643] In June 2006, the operator and the Government reached an agreement to allow operation of the reactor until 2033.[644]

On 23 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". The company provided the following reasons for its decision: "The financial crisis, combined with the substantial investment needed for a second nuclear power plant, current investment conditions, overcapacity in the electricity market and low energy prices."[645]

In September 2013, the results of a two year policy development process was announced that has been described by some as a Dutch *Energiewende*. The origin of the initiative was a Parliamentary motion on 26 April 2011 that called on the government to develop a "National Energy Transition Accord". The Accord is not government policy, though the Minister of Economic Affairs was part of the 40 organizations or departments, including trade unions, business associations and the National Association of Municipal Councils, that signed up to it. The main recommendations of the Accord relate to energy efficiency and renewables[646], remaining "silent on nuclear".[647]

Spain operates seven reactors; an eighth unit was shut down at the end of 2012. Nuclear plants provided 54.3 TWh or 19.7 percent of the country's electricity in 2013 (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 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".[648]

---

[642] These figures are from AGEB, "Bruttostromerzeugung in Deutschland von 1990 bis 2013 nach Energieträgern", June 2014, see http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=20140207_brd_stromerzeugung1990-2013.pdf, accessed 5 July 2014.
[643] BP, "Statistical Review of World Energy", June 2014.
[644] WNA, "Nuclear Power in the Netherlands", see www.world-nuclear.org/info/inf107.html, accessed 2 June 2013.
[645] DELTA, "DELTA puts off decision for a few years, no second nuclear plant at Borssele for the time being", Press Release, 23 January 2012.
[646] Energypost.eu, "The Dutch Energiewende", 4 October 2013, see http://www.energypost.eu/the-dutch-energiewende/, accessed 5 July 2014.
[647] WNA, "Nuclear Power in the Netherlands", Updated June 2014.
[648] Reuters, "Spain Insists on Energy Saving, Not Nuclear Plants", 21 January 2009.

Spain has, however, been implementing both uprating and lifetime extensions for existing facilities. Licenses for the operating units would have or will run out between 2010 and 2018. In 2009, the Government extended the operating license of the then 40-year old Garoña plant to 2013, and in 2010 it granted the 30-year old Almaraz-1 plant a 10-year extension and a capacity increase of seven percent. The 28-year old Almaraz-2 plant also will be uprated.[649] 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.[650]

Nevertheless, on 16 December 2012, Garoña was reportedly shut down permanently. The operator Nuclenor had calculated that further operation of the 446 MW plant would not be economic. Not only would Nuclenor have to invest about €120 million (US$164 million) to upgrade the 42-year old plant, but it would also have to face a new tax of €153 million (US$210 million) in 2013 following an energy tax reform that was overdue in Spain.

The Cabinet of the new 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 the license,[651] but so far the reactor has no license to restart, with a decision expected within a year. Eleven mayors of towns in the vicinity of the plant have protested against the proposed restart and call for the closure of the unit to be confirmed.[652]

In 2013, for the first time, wind power produced more electricity (55.8 TWh) than nuclear power (54.3 TWh), with solar, hydropower, and biomass providing an additional 54 TWh.[653]

Sweden operates ten reactors that provided 63.7 TWh or 42.7 percent of the country's electricity in 2013 (down from a maximum of 52.4 percent in 1996). Sweden's per capita power consumption is among the highest in the world, due primarily to the widespread and inefficient thermal use of electricity. In recent years, however, Swedish residential electricity consumption has shrunk.[654]

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; the other six were 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) went off line 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.[655] As a result, new plants could again be built—but only if an existing plant is shut down, meaning that the maximum number of operating units will not exceed the current ten. This puts Sweden many years away from potential new construction. Trade journal *Nuclear Intelligence Weekly* noted: "In 2012 Vattenfall asked the regulator for more clarity regarding the newbuild process, but 2025 is the earliest date for any new units."[656] In November 2013, the Swedish Energy Minister stated: "We won't address any direct or indirect subsidies for new nuclear power production in Sweden, which means that we will not introduce any

---

[649] Bloomberg.com, "Spain Approves Increase in Nuclear Power Output, *Expansion* Says", 4 January 2011.
[650] WNN, "No Limits for Spanish Reactors", 17 February 2011.
[651] Nuclenor, "Nuclenor submits application to renew the operating licence of the plant Garoña", Press Release, 27 May 2014.
[652] EITB, "Mayors urge EU to monitor the possible re-opening of Garoña", 17 June 2014, see http://www.eitb.com/es/noticias/sociedad/detalle/2337498/central-nuclear-garona--alcaldes-piden-cierre-plnata/, accessed 3 July 2014,
[653] BP, "Statistical Review of World Energy", June 2014.
[654] JRC, "Energy Efficiency Status Report 2012", 2012.
[655] NEI, "Swedish Government Overturns Nuclear Ban", 21 June 2010.
[656] NIW, "Potential and Existing Global Nuclear Newbuild Projects Open to International Vendors", 15 March 2013.

feed-in tariff for nuclear."[657] Despite this, in January 2014 Vattenfall started a decade-long public consultation on the construction on new nuclear power plants.[658]

In the meantime utility Vattenfall envisages extending lifetimes of five of its seven units at Forsmark and Ringhals to 60 years. The objective for Ringhals-1 and -2 is a 50-year lifetime.[659]

Operators have pushed uprating projects to over 30 percent. A 33-percent uprate has been implemented 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 is now seriously delayed with safety upgrades going first. On 20 June 2014, the operator declared to Nord Pool that "connection to grid is expected to take place during the summer of 2015" but that it proposes "to postpone the upgrade of the effect [increased capacity] at Oskarshamn-2 until 2017".[660]

The **United Kingdom** operates 16 reactors, which provided 64 TWh or 18.3 percent of the country's electricity in 2013 (down from a maximum of 26.9 percent in 1997). The first-generation Magnox reactors, with 11 stations, have all been retired, except for one at Wylfa, which was to be closed by the end of 2014, but in the Periodic Safety Review submitted to the Office of the Nuclear Regulator in October 2013, requested that the reactor's operating life be extended by one year to enable it to fully utilize the fuel that it obtained by closing unit 2.[661] The seven second-generation stations, each with two Advanced Gas-cooled Reactors (AGR), are also at or near the end of their design life, although the owners now plan to extend their life by seven years to 40 years with retirements only in 2016–29. The newest plant, Sizewell-B, is the United Kingdom's only PWR and was completed in 1995.

The industry has a long history of economic and technical problems (see the chapter Economics of Nuclear Power), right up through the past decade: In 2004 the government prevented privately owned nuclear generator British Energy from going into liquidation. While the state-owned nuclear fuel and technology company BNFL was also effectively bankrupt because it could not meet its liabilities, the Government split up the company, passing the physical assets (and its costly decommissioning obligations) to a new agency, the Nuclear Decommissioning Authority (NDA), while the capabilities were privatized.

The NDA is now responsible for decommissioning all Britain's civil nuclear facilities except those owned by British Energy. In 2014, the NDA announced that its discounted liability was estimated to be in excess of £64.9 billion (US$110.7 billion)—£110 billion (US$188 billion) if undiscounted[662]—an increase of £6 billion (US$10 billion) over the previous year and up from less than £34 billion (US$58 billion) in 2007. Furthermore, the NDA states: "The NDA has reviewed a number of scenarios with a range of possible outcomes, the estimated cost could have a potential range from £88 billion to £218 billion" (US$150–372 billion). The NDA inherited negligible funds for this task, relying partly (and increasingly) on government grants and partly on income from the facilities still in operation, including one remaining Magnox reactor, the THORP reprocessing plant, and previously the Sellafield MOX Plant (SMP)—a plutonium fuel manufacturing plant. Both of the latter facilities, however, have been plagued by very serious technical problems that have kept their operation significantly below expectations, if they were operating at all. An internal Government report on the SMP, released in June 2013, revealed that the plant had cost the taxpayer £2.2 billion (US$3.75 billion) and that it was "not fit for purpose"[663]. SMP was closed in 2011 and THORP is to follow in the next few years.

In 2008, the Labor Government of Gordon Brown 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.[664] The eight "potentially suitable" sites considered in the document for deployment

[657] Reuters, "Sweden rejects British model for new nuclear plant deals", 20 November 2013, see http://uk.reuters.com/article/2013/11/20/uk-sweden-nuclear-idUKBRE9AJ0O820131120, accessed 5 July 2014.
[658] WNA, "Nuclear Power in Sweden", World Nuclear Association, Updated June 2014, see see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Sweden/, accessed 19 July 2014.
[659] Vattenfall, "Vattenfall plans to provide nuclear power for up to 60 years", Press Release, 22 May 2013, see http://www.vattenfall.com/en/pressreleasedetailhidden.htm?newsid=943A721F600C4F72AF3AC1D4F96C601A, accessed 2 June 2013.
[660] Nord Pool, "Outage or Limitation : Maintenance – Oskarshamn 2", 19 June 2014, see http://umm.nordpoolspot.com/messages/30213, accessed 5 July 2014.
[661] Magnox, "Periodic Safety Review Submitted", Press Release, 9 October 2014.
[662] Nuclear Decommissioning Authority, "Annual Report and Accounts 2013/14", 2014.
[663] Independent, "Revealed: £2bn cost of failed Sellafield plant", 9 June 2013.
[664] DECC, "National Policy Statement for Nuclear Power Generation", July 2011.

"before the end of 2025" are exclusively current or past nuclear power plant sites in England or Wales.[665] Northern Ireland and Scotland[666] are not included.

EDF Energy, wholly owned by French state utility EDF and currently the only remaining utility with a concrete investment timetable and plan, was given planning permission to build two reactors at Hinkley Point in April 2013. In February 2013 Centrica withdrew from the Hinkley project, saying that "since our initial investment [in 2008], the anticipated project costs in new nuclear have increased and the construction timetable has extended by a number of years[667]." In October 2013, EDF and the UK Government announced the provisional agreement of commercial terms of the deal for the £17 billion (US$30 billion) construction of Hinkley C. At the time, they said that the deal will be finalized in July 2014, but that timetable has slipped. The key points for the deal were a Contract For Difference, 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, along with Government debt guarantees of up to £10 billion (US$17 billion). This led to formal State Aid notification of the proposal to the European Commission in October, and on 18 December 2013, the Commission announced it was investigating the deal. On 31 January 2014, the Commission released a letter that raised a number of questions. While many expected this, the letter's tone was a shock with national newspapers describing it as "a damning critique…a searing letter" (Daily Telegraph) and "a scathing initial assessment" (Financial Times). (See Economics of Nuclear Power)[668]. It is unclear when these negotiations will reach a conclusion and what impact EU State Aid approval or refusal will have.

Two other consortia are considering investment in new nuclear in the U.K. 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.[669] The remaining consortium, NuGen, in June 2014, finalized a new ownership structure with Toshiba-Westinghouse (60%) and GDF-Suez (40%), as Iberdrola sold their shares. The group plans to build AP1000 reactors, with units proposed to begin operating in 2024.[670]

The only non-EU Western European country that operates nuclear power plants is **Switzerland**. It operates five reactors that generated 25 TWh and generated 36.4 percent of the country's electricity in 2013 (down from a maximum of 44.4 percent in 1996).

With an average age of 39.2 years, Switzerland operates the oldest reactor fleet in the world. In a damning report, Dieter Majer, former Director for Nuclear Facilities Safety of the German Nuclear Regulator, states: "The reactors show advanced aging processes that continuously reduce the originally existing safety level. The facilities, designed and built in the sixties and the seventies, are far from state of the art in science and technology." Especially the reactors Mühleberg and Beznau "should be shut down immediately", Majer concludes.[671] The Swiss Nuclear Regulator took four months to refute the report in a detailed 16-page rebuttal[672]. Majer welcomes the regulator's reaction

[665] Bradwell, Hartlepool, Heysham, Hinkley Point, Oldbury, Sizewell, Sellfield, and Wylfa.

[666] The Scottish government is opposed to new-build and said it would not allow replacement of the Torness and Hunterston plants, once they will be shut down (likely 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.

[667] Guardian, "Centrica withdraws from new UK nuclear projects", 4 February 2013.

[668] See also numerous items in the Essential News section at www.WorldNuclearReport.org.

[669] Telegraph, "Hitachi reluctant about UK nuclear reactor plan", 14 April 2013.

[670] 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 5 July 2014.

[671] Dieter Majer, "Risiko Altreaktoren Schweiz", February 2014, commissioned by Schweizerische Energie-Stiftung, February 2014, see http://www.energiestiftung.ch/energiethemen/atomenergie/risiken/risiko-altreaktoren/, accessed 24 July 2014.

[672] ENSI, "Stellungnahme zur Studie 'Risiko Altreaktoren Schweiz'", 23 June 2014, see http://static.ensi.ch/1403524112/ensi-stellungnahme_studie_risiko_altreaktoren_schweiz_ensi-an-8874.pdf, accessed 19 July 2014. The Swiss Energy Foundation, that commissioned the Majer report, criticized in a statement the "lack of willingness for exchange and problem-solving" on the side of ENSI. Majer had not received any answers from ENSI to his information requests in the framework of his investigation. See SES, "SES-Studie 'Risiko Altreaktoren Schweiz' – ENSI weicht der Kritik weiterhin aus", 23 June 2014, see

and considers that "this could be the beginning of a critical dialogue between the public and the institution responsible for the safety of Swiss nuclear power plants" before responding in a further 10-page paper.[673] To be continued.

Until after 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. A local referendum on 13 February 2011 saw a slim 51/49 percent majority for future replacement of the now 43-year old Mühleberg reactor that then was expected to shut down by 2022. However, Fukushima had a significant impact in Switzerland. Only three days after 3/11, the Government suspended the procedures around license requests for new-build. Opinion polls a week later showed that support for new-build nuclear power had plunged by 34 points, from 55 percent to 21 percent in two months.[674] 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". The criteria for reactor closure remain uncertain. The Strategy includes measures to reduce energy consumption and to boost renewable energies. The Government intends to articulate its Energy Strategy 2050 as an "indirect counter proposal" to the "Nuclear Phase-out Initiative" launched in early 2013.[675] Various environmental, clean energy and anti-nuclear groups have initiated a campaign to limit the lifetime of the nuclear plants to 40 years and thus shut down the last reactor by 2029. A national petition drive was launched in late May 2013.[676]

In October 2013 the 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." The introduction of a closure date was despite the fact that the reactor had effectively, depending on meeting safety requirements, obtained an open-ended operating license.[677] In May 2014, a clear majority (63.3 percent) of people polled in a local referendum in the canton of Bern rejected the option to shut down the plant immediately.[678]

Central and Eastern Europe

In **Bulgaria,** nuclear power provided 13.3 TWh or 30.7 percent of the country's electricity in 2013 (down from a maximum of 47.3 percent in 2002), with generation occurring from the remaining two units of the Kozloduy plant, where originally there were six reactors—four reactors were closed as part of the agreement for Bulgaria to join the EU. It is important to note that in 2013, net electricity exports were nearly 7 TWh, equivalent to about 50 percent of the electricity produced from Kozloduy. The two remaining VVER1000 reactors are currently licensed to 2017 and 2021,[679] but the operator has begun a relicensing program and hopes to extend their operating lifetimes to 50 years from the current 30, although a ten-year life extension seems more realistic.

There have been ongoing attempts since the mid-1980s to build another nuclear power plant at Belene in Northern Bulgaria. Over the years various consortia, including firms from Bulgaria, France, Germany, and Russia, have attempted to develop the project. In February 2013 the Parliament finally confirmed the previous Prime Minister's decision to abandon the plant. However, while the current socialist government was proposing to restart the construction process for Belene during the 2013

http://www.energiestiftung.ch/aktuell/archive/2014/06/23/ses-studie-risiko-altreaktoren-schweiz-ensi-weicht-der-kritik-weiterhin-aus.html; both URLs accessed 5 July 2014.

673 Dieter Majer, "Stellungnahme zur Aktennotiz des ENSI vom 23.6.14 (…)", 2 July 2014, see http://www.energiestiftung.ch/files/pdf/stellungnahme-von-dieter-majer-zur-ensi-aktennotiz.pdf, accessed 19 July 2014.

674 AREVA, "Impact of Fukushima event on nuclear power sector – Preliminary assessment", 25 March 2011.

675 Schweizerische Eidgenossenschaft, Bundesrat, "Bundesrat legt Energiestrategie 2050 als indirekten Gegenvorschlag zur Atomausstiegsinitiative vor", 15 March 2013, see http://www.news.admin.ch/message/index.html?lang=de&msg-id=48168, accessed 5 June 2013.

676 Schweizerische Energiestiftung, "40 Jahre sind genug – Jetzt Petition unterzeichnen", 22 May 2013, see http://www.energiestiftung.ch/aktuell/archive/2013/05/22/40-jahre-sind-genug-jetzt-petition-unterzeichnen.html, accessed 5 June 2013.

677 NIW, "Switzerland – News Briefs", 1 November 2013.

678 NucNet, "Bern Voters Reject Bid To Close Mühleberg Immediately", 19 May 2014.

679 Republic of Bulgaria, "Sixth National Report under the Convention on Nuclear Safety", 2013.

election campaign, no practical steps have been taken. In 2013, there was a string of arrests and high-profile raids involving individuals and firms connected with the Belene project.[680]

The Government and industry have now focused their efforts on building more reactors 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."[681] 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 (which owns 87 percent of Westinghouse) to become the strategic investor in the construction of an AP1000 reactor. The reactor vendor Toshiba will 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 is 30 September 2014.[682] The potential involvement of national export-import banks from the U.S. and Japan already highlights the difficulties in building a reactor without state support and contradicts previous pledges. In early June 2014, Toshiba withdrew from the project and was replaced by Westinghouse as the strategic investor. Reasons for the move remain unclear at this point.[683]

The Government has said that it hopes construction could start in 2016, although no announcement has been made on the price. The scoping phase of the Environmental Impact Assessment has started but has yet to begin the trans-boundary consultation. Further timing concerns have been raised over the licensing review of an AP1000 reactor, which according to the chairman of the Nuclear Regulator Agency could take years.[684]

The tensions between Russia and Ukraine have caused concerns not only for gas supply, with Bulgaria's 90 percent dependency on Russia, but also for the operation of Kozloduy. Consequently, an emergency plan on Ukraine was adopted by the Security Council with the Council of Ministers, which included a review of the plans for the transportation of fresh and used nuclear fuel, as Russia is the sole supplier of nuclear fuel and also takes back spent fuel for reprocessing.[685]

The **Czech Republic** has six Russian-designed reactors in operation at two sites, Dukovany and Temelín. The former houses four VVER440-213 reactors, and the latter two VVER1000-320 units. Between them they produced 29 TWh or 35.8 percent of the country's electricity in 2013. Nuclear power production and share peaked in 2013. In 2013, the Czech Republic was a net exporter of 17 TWh of electricity, equivalent to close to 60 percent of the nuclear output.

The Dukovany units were started between 1985–87 and have undergone a life extension engineering program under the expectation to operate until 2025, though require still a restart permission from the nuclear regulator after a periodic safety review. The Temelín reactors eventually started in 2000 and 2002 with financial assistance from the U.S. Export-Import Bank and with instrumentation and control technology supplied by Westinghouse.

In 2004 Government plans proposed the construction of at least two more reactors. By 2010 three consortium were being considered, led by Westinghouse, AREVA and Skoda-Rosatom. However, in November 2012, the AREVA bid was excluded, since it had "not fulfilled some other crucial criteria defined in the tender."[686] AREVA contested the decision but its appeal was rejected by the anti-monopoly office and AREVA turned to the Czech courts. However, in February 2014, Czech President Milos Zeman said that he would welcome the return of AREVA to the bidding process, and a spokesperson for CEZ said it too would accept AREVA's re-inclusion.[687]

---

680 NIW, "Government says Belene Depends on Rooting Out Corruption", 18 October 2013.

681 AFP, "Bulgaria approves new reactor at nuclear plant", 11 April 2012.

682 Sofia Globe, "Bulgaria to begin talks with Westinghouse on new Kolzoduy nuclear reactor", 11 December 2013, see http://sofiaglobe.com/2013/12/11/bulgaria-to-begin-talks-with-westinghouse-on-new-kozloduy-nuclear-reactor/, accessed 13 June 2014.

683 Mediapool, 4 June 2014, (in Bulgarian), see http://www.mediapool.bg/toshiba-se-ottegli-kato-investitor-v-v-blok-v-aets-kozlodui-news221108.html, accessed 18 June 2014.

684 NIW, "Briefs, Bulgaria", 28 February 2014.

685 Novinite, "Bulgarian Ministers Agree Measures on Ukrainian Conflict", 5 March 2014, see http://www.novinite.com/articles/158660/Bulgarian+Ministers+Agree+Measures+on+Ukrainian+Conflict#sthash.GlsyNLyq.dpuf, accessed 13 June 2014.

686 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 November 2014, see http://www.cez.cz/en/investors/inside-information/1499.html, accessed 13 June 2014.

687 Prague Daily Monitor, "Zeman would welcome return of Areva to Temelín tender", 18 February 2014.

A key issue for new-build is the level of state support. Prime Minister Bohuslav Sobotka has 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."[688] The 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 Temelin under the current market conditions."[689] Then, in April 2014, CEZ simply cancelled its call for tenders for the two new units at Temelin, citing the low electricity market price and the lack of government guarantees. Following the announcement, the share prices of CEZ rose by 2.8 percent.[690] AREVA withdrew its court complaints.[691]

Hungary has only one nuclear power plant at Paks, which houses four VVER 440-213 reactors that provided 14.5 TWh or 50.7 percent of the country's electricity in 2013. The reactors started commercial 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. Operating licenses were extended in 2012. The first unit received permission to operate for another 10 years after a periodic safety review finished in 2013, and the Hungarian nuclear regulator is currently submitting the second unit to a periodic safety permission review. However, unit 2 faces the problem that it currently stores the radioactive wastes from an INES 3 accident in 2003 in its fuel pool. Plans to have this exported to Russia are being challenged under European legislation.[692]

In March 2009, the Hungarian parliament approved a government decision-in-principle to build additional reactors at Paks.[693] Even at this time, Russian assistance seemed to be the preferred option, and Hungary's foreign minister indicated that expansion of the Paks plant would be part of a "package deal" on outstanding economic issues with Russia.[694] In January 2014, an intergovernmental agreement was reached between Hungary and Russia for a €10 billion (US$13.5 billion) loan for the construction of two additional blocks at the Paks by Russia's Rosatom. The deal has been criticized because was finally agreed just five days before a general election, and only a few of the crucial terms and conditions of the deal have been made public.[695] What is reported is that 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, but penalty conditions could bankrupt the Hungarian State. Secondly, the deal is likely on several points to be in breach of EU competition and state aid rules. Opposition Parliamentarians have called for the Government to cancel the project. The project represents a U-turn for the ruling party, which had fiercely criticized previous socialist governments for failing to diversify away from reliance on Russian energy. Russia already provides about three-quarters of the country's oil and gas needs.[696]

Romania has one nuclear power plant at Cernovoda, which has two Canadian designed CANDU reactors that began operating in 1996 and 2007. In 2013, they provided 10.7 TWh or 19.8 percent of the country's electricity—both just below historic peaks. Construction started in the 1980s, with the initial intention of five units. The first two units were partly funded by the Canadian Export Development Corporation with the second unit co-funded by Euratom. Over the past decade numerous foreign firms have been linked to the completion of additional Cernavoda units, including AECL and SNC-Lavalle (Canada), Ansaldo (Italy), AtomTechnoProm (Russia), CEZ (Czech Republic), Electrabel (Belgium), ENEL (Italy), GDF Suez (France), Iberdrola (Spain), KHNP (South Korea), RWE (Germany), and Arcelor Mittal (France).[697] In December 2013, Arcelor Mittal and ENEL, as the last foreign partners, sold back their shares in the project to the Romanian state. The latest attempt

[688] Ceskenoviny, "Government won't guarantee electricity prices for Temelin – PM Sobotka", 6 February 2014.
[689] Reuters, "Czech CEZ boss says prefers dividend predictability", 31 March 2014.
[690] Reuters, "UPDATE 4-CEZ scraps tender to expand Temelin nuclear power plant", 10 April 2014.
[691] Prague Monitor, "Areva withdraws court appeal after cancellation of Temelín tender", 18 April 2014, see http://praguemonitor.com/2014/04/18/areva-withdraws-court-appeal-after-cancellation-temel%C3%ADn-tender, accessed 13 June 2014.
[692] Nuclear Transport Watch, "Complaint to the European Commission about radioactive waste export from Hungary to Russia", January 2014, see http://www.nuclear-transparency-watch.eu/activities/complaint-european-commission-radioactive-waste-export-hungary-russia.html, accessed 13 June 2014.
[693] John Shepherd, "Hungary's Parliament Paves Way to Build New Reactor Unit", NucNet, 31 March 2009.
[694] Realdeal.hu, "Hungary, Russia Seek to Resolve All Outstanding Issues in One Package, Says FM", 21 January 2011.
[695] Politics.hu, "Hungary signs EUR 10 billion Paks agreement with Russia", 1 April 2014.
[696] Financial Times, "Russia builds clout in eastern Europe with €10bn loan to Hungary", 14 January 2014.
[697] WNA, "Nuclear Power in Romania", updated December 2013

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.[698] However, the CEO of SNN has suggested that no final commitment will be made until early 2016.[699] Furthermore, there is no details of the expected cost of the project, but according to the *Curierul National*, the latest feasibility study conducted by Ernst & Young shows that the investment required to build reactors 3 and 4 is €7.67 billion (US$10.5 billion), almost double the 2008 estimate of €4 billion (US$5.5 billion).[700]

In **Slovakia**, the state utility Slovenské Elektrárne (SE) operates all nuclear power plants at two sites, Jaslovské Bohunice, which houses two VVER440 units, and Mochovce, which has two similar reactors. In 2013, these accounted for 14.6 TWh or 51.7 percent of the country's electricity production. 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. In February 2007, SE announced that it was proceeding with this initiative and that ENEL had agreed to invest €1.8 billion (US$2.6 billion) in the completion of Mochovce. Construction restarted on 3 December 2008 and at the time the units were expected to commence operation in 2012 and 2013.[701] On 21 August 2013, the Slovakian Supreme Court ruled that the national nuclear regulator had broken domestic law during the Environmental Impact Assessment process by refusing to let Greenpeace Slovakia take part in the licensing process for units 3 and 4.[702] The regulator has said that it will now undertake another round of public consultation, but has allowed construction to continue in the meantime. At the same time, the Slovak Government announced that the cost of completion had risen by €250 million (US$340 billion). Then, in April 2014, at the Annual Shareholders meeting for SE, it was revealed that another €400 million (US$550 million) would be needed to complete the units, taking the total costs of completion to €3.8 billion (US$5 billion), with start-up now scheduled for the end of 2014 and 2015.[703] In June 2014 it was announced that the Russian Bank Sberbank will provide an €800 million (US$1 billion) loan for 7.5 years for SE; €300 million (US$410 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.[704] The project is therefore at least two years behind schedule and €2 billion (US$2.7 billion) over budget. In addition to the delays and cost overruns, concerns have been raised about the state of the power market and electricity demand due to the sluggish economy. It is expected that if and when the Mochovce units are completed, their capacity will primarily be used for export, so given the low electricity price in the European market, the chance of ENEL and SE recovering their ever-increasing investment seems slim. In July 2014 ENEL announced that they were seeking to sell their share in SE, as well as investments in Romania.[705] Plans for two new reactors in Jaslovksé Bohunice faced problems when the Russian nuclear construction company Rosatom withdrew its interest in taking over the 49 percent participation of Czech utility CEZ in the project in December 2013.[706]

Slovenia jointly owns the Krsko nuclear power plant with **Croatia**. The unit is a 696 MW Westinghouse PWR. In 2013, it provided 5 TWh or 33.6 percent of the Slovenia's electricity (down from a maximum of 42.4 percent in 2005). The reactor was started in 1981 and has an initial operational life of 40 years. However, it is intended to seek a 20 year life extension for the unit.

---

[698] Telgraf, "Construction of NPP units 3 and 4, the petty cash", 22 March 2014.
[699] NIW, "SNN's Way Forward with CGN at Cernovoda", 31 January 2014.
[700] Curierul National, "Nuclearelectrica dry before listing", 4 April 2013, (in Romanian), see http://www.curierulnational.ro/Eveniment/2013-04-04/Nuclearelectrica,+uscata+inainte+de+listare, accessed 19 July 2014.
[701] WNA, "Nuclear Power in Slovakia", April 2013, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Slovakia/#.UXeiuaI3vX4, accessed 19 July 2014.
[702] Bloomberg, "ENEL Nuclear Building Permit Violated Law, Slovak Court Says", 21 August 2013.
[703] Spectator, "Shareholders approve additional funding for Mochovce plant", 9 April 2014.
[704] WSJ, "Sberbank to lend-$1.1 billion to Slovakia's Largest Power Company", 10 June 2014.
[705] WNN, "ENEL's Slovakian Interest for Sale", 11 July 2014, see http://www.world-nuclear-news.org/C-For-sale-Enels-Slovakian-interests-1107147.html, accessed 17 July 2014; and NIW, "Weekly Round-up", 11 July 2014.
[706] The Daily SK, "Slovakia Ends Talks on Rosatom's Entry to Nuclear Project", 30 December 2013, see https://www.thedaily.sk/slovakia-ends-talks-on-rosatoms-entry-to-nuclear-project/, accessed 16 July 2014.

Discussions for the construction of a second reactor at the site remain hampered by the negative seismic assessment by IRSN, the Technical Support Organization (TSO) of the French Nuclear Safety Authorities. While in early 2013 the Slovenian state-owned utility, GEN Energija, had judged that IRSN's conclusions on site suitability "might be premature", in a December 2013 presentation[707], IRSN released excerpts of its January 2013 letter to GEN concluding that "GEN should consider revising its strategy for the Krsko II project and further examine the possibility to search for an alternative site." [708] While IRSN recommends to update earlier seismic studies and continue investigations, it is obvious that their experts remain highly critical of the suitability of the site.

Former Soviet Union

Armenia has one remaining reactor at the Medzamor (Armenia-2) nuclear power plant, which is situated within 30 kilometres of the capital Yerevan and provided 2.17 TWh or 29.2 percent of the country's electricity in 2013 (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."[709] In October 2012, the Armenia Government announced that it would operate the Medzamor unit until 2026. This led to the Turkish authorities' calling for the immediate closure of the power station.[710] 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."[711]

Armenia is negotiating with Russia for the construction of a new 1000 MW unit, which led to the signing of an inter-government agreement in August 2010. It was estimated by a U.S.-funded feasibility study that it would cost US$5 billion.[712] In March 2014, the energy minister admitted that it was having difficulty in attracting funds to start construction.[713]

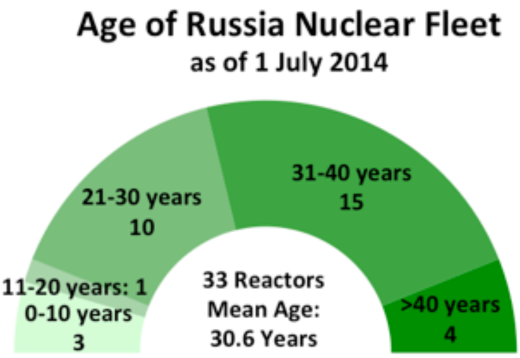
The year 2014 has seen the 60th anniversary of the connection of the world's first civilian nuclear power plant to the grid, which occurred on 26 June 1954 at the Obninsk reactor in **Russia**. Since then the industry has experienced growth but also long periods of stagnation in particular in the 1980s—following Chernobyl—and the 1990s, as a result of the political changes and economic problems. However, there is now a new confidence emanating from the Russian nuclear industry, and in 2011 President Putin said of nuclear power: "Nuclear energy is on the rise. There's a rebirth, a renaissance, of the nuclear sphere taking place right now."[714] The industry is seeking to increase its domestic production as well as its global influence, through the export of reactors backed by cheap finance. However, despite this confidence domestically, not much has changed with ongoing problems for new construction and the growing problem of the aging of the existing reactors (see Figure 35). In 2013, Russia's 33 reactors provided 162 TWh or 17.5 percent of the country's electricity. While Russia is one of the few countries in which nuclear power's contribution has been increasing—peaking in 2012—this is happening slowly.

According to the IAEA, Russia has ten 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 to the customer at the end of

[707] Oona Scotti, "Presentation of IRSN report on possible NPP Krsko II site. What are the implications of this report?", IRSN, Event on nuclear in Ljubljana, Slovenia, 2 December 2013.
[708] IRSN, Letter to GEN Energija, dated 9 January 2013.
[709] DOE, Office on Energy Intelligence, "Most Dangerous Reactors: A Worldwide Compendium of Reactor Risk", Washington, DC, May 1995.
[710] USAID, "Turkey renews demands for 'immediate closure' of Armenian nuke plant", 5 November 2012.
[711] Hurriyet Daily, "Turkey wants nuclear plant in Armenia to be shut down", 22 March 2014.
[712] USAID, "Government extends service life of Metsamor NPP for another ten years", 19 October 2012.
[713] Business New Europe, "Armenia denies plans to abandon nuclear power plant project", 28 March 2014.
[714] Fox News, "Putin Attends Russian Launch of New Nuclear Reactor", 12 December 2011.

2012.[715] The latest official start-up date is said to be 6 September 2016,[716] although other reports suggest the vessels will be launched only in 2019.[717] 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 will increase the risks of nuclear material proliferation.[718]

Figure 35. Age Distribution of Russian Nuclear Fleet (by Decade)



Sources: IAEA-PRIS, MSC, 2014

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 a recognition of the limited market for the electricity, especially after Germany's Foreign Minister Guido Westerwelle denied interest in an undersea cable linking the Kaliningrad enclave with Germany.[719] It was later clarified that "construction was frozen for two years".[720] Despite this, the project remains "under construction" in IAEA statistics. However, with the ongoing problems for electricity markets, namely low market prices and little increase in demand, there seems little incentive for construction to restart.

Also included on the list of reactors officially under construction is the Beloyarsk-4 fast breeder reactor. Construction of the 880 MW unit began initially in 1986 but was subsequently suspended and restarted in July 2006. Fuel was said to be being loaded into the reactor in June 2014[721], although no startup date has been published. Two VVER 1200 MW units are being built at Leningrad, where construction started in 2008 and 2010. At the time of ordering, the reactors were expected to start up in 2013 and 2016; startup is now expected respectively in 2016 and 2018.[722]

Two other reactors are expected to be completed in 2014—a VVER1200 reactor at Novovorenezh, where construction started in 2008 and is two years late, and another VVER1000 unit at Rostov, where construction initially started in 1983, but was suspended and then restarted in 2009. Additional units are being built at Novovorenzh, expected to be completed in 2015, and at Rostov, expected to be completed in 2017. Therefore of the ten reactors under-construction, three were started in the 1980s, while all of the others are either currently suspended or running at least two years late.

Targets for the deployment of new units have also continually been downgraded. In September 2006 Rosatom announced a target for nuclear power to provide 23 percent of Russia's electricity by 2020 and the operation of 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 nuclear in 2020. This would require just the completion of the ten reactors currently under construction, taking into account the closure of the first two RBMK units at Leningrad.

---

[715] NEI, "KLT-40S nuclear barge project still afloat", 9 March 2010.
[716] World Nuclear News, "Reactors installed on floating plant", 1 October 2013.
[717] U.S.EIA, "Russia", 12 March 2014, see http://www.eia.gov/countries/cab.cfm?fips=RS, accessed 6 April 2014.
[718] 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 6 April 2014.
[719] Marke Menkinszak, "Russia Freezes the construction of the nuclear power plant in Kaliningrad", OSW, 12 June 2013, see http://www.osw.waw.pl/en/publikacje/analyses/2013-06-12/russia-freezes-construction-nuclear-power-plant-kaliningrad, accessed 19 July 2014.
[720] 15 Min.lt, "Rosatom orders conservation of unfinished nuclear power plant at Kaliningrad", 4 June 2013, see http://www.15min.lt/en/article/world/rosatom-orders-conservation-of-of-unfinished-nuclear-power-plant-in-kaliningrad-529-341922, accessed 6 July 2013.
[721] WNN, "Rosatom targets growth", 3 June 2014.
[722] WNN, "Moscow cruise for Leningrad II parts", 19 June 2014.

A key issue for the industry is how to manage its aging reactors. There are three major classes of reactors in operation: the RBMK, 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 2014, 19 have operated for over 30 years, of which four have run for over 40 years.

The biggest changes in the Russian industry over the past few years have been its export ambitions. Within Europe, Russia is involved in construction or is still in the bidding process for projects in Hungary (financing and construction) and Finland (financing and construction). It is also actively engaged in finance and construction, through a Build, Own and Operate (BOO) agreement in Turkey. In Eastern Europe, Russia also retains influence, with a loan and construction of reactors in Belarus and in Ukraine where two reactors at Khmelnitsky are scheduled to be built, but political tensions may delay or lead to the cancellation of the projects. Two Russian reactors are in operation in China at Tianwan with an additional two under construction. Also in Asia are proposals for Russian reactors in Bangladesh, India, and Vietnam. In total around 30 Russian reactors are under construction or planned, which makes Russia by far the largest international nuclear exporter. It is unclear whether Rosatom and the other vendors have the capacity to deliver such an ambitious construction slate.

To date the political situation in Ukraine and the subsequent economic sanctions against Russia apparently have not affected the nuclear sector, although other state owned energy sectors have been targeted, with Rosneft's Chief Executive Igor Sechin having been specifically named and restricted from travelling to the U.S.[723] However, given the uncertainty over the situation in Ukraine, the future extension of sanctions cannot be ruled out.

Due to the ongoing dispute between Russia and **Ukraine** over Crimea, energy has become an even more high-profile political and economic issue. Ukraine has been and remains heavily dependent on Russia for its oil, two thirds of its natural gas and all its nuclear fuel, though it is largely self-sufficient in coal. As Russia is the only manufacturer of the nuclear fuel used in Ukraine's VVER reactors, it poses a particular, but not necessarily acute, problem. Furthermore, Ukraine has historically been sending its used fuel to Russia for storage or reprocessing and has no long-term storage facility for high-level waste. Sergei Kiriyenko, head of Russia's state nuclear corporation Rosatom, said in March 2014: "We currently have complex relations with Ukraine, but we will deliver nuclear fuel to each of its reactors."[724] Ukraine has 15 operating reactors, two of the VVER440 designs the rest VVER1000s, which provided 78 TWh or 43.6 percent of power in 2013. Many of the reactors were built in the 1980s, with nine reactors over 25 years old. This raises important questions for aging of components and the lifetime management of the facility.

In March 2013, the European Bank for Reconstruction and Development (EBRD) awarded the state-owned nuclear operator, Energoatom, a €300 million (US$410 million) loan for an upgrading program at all the country's reactors. The total cost of the program is expected to be €1.45 billion (US$2 billion), with further funding, also of around €300 million (US$410 million), to come from the EU through the Euratom loan facility.[725] The project is expected to be completed by 2017. Energoatom claims that the upgrading program "will impact only the future scope of works concerning the lifecycle extension of the operating power units, but will not influence the decision of life extension."[726] This is an artificial distinction as the upgrading program is not economic without extending the operating lives and many of the reactors would otherwise have to close before the upgrading program was complete. Local NGO EcoClub Rivne filed a complaint to the Espoo Convention Implementation Commission concerning the lack of an environmental impact assessment (EIA) for lifetime extension of the Rivne 1 and 2 reactors. The Commission concluded that Ukraine was indeed in breach with the Convention on this point and should have carried out a cross-border EIA before permission for restart was given after the 10-year periodic safety review. The conclusion of the Commission was awaiting confirmation of the Meeting of Parties in 2014.

Two reactors, units 3 and 4 at Khmelnitsky, are officially under construction. Building work started in 1986 and 1987 on the units, but was stopped in 1990. In February 2011 Russia and Ukraine signed an intergovernmental agreement to complete the reactors, and the following year the Ukrainian Parliament adopted legislation to create a framework to finance the project, which included 80 percent of the funds coming from Russia. It is unclear how much of the units have been completed, with the documentation for

723 NIW, "Energy-Related Sensations Avoid Nuclear, so far", 2 May 2014.

724 Bellona, "Rosatom vows continue nuclear fuel flow to Ukraine in spite of Putin-imposed embargo", 14 March 2014.

725 EBRD, "Nuclear Power Plant Safety Upgrade Programme", European Bank for Reconstruction and Development, last updated 15 December 2011, see http://www.ebrd.com/english/pages/project/psd/2011/42086.shtml, accessed 9 June 2014.

726 Energoatom, "Ecological Assessment Report – Main Report", 31 January 2012, see http://www.energoatom.kiev.ua/files/file/ecological_assessment_report.%20main%20report.pdf, accessed 9 June 2014.

the Environmental Impact Assessment stating the units were between 35–40 percent and 5–10 percent 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.[727] However, once again the project was delayed at the end of 2013, and the energy minister said that construction might resume only in 2015[728]. Therefore, the IAEA's suggested operational dates of 2015 and 2016 are unrealistic.

In February 2014 the country's interim Government released a new energy strategy for 2030, which is more focused on efficiency and pragmatism rather than massive growth in energy and new generating capacity. The previous 2006 strategy envisaged electricity demand rising to 395 TWh by 2030, but this has been revised down to 282 TWh. The impact on the need for nuclear capacity is immense, with the previous assessment envisaging 20–21 GW of nuclear capacity by 2030. This has now been reduced to 5 GW or even just 2 GW—effectively just the completion of Khmelnitsky 3 and 4.[729]

[727] Oda Becker, et al., "Khmelnitsky NPP Construction of Units 3 and 4–Expert Statement to the Information and Analytical Survey (IAS) of the Feasibility Study (FS) and the EIA Report of the FS", Umweltbundesamt (Environment Agency Austria), Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2013, see http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0441.pdf, accessed 19 July 2014.
[728] WNA, "Nuclear Power in Ukraine", Updated March 2014.
[729] NIW, "Energy Program Highlights Lower Demand, Efficiency", 14 February 2014.

Annex 2: Japanese Nuclear Reactor Status 1 July 2014

Table 11: Japanese Nuclear Reactor Status 1 July 2014

Owner	Reactor	Capacity MWe	Start up – Age (1)	Shutdown (2)	NRA guidelines compliance		Status Long Term Outage (LTO)	Length of shutdown: 1 July 2014	
					Application	Approval by NRA		Days	Years
Kyushu Electric	Sendai Unit 1 PWR	890	1983 – 31 years	10/05/11	08/07/13	16/07/14(3)	Yes	1148	3.2
	Sendai Unit 2 PWR	890	1985 – 29 years	01/09/11	08/07/13	16/07/14(3)	Yes	1034	2.8
	Genkai Unit 1 PWR	559	1975 – 39 years	01/12/11			Yes	943	2.8
	Genkai Unit 2 PWR	559	1980 – 34 years	29/01/11			Yes	1249	3.5
	Genkai Unit 3 PWR	1180	1993 – 21 years	11/12/10	12/07/13		Yes	1298	3.6
	Genkai Unit 4 PWR	1180	1996 – 18 years	25/12/11	12/07/13		Yes	919	2.6
Shikoku Electric	Ikata Unit 1 PWR	556	1977 – 37 years	04/09/11			Yes	1031	2.8
	Ikata Unit 2 PWR	556	1981 – 33 years	13/01/12			Yes	900	2.5
	Ikata Unit 3 PWR	890	1994 – 20 years	29/04/11	08/07/13		Yes	1159	3.3
Hokkaido Electric	Tomari Unit 1 PWR	579	1988 – 26 years	22/04/11	08/07/13		Yes	1166	3.3
	Tomari Unit 2 PWR	579	1990 – 24 years	26/08/11	08/07/13		Yes	1040	2.9
	Tomari Unit 3 PWR	912	2009 – 5 years	05/05/12	08/07/13		Yes	787	2.2
Chugoku Electric	Shimane Unit 1 BWR	460	1973 – 41 years	08/11/10			Yes	1331	3.7
	Shimane Unit 2 BWR	820	1988 – 26 years	27/01/12	25/12/13		Yes	886	2.5
Kansai Electric	Takahama Unit 1 PWR	826	1974 – 40 years	10/01/11			Yes	1268	3.5
	Takahama Unit 2 PWR	826	1975 – 39 years	25/11/11			Yes	949	2.7
	Takahama Unit 3 PWR	870	1984 – 30 years	20/02/12	08/07/13		Yes	862	2.4
	Takahama Unit 4 PWR	870	1984 – 30 years	21/07/11	08/07/13		Yes	1076	3.0
	Ohi Unit 1 PWR	1175	1977 – 37 years	10/12/10			Yes	1299	3.6
	Ohi Unit 2 PWR	1175	1978 – 36 years	16/12/11			Yes	928	2.6
	Ohi Unit 3 PWR	1180	1991 – 23 years	02/09/13	08/07/13		No	302	0.8
	Ohi Unit 4 PWR	1180	1992 – 22 years	15/09/13	08/07/13		No	289	0.8
	Mihama Unit 1 PWR	340	1970 – 44 years	24/11/10			Yes	1315	3.7
	Mihama Unit 2 PWR	500	1972 – 42 years	18/02/11			Yes	926	2.6
	Mihama Unit 3 PWR	826	1976 – 38 years	14/05/11			Yes	1144	3.2
Tokyo Electric	Kashiwazaki-Kariwa Unit 1 BWR	1100	1985 – 29 years	06/08/11			Yes	1060	2.9
	Kashiwazaki Kariwa Unit 2 BWR	1100	1990 – 24 years	19/02/07			Yes	2689	7.4
	Kashiwazaki Kariwa Unit 3 BWR	1100	1992 – 22 years	16/07/07			Yes	2542	7
	Kashiwazaki Kariwa Unit 4 BWR	1100	1993 – 21 years	16/07/07			Yes	2542	7
	Kashiwazaki Kariwa Unit 5 ABWR	1100	1989 – 25 years	25/01/12			Yes	888	2.5
	Kashiwazaki Kariwa Unit 6 ABWR	1365	1996 – 18 years	23/06/12	27/09/13		Yes	827	2.3
	Kashiwazaki Kariwa Unit 7 BWR	1365	1996 – 18 years	23/08/11	27/09/13		Yes	1043	2.9

Owner	Reactor	Capacity MWe	Start up - Age	Shutdown(1)	NRA guidelines compliance		Status Long Term Outage (LTO)	Length of shutdown: 1 July 2014	
					Application	Approval by NRA		Days	Year
JAPCO	Tsuruga Unit 1 BWR	357	1969 – 45 years	26/01/11			Yes	1252	3.5
	Tsuruga Unit 2 – PWR	1160	1986 – 28 years	29/08/11			Yes	1037	2.9
	Tokai Unit 2 BWR	1100	1978 – 36 years	21/05/11	20/05/14		Yes	1137	3.2
Chubu Electric	Hamaoka Unit 3 BWR	1100	1987 – 27 years	29/11/10			Yes	1310	3.7
	Hamaoka Unit 4 BWR	1137	1993 – 21 years	13/05/11	14/02/14		Yes	1145	3.2
	Hamaoka Unit 5 ABWR	1380	2005 – 9 years	14/05/11	30/05/14		Yes	1144	3.2
Tohoku Electric	Higashidori Unit 1 BWR	1100	2005 – 9 years	06/02/11	10/06/14		Yes	1241	3.4
	Onagawa Unit 1 BWR	524	1983 – 31 years	10/09/11			Yes	1025	2.8
	Onagawa Unit 2 BWR	825	1994 – 20 years	06/11/10	27/12/13		Yes	1333	3.7
	Onagawa Unit 3 BWR	825	2001 – 13 years	10/09/11			Yes	1025	2.8
Hokuriku Electric	Shika Unit 1 BWR	540	1993 – 21 years	01/03/11			Yes	1218	3.3
	Shika Unit 2 ABWR	1358	2005 – 9 years	11/03/11			Yes	1208	3.3
JAEA	Monju – FBR	280	1995 – 19 years	08/12/95			Yes	6780	18.6

Notes:
(1) Grid connection year
(2) The shutdown dates are based on from Japan Atomic Industrial Forum. JAIF. Nuclear Power Plants in Japan (In operation and under construction). as of 10 June 2014. http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS02_1402531967P.pdf. *accessed 13 June 2014.*
(3) NRA Draft Review Report on Sendai

WNISR considers that the 10 Fukushima units are shut down and will never restart. All of the remaining nuclear reactors but Ohi 3 and 4. thus 43 out of 45 units (including Monju), fall under the criteria of the WNISR new Long Term Outage (LTO) category since none of them has generated any electricity in 2013 and in the first half of 2014.

All but two reactors in Japan, Ohi unit-1 and unit-2. should be included in the Long-term Shutdown (LTS) under the criteria set by the International Atomic Energy Agency (IAEA).[730] 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”.

[730] IAEA, Power Reactor Information System, “Glossary of Terms in PRIS Reports”, see http://www.iaea.org/pris/Glossary.aspx, accessed 6 June 2014.

Annex 3: Status of Lifetime Extension in the U.S.

Table 12: Lifetime Extension of U.S. Nuclear Power Plants

Plant	Grid Connection	Extension Applied for	Extension Granted
Calvert Cliffs 1, 2	1/75. 12/75	4/98	3/00
Oconee 1, 2, 3	5/73, 12/73, 9/74	7/98	5/00
Arkansas 1	8/74	2/00	6/01
Hatch 1, 2	11/74, 9/78	3/00	1/02
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, 5/73	1/03	10/04
Farley 1, 2	8/77, 5/81	9/03	5/05
Arkansas 2	12/78	10/03	6/05
Cook 1, 2	2/75, 3/78	11/03	8/05
Browns Ferry 1, 2, 3	10/73, 8/74, 9/76	1/04	5/05
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 Applied for	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
Vermont Yankee*	9/72	1/06	6/11
Fitzpatrick	2/75	8/06	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
Kewaunee*	4/74	8/08	2/11
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
Crystal River 3*	1/77	12/08	-
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	-
South Texas 1, 2	3/88, 4/89	10/10	-
Limerick 1, 2	4/84, 5/89	6/11	-

Plant	Grid Connection	Extension Applied for	Extension Granted
Grand Gulf	10/84	11/11	-
Callaway	10/84	12/11	-
Sequoyah 1, 2	7/80, 12/81	2/13	-
Braidwood 1, 2	7/87. 5/88	5/13	-
Byron 1, 2	3/85, 2/87	5/13	-
Fermi 2	9/86	4/14	-

Sources: For grid connection: http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=U.S.

and for life extension dates:

http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-reactor-license-renewal.html , For Sequoyah, see Inside NRC "TVA applies for license renewal for Sequoyah-1 and -2", 11 February 2013

Notes

1. *Reactors marked * have been permanently closed.*
2. *Pairs of reactors marked † have significantly different designs.*
3. *Nine Mile Point 2 applied for and received a license extension before its 20th birthday.*

Table 13: U.S. Nuclear Reactors Yet to Apply for Lifetime Extension

Plant	Grid connection	Expected life extension application
Clinton	4/87	1-3/17
Comanche Peak 1, 2	4/90, 4/93	7-9/16, 10-12/18
Lasalle 1, 2	9/82, 4/84	1-3/15
Perry	12/86	9/15
River Bend	12/85	1-3/16
Waterford 3	3/85	1-3/15
Watts Bar	2/96	

Sources: For grid connection: http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US and for life extension dates: http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html

Note: 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.

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		
Aa3		AA-		AA-		
A1		A+	A-1	A+	F1	Upper medium grade
A2		A		A		
A3	P-2	A-	A-2	A-	F2	
Baa1		BBB+		BBB+		Lower medium grade
Baa2	P-3	BBB	A-3	BBB	F3	
Baa3		BBB-		BBB-		
Ba1	Not prime	BB+	B	BB+	B	Non-investment grade speculative
Ba2		BB		BB		
Ba3		BB-		BB-		
B1		B+		B+		Highly speculative
B2		B		B		
B3		B-		B-		
Caa1		CCC+	C	CCC	C	Substantial risks
Caa2		CCC				Extremely speculative
Caa3		CCC-				In default with little prospect for recovery
Ca		CC				
		C				
C		D	/	DDD	/	In default
/				DD		
/				D		

Source: Wikipedia, 2012

Annex 5: About the Authors

Mycle Schneider is an independent international consultant on energy and nuclear policy based in Paris. He 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, and the EU. He is a part time senior research fellow at the Royal Institute of International Affairs – Chatham House in London. He is a regular speaker at conferences, universities, and training programs across the region. Prior to working freelance, Antony served for nine years as a nuclear campaigner and coordinator for Greenpeace International.

Yurika Ayukawa is Professor for Energy and Environment Policy, Faculty of Policy Informatics, Chiba University of Commerce, Japan. She is the acting Chair of Ichikawa City's Environmental Committee. Between 1997 and 2008, she represented WWF Japan's Climate Change Program and acted as the Vice Chair of the "2008 G8 Summit NGO Forum". She testified at national parliament's environmental committee and was a member of various government appointed committees (e.g. on Kyoto mechanism, environmental tax, environmental education). Between 1988 and 1995, Yurika worked as the International Relations Director at Citizens' Nuclear Information Center. She holds a Master of Public Administration from Harvard Kennedy School and a Bachelor of Arts from Sophia University in Tokyo.

Shaun Burnie, currently based in Hamburg, Germany, has been an independent nuclear consultant for the past seven years, specializing in nuclear policy in East Asia, nuclear fuel cycle issues and nuclear power plant safety. He has worked in Japan over a period of twenty years. He was formerly nuclear coordinator at Greenpeace International, including leading investigations into the Fukushima-Daiichi plant during the 1990s-early 2000s. He holds a Master's degree from King's College, University of London in Strategic Studies. In May 2014, he joined Greenpeace Germany as a nuclear specialist in their energy unit.

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.

Raffaele Piria, works as independent energy policy expert based in Berlin, Germany. He advises non-profit organizations and companies involved in the transition to an energy system based on renewables and energy efficiency. His expertise includes the integration of renewables into the power system, renewable heating and cooling, energy efficiency and energy security. He has been CEO of the European Solar Thermal Industry Federation, Head of policy consulting at eclareon, and assistant of the Green MEP Claude Turmes. Grown up in Italy, he holds Masters from the Freie Universität Berlin and from the London School of Economics.

Tatsujiro Suzuki is a Vice-Director and Professor of the Research Center for Nuclear Weapons Abolition (RECNA) at Nagasaki University, Japan. He is a Council Member of Pugwash Conferences on Science and World Affairs. He has a Ph.D. in nuclear engineering from the University of Tokyo (1988). From January 2010 to March 2014 he served as Vice-Chairman of the Japan Atomic Energy Commission (JAEC).

Steve Thomas is Professor of Energy Policy and Director of Research for the Business School, University of Greenwich. Mr. Thomas 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 6: Abbreviations

ABB – Asea Brown Boveri

ABWR – Advanced Boiling Water Reactor

ADR – Alternative Dispute Resolution

AEA – Atomic Energy Act

AECL – Atomic Energy Canada Limited

AEE – Asociación Empresarian Eólica

AESJ – Atomic Energy Society of Japan

AFP – Agence France Presse

AGEB – Artbeitsgemeinschaft Energiebilanz

AGR – Advanced Gas cooled Reactor

ALARA – As Low As Reasonably Achievable

ALPS – Advanced Liquid Processing System

APWR – Advanced Pressurized Water Reactor

AR5 – 5th Assessment Report of the International Panel on Climate Change

ASLB – Atomic Safety Licensing Board of the U.S. Nuclear Regulatory Commission

ASN – Nuclear Safety Authority, France

BERR – Department for Business, Enterprise and Regulatory Reform, U.K.

BNDES – Brazilian National Development Bank

BNEF – Bloomberg New Energy Finance

BNFL – British Nuclear Fuels Limited

BOO – Build, Own and Operate

BOOT – Build-Own-Operate-Transfer

BP – Beyond Petroleum

BWR – Boiling Water Reactor

CANDU – Canadian Deuterium Uranium

CBI – Confederation of British Industry

CCGT – Combined Cycle Gas Turbine

CCS – Carbon Capture and Storage

CEA – French Atomic Energy Commission

CEIP – Carnegie Endowment for International Peace

CEO – Chief Executive Officer

CEZ – České Energetické Závody

CFD – Contract for Difference

CGN or CGNPC – Chinese Guangdong Nuclear Power Company

CHP – Combined Heat and Power

CIPN – Centre d'Ingénierie du Parc Nucléaire

CNEA – Comision Nacional de Energia Atomica, Argentina

CNECC – China Nuclear Engineering Construction Corporation

CNNC – Chinese National Nuclear Company

CNSC – Canadian Nuclear Safety Commission
COL – Construction and Operation License
COLA – Combined Operating License Applications
CPUC – California Public Utilities Commission
CRE – Energy Regulatory Commission, France
CSN – Consejo de Seguridad Nuclear, Spain
CSP – Concentrating Solar Power
CWIP – Construction Work in Progress
D/W – Drywell
DAC – Design Acceptance Certificate
DAE – Department of Atomic Energy, India
DECC – Department of Energy and Climate Change, U.K.
DTE – Detroit Edison Company
DGEC – Direction générale de l'énergie et du climat, France
DGEMP – Direction Générale de l'Énergie et des Matières Premières, France
DGSNR – Direction Générale de la Sûreté Nucléaire et de la Radioprotection, France
DOE – Department of Energy, U.S.
DPJ – Democratic Party of Japan
DPP – Democratic Progressive Party
DSIN – Direction de la Sûreté des Installations Nucléaires, France
DSR – Design Safety Review
DTI – Department of Trade and Industry, U.K.
EBITDA – Earnings before interest, taxes, depreciation and amortization
EBRD – European Bank for Reconstruction and Development
EC/EBIDTA – Enterprise Value Earnings before interest, depreciation, taxes, and amortization
EDF - Électricité de France
EEX – European Energy Exchange
EIA – U.S. Energy Information Administration or Environmental Impact Assessment
EITB – Euskal Irrati Telebista
EMR – Electricity Market Reform
ENEC – Emirates Nuclear Energy Corporation
ENEL – Ente Nazionale per l'energia Elettrica — National Agency for Electric Energy, Italy
ENSI – Eidgenössische Nuklearsicherheitsinspektorat
ENTSO-E – European Network of Transmission System Operator for Electricity
EPIA – European Photovoltaic Industry Association
EPR – European Pressurized Water Reactor or Evolutionary Pressurized Water Reactor#
ERD – Economic Relations Division of Bangladesh
ERÚ – Czech Energy Regulatory Office
ESBWR – Economic Simplified Boiling Water Reactor
ESP – Early Site Permit
EU – European Union

EU15 – the 15 Western European countries of the EU

EU28 – European Union 28 Member States

EUAS – Elektrik Üretim A.Ş. Genel Müdürlüğü - Turkish Electricity Generation Company

EU ETS – European Union Emissions Trading System

EVN – Electricity of Vietnam

EWEA – European Wind Energy Association

FANC – Federal Agency for Nuclear Control, Belgium

FANR – Federal Authority for Nuclear Regulation, United Arab Emirates

FCF – Free Cash Flow

FEPCO – Federation of Electric Power Companies

FERC – Federal Energy Regulatory Commission

FL3 – Flamanville-3

FIT – Feed-in Tariff

FOCD – Foreign Ownership Restriction

FPL – Florida Power & Light Company

FS – Feasibility Study

FSAR – Final Safety Analysis Report

FY(2014) – Financial Year

GDF – Gaz de France

GAO – Government Accountability Office

GDA – Generic Design Assessment

GDP – Gross Domestic Product

GE – General Electric

GEH – GE Hitachi

GEIS – Generic Environmental Impact Statement

GHG – Greenhouse Gas

GRSR – Generic Reactor Safety Review

GWEC – Global Wind Energy Council

HMSO – Her Majesty's Stationery Office, U.K.

HTR – High Temperature Reactor

I&C – Instrumentation and Control

IAEA – International Atomic Energy Agency

IAS – Information and Analytical Survey

ICANPS – Investigation Committee on the Accident at Fukushima Nuclear Power Station of Tokyo Electric Power Company

IDAC – Interim Design Acceptance Certificate

IEA – International Energy Agency (OECD)

IEEJ – Institute for Energy and Economics of Japan

INES – International Nuclear Event Scale

INIG – Integrated Nuclear Infrastructure Group

IPCC – International Panel on Climate Change

IPFM – International Panel on Fissile Materials
IRSN – Institut de Radioprotection et de Sûreté Nucléaire, France
ISE – Institute for Solar Energy Systems
IZES – Institut für Zukunfts Energie Systeme
JAEC –Japan Atomic Energy Commission or Jordanian Atomic Energy Commission
JAIF – Japan Atomic Industrial Forum
JAPCO – Japan Atomic Power Company
JFBA – Japan Federation of Bar Association
JINED – Japan International Nuclear Energy Development
JNES – Japan Nuclear Energy Safety Organisation
JRC – Joint Research Centre
JSC – Joint Stock Company
JST – Japan Science and Technology Agency
JSW – Japan Steel Works
KA-CARE – King Abdullah City for Atomic and Renewable Energy
KEPCO – Korea Electric Power Corporation, South Korea or Kansai Electric Power Corporation, Japan
KGHM – Copper Mining and Smelting Industrial Complex, Poland
KHNP – Korea Hydro and Nuclear Power
KINS – Korean Institute of Nuclear Safety
KMT – Chinese Nationalist Party
KPMG – Klynveld, Peat, Marwick, Goerdeler
K-POPONS – The Korean Professors' Organization for a Post-Nuclear Energy Society
LDP – Liberal Democratic Party, Japan
LNG – Liquefied Natural Gas
LOCA – Loss of Coolant Accident
LTO – Long Term Outage
LTS – Long Term Shutdown
METI – Ministry of Economics, Trade and Industry, Japan
MHI – Mitsubishi Heavy Industries
MOE – Ministry of Environment, Japan
MoU – Memorandum of Understanding
MOX – Mixed Oxide Fuel
MSC – Mycle Schneider Consulting
NAIIC – National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission
NDA – Nuclear Decommissioning Authority
NEA – Nuclear Energy Agency
NEI – Nuclear Engineering International or Nuclear Energy Institute
NEPA – National Environmental Policy Act
NEXI – Nippon Export and Investment Insurance
NHK – Nippon Hoso Kyokai – Japan Broadcasting Corporation

NINA – Nuclear Innovation North America
NIW – Nuclear Intelligence Weekly
NNB GenCo – Nuclear New Build Generation Company
NNC – National Nuclear Centre, Kazakhstan
NNEGC – National Nuclear Energy Generating Company, Ukraine
NNSA – National Nuclear Safety Administration, China
NPCIL – Nuclear Power Corporation of India Ltd
NPI – Nuclear Power International
NPP – Nuclear Power Plant
NPS – National Policy Statement, U.K.
NPT – Non-Proliferation Treaty
NPV – net present value
NRA – Nuclear Regulation Authority, Japan
NRC – Nuclear Regulatory Commission, U.S.
NRDC – Natural Resources Defense Council
NSG – Nuclear Suppliers Group
NSSC – Nuclear Safety and Security Commission, Korea
NTI – Nuclear Threat Initiative
NW – Nucleonics Week (McGraw Hill)
OECD – Organisation for Economic Development and Co-operation
OFGEM – Office for Gas and Electricity Markets, U.K.
OL3 – Olkiluoto-3
OL4 – Olkiluoto-4
O&M – Operation & Maintenance
ONR – Office of Nuclear Regulation, U.K.
OPG – Ontario Power Generation
OSW – Ośrodek Studiów Wschodnich, Poland
OTC – "Over-The-Counter"
PAEC – Pakistan Atomic Energy Commission
PBMR – Pebble Bed Modular Reactor
PG&E – Pacific Gas and Electric Company
PGE – Polska Grupa Energetyczna
PJM – Pennsylvania-New Jersey-Maryland Interconnection LLC
PLEX – Plant Life Extension
PPA – Power Purchase Agreement
PRIS – Power Reactor Information System
PSC – Public Service Commission, (Florida) USA
PV – Photovoltaic
PwC – PricewaterhouseCoopers
PWR – Pressurized Water Reactor
R&D – Research & Development

RBMK – Light water cooled, graphite moderated reactor

RE – Renewable Energy

RECNA – Research Center for Nuclear Weapons Abolition

REN21 – Renewable Energy Policy Network for the 21st Century

RJIF – Rebuild Japan Initiative Foundation

RTE – Réseau de Transport d'Électricité, France

RWE – Rheinisch-Westfälisches Elektrizitätswerk

S&P – Standard and Poor's

S&SE – Scottish & Southern Energy

SACE – Southern Alliance for Clean Energy

SCRO – State Research Council Office, China

SCE(&G) – Southern California Electric (& Gas)

SCSIN – Service Central de Sûreté des Installations Nucléaires, France

SE – Slovenské Elektràrne ; Slovak Electric

SEA – Strategic Environmental Assessment

SES – Schweizerische Energie-Stiftung

SF – Suomi Finland

SGEI – Service of General Economic Interest

SIEAC – Seoul International Advisory Council

SMP – Sellafield MOX Plant

SNN – Societatea Nationala Nuclearelectrica —Power Generating, and Nuclear Fuel Manufacturing National Society, Romania

SNPTC – State Nuclear Power Technology Corp., China

STP – South Texas Project

STUK – Finnish Radiation and Nuclear Safety Authority

TAEK – Turkish Atomic Energy Authority

TANE – Toshiba American Energy Corporation

TEPCO – Tokyo Electric Power Company

TETAS – Turkish Electricity Trading and Contracting Company

TFEU – Treaty on the Functioning of the European Union

THORP – Thermal Oxide Reprocessing Plant

TSO – Technical Support Organization (of the French Nuclear Safety Authorities)

TVA – Tennessee Valley Authority

TVO – Teollisuuden Voima Tyj

UAE – United Arab Emirates

UBS – Union Bank of Switzerland

UNEP – United Nations Environment Programme

VAT – Value Added Tax

VEB – Vnesheconombank

VRE – Variable Renewable Energy Source

VVER – Light Water Reactor – Russian design

WACC – Weighted Average Cost of Capital
WANO – World Association of Nuclear Operators
WNA – World Nuclear Association
WEC – World Energy Council
WNISR – World Nuclear Industry Status Report
WNN – World Nuclear News
WRI – World Resources Institute
WWF – World Wildlife Fund

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)
MWe – megawatt electric
GW – gigawatt (10^9)
GWe – gigawatt electric
TWh – terawatt hour (10^{12})
----
mSv – millisievert
mSv/h – millisievert per hour
Sv – Sievert
Sv/h – Sievert per hour
Sv/y – Sievert per year

Annex 7: Status of Nuclear Power in the World (1 July 2014)

Countries	Nuclear Reactors[1]				Power[2]	Energy[3]
	Operate (Reactors)	Capacity (MWe)	Average Age (Years)	Under Construction[4] (Reactors)	Share of Electricity[5]	Share of Commercial Primary Energy
Argentina	3	1 627	24	1	4%(=)	2%
Armenia	1	375	34	2	29%(+)	?%
Belarus						
Belgium	7	5 926	34		52%(=)	16%
Brazil	2	1 884	23	1	3%(=)	2%
Bulgaria	2	1 906	25		31%(=)	19%
Canada	19	13 500	31		16%(=)	7%
China	21	16 998	8	28	2%(=)	<1%
Czech Republic	6	3 884	23		36%(=)	17%
Finland	4	2 752	35	1	33%(=)	21%
France	58	63 130	29	1	73%(–)	39%
Germany	9	12 068	29		15%(=)	7%
Hungary	4	1 889	29		50%(+)	17%
India	20	5 125	18	6	3%(=)	1%
Iran	1	915	3		1% (+)	<1%
Japan[7]	2	2 254	22		1,7%(=)	<1%
Mexico	2	1 530	22		5%(=)	1%
Netherlands	1	482	41		3%(=)	<1%
Pakistan	3	690	20	2	4%(+)	1%
Romania	2	1 300	13		20%(=)	8%
Russia	33	23 643	31	9	18%(=)	6%
Slovakia	4	1 816	22	2	52%(–)	21%
Slovenia	1	688	33		34%(–)	?%
South Africa	2	1 860	29		6%(=)	3%
South Korea	22	20 061	18	5	28%(–)	12%
Spain	7	7 121	30		20%(=)	10%
Sweden	10	9 474	35		43%(+)	30%
Switzerland	5	3 308	39		36%(=)	20%
Taiwan	6	5 032	33		19%(=)	8%
Ukraine	15	13 107	26	2	44%(–)	16%
UAE				2		
United Kingdom	16	9 243	31		18%(=)	8%
USA	100	99 070	35	5	19%(=)	8%
EU28	**131**	**121 679**		**4**	**27%(=)**[6]	**12%**
World Total	**388**	**332 548**	**28.5**	**67**	**11%(=)**[5]	**4.4%**

Notes
[1] Mycle Schneider Consulting, based on IAEA, PRIS database, July 2014, and others.
[2] In 2013, based on IAEA, PRIS database, July 2014.
[3] BP, "Statistical Review of World Energy", June 2014.
[4] As of 1 July 2014.
[5] A +/-/= in brackets refer to change in 2013 versus the level in 2012; a change of less than 1% is considered =.
[6] Eurostat, "Electricity Statistics 2013.xls", 9 May 2014, see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Electricity_Statistics_2013.xls, accessed 13 July 2014; and http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Electricity_Statistics_2011_%28in_GWh%29.png&filetimestamp=20120507123319, accessed 7 June 2012.
[7] Average age of Japanese fleet, including LTO: 27 years.

Annex 8. Nuclear Reactors in the World Listed as "Under Construction" (1 July 2014)

Country	Units	MWe (Net)	Construction Start	Planned Grid Connection
Argentina	1	25		
Carem25			08/02/14	2018[1]
Belarus	2	2218		
Belarusian-1		*1109*	06/11/13	2019[2]
Belarusian-2		*1109*	/06/14	2020[3]
Brazil	1	1245		
Angra-3			01/06/10	5/2018[4]
China[5]	28	*27 758*		
Changjiang-1		*610*	25/04/10	4/2015
Changjiang-2		*610*	21/11/10	2/2016
Fangchenggang-1		*1000*	30/07/10	6/2015
Fangchenggang-2		*1000*	23/12/10	2/2016
Fangjiashan-1		*1000*	26/12/08	9/2014
Fangjiashan-2		*1000*	17/07/09	4/2015
Fuqing-1		*1000*	21/11/08	7/2014
Fuqing-2		*1000*	17/06/09	1/2015
Fuqing-3		*1000*	31/12/10	9/2015
Fuqing-4		*1000*	01/10/12	7/2017
Haiyang-1		*1000*	24/09/09	3/2016
Haiyang-2		*1000*	21/06/10	9/2016
Hongyanhe-3		*1000*	07/03/09	9/2014
Hongyanhe-4		*1000*	15/08/09	3/2015
Ningde-3		*1018*	08/01/10	12/2014
Ningde-4		*1018*	29/09/10	8/2015
Sanmen-1		*1000*	19/04/09	12/2015
Sanmen-2		*1000*	17/12/09	6/2016
Shandong Shidaowan		*200*	01/12/12	2/2017
Taishan-1		*1660*	28/10/09	6/2015
Taishan-2		*1660*	15/04/10	9/2015
Tianwan-3		*990*	22/12/12	2/2018
Tianwan-4		*990*	27/09/13	11/2018
Yangjiang-2		*1000*	04/06/09	10/2014
Yangjiang-3		*1000*	15/11/10	9/2015
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[6]			12/08/05	2016
France	1	1 600		
Flamanville-3			03/12/07	2016
India	6	3 907		
Kakrapar-3		*630*	22/11/10	6/2015 (commercial operation)[7]
Kakrapar-4		*630*	22/11/10	12/2015 (commercial operation)[8]
Kudankulam-2		*917*	04/07/02	3/2015 (commercial operation)[9]
PFBR		*470*	23/10/04	09/2014 ("start up date")[10]
Rajasthan-7		*630*	18/11/11	06/2016 (commercial operation)[11]
Rajasthan-8		*630*	30/09/11	12/2016 (commercial operation)[12]
Pakistan[13]	2	630		
Chasnupp-3		*315*	28/05/11	12/2016 (commercial operation)
Chasnupp-4		*315*	18/12/11	10/2017 (commercial operation)

Country	Units	MWe (Net)	Construction Start	Planned Grid Connection
Russia[14]	9	7 273		
BN-800		*789*	01/01/85	2014[15]
Leningrad-2-1		*1085*	25/10/08	2016
Leningrad-2-2		*1085*	15/04/10	2018[16]
Novovoronezh-2-1		*1114*	24/06/08	2014
Novovoronezh-2-2		*1114*	12/07/09	2015[17]
Rostov-3		*1011*	01/01/83	Late 2014[18]
Rostov-4		*1011*	01/01/83	06/2017[19]
Severodvinsk - Lomonosov-1		*32*	15/04/07	31/12/19[20]
Severodvinsk - Lomonosov-2		*32*	15/04/07	01/12/19[21]
Slovakia	2	880		
Mochovce-3		*440*	01/01/85	12/2014[22]
Mochovce-4		*440*	01/01/85	10/2015[23]
South Korea[24]	5	6 320		
Shin-Hanul-1		*1340*	10/07/12	04/2017 (commercial operation)[25]
Shin-Hanul-2		*1340*	19/06/13	02/2018 (commercial operation)[26]
Shin-Kori-3		*1340*	31/10/08	08/2014 (commercial operation)[27]
Shin-Kori-4		*1340*	15/09/09	09/2014 (commercial operation)[28]
Shin-Wolsong-2		*960*	23/09/08	07/2014 (commercial operation)[29]
Ukraine[30]	2	1 900		
Khmelnitski-3		*950*	01/03/86	2019 ?
Khmelnitski-4		*950*	01/02/87	2019
United Arab Emirates[31]	2	2 690		
Barakah-1		*1345*	01/07/12	2017
Barakah-2		*1345*	30/05/13	2018
USA	5	5 633		
Virgil C. Summer-2		*1117*	09/03/13	Late 2017
Virgil C. Summer-3		*1117*	02/11/13	Late 2019
Vogtle-3		*1117*	12/03/13	2018[32]
Vogtle-4		*1117*	19/11/13	2017
Watts Bar-2		*1165*	01/12/72	Sept 2015-June 2016[33]
TOTAL	*67*	63 677	1972-2014	2014-2020

Sources: IAEA-PRIS, 2014, unless otherwise noted.

[1] No startup date in IAEA/PRIS. Commercial operation from WNA, "Nuclear Power in Argentina", Updated May 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Argentina/, accessed 22 May 2014.

[2] No startup date in IAEA/PRIS. This date from WNA, "Nuclear Power in Belarus", Updated June 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Belarus/, accessed 12 June 2014.

[3] No startup date in IAEA/PRIS. Idem.

[4] Delayed numerous times. Latest "commissioning" estimate from NIW, "Potential and Global Nuclear Newbuild Projects", 25 April 2014. By the end of 2013, the unit was said to be about half complete.

[5] Delays officially acknowledged for all 21 pre-2012 construction starts. All dates 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] Delayed. After numerous revisions of the original planned commissioning in 2009, the date refers to "commercial operation". In 2013, Teollisuuden Voima (TVO) was preparing for the possibility that the start of regular electricity production of Olkiluoto 3 may be postponed until year 2016, 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, "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.

[7] Delayed. Grid Connection (31 March 2015) and commercial operation dates deleted from IAEA/PRIS in August 2013. This commercial operation date from NPCIL, "Plants Under Construction, Kakrapar", see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=91, accessed 23 May 2014.

[8] Delayed. Grid Connection (30 September 2015) and commercial operation dates deleted from IAEA/PRIS in August 2013. This commercial operation date from NPCIL, "Plants Under Construction, Kakrapar", see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=91, accessed 23 May 2014.

[9] Delayed numerous times. Construction at least 6 years behind schedule. No IAEA/PRIS startup date. This commercial operation date from NPCIL, "Plants Under Construction, Kudankulam", see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=77, accessed 29 June 2014.

[10] Delayed numerous times. No IAEA start-up date. Latest estimate from WNA, "Nuclear Power in India", Updated 26 June 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/India/, accessed 29 June 2014.

[11] Delayed. Startup date (31 March 2016) was deleted from IAEA/PRIS. This date from NPCIL, "Plants Under Construction, Rajasthan", see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=87, accessed 29 June 2014.

[12] Delayed. Startup date (30 September 2016) was deleted from IAEA/PRIS. This date from NPCIL, "Plants Under Construction, Rajasthan", see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=87, accessed 29 June 2014.

[13] Delayed by three months. Dates were deleted from IAEA/PRIS. These dates from WNA, "Nuclear Power in Pakistan", Updated March 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Pakistan/, accessed 23 May 2014.

[14] No dates for Russian reactors in IAEA/PRIS. All dates ("Start") from WNA, "Nuclear Power in Russia", Updated May 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Russia--Nuclear-Power/, accessed 23 May 2014, unless otherwise noted.

[15] Delayed numerous times. Criticality in June 2014. Grid connection expected soon.

[16] Uncertainty concerning previous planned startup date (2016).

[17] Previously announced to start up in 2016.

[18] Delayed numerous times.

[19] Delayed numerous times.

[20] Delayed several times. This estimate 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 23 May 2014.

[21] Delayed several times. This estimate from WNA Reactor Database, "Akademik Lomonosov 2", see http://world-nuclear.org/NuclearDatabase/reactordetails.aspx?id=27570&rid=A0D78EB7-B62A-48FF-9D78-21A8E4534D90, accessed 23 May 2014.

[22] Delayed numerous times. Latest IAEA/PRIS date was deleted. This estimate from WNA, "Nuclear Power in Slovakia", Updated April 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Slovakia/, accessed 23 May 2014.

[23] Delayed numerous times. Latest IAEA/PRIS date was deleted. WNA says "first power 10/2015"; WNA, "Nuclear Power in Slovakia", Updated April 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Slovakia/, accessed 23 May 2014.

[24] No IAEA startup date for any Korean reactor. All dates from KHNP (Korean Hydro and Nuclear Power Co).

[25] KHNP, "Shin-Hanul #1, 2", as of 30 April 2014, see http://cms.khnp.co.kr/eng/shin-ulchin-12/, accessed 29 June 2014.

[26] Ibidem.

[27] Delayed by at least 11 months. KHNP, "Shin-Kori #3, 4", as of 30 April 2014, see http://cms.khnp.co.kr/eng/shin-kori-34/, accessed 29 June 2014; WNA says possibly to 2015 following quality-control falsification scandal; WNA, "Nuclear Power in South Korea", see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/South-Korea/, accessed 29 June 2014.

[28] Delayed by at least 3 months. KHNP, "Shin-Kori #3,4", as of 30 April 2014, see http://cms.khnp.co.kr/eng/shin-kori-34/, accessed 29 June 2014; WNA says possibly to 2016 following quality-control falsification scandal, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/South-Korea/, accessed 29 June 2014.

[29] Delayed by about 2 years. KHNP says "Follow-up process postponed due to delay in acquisition of Operating License". KHNP, "Shin-Wolsong #1,2", see http://cms.khnp.co.kr/eng/shin-wolsong-2/, accessed 29 June 2014.

[30] Delayed numerous times. Latest IAEA/PRIS grid connection dates were deleted. Commercial operation dates from WNA, "Nuclear Power in Ukraine", Updated May 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/Ukraine/, accessed 23 May 2014.

[31] No IAEA startup dates. Dates for both reactors from WNA, "Nuclear Power United Arab Emirates", Updated April 2014, see http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Arab-Emirates/, accessed 23 May 2014.

[32] Delayed from planned startup date (April 2016 to January 2018), see Athens Baner Herald, "Monitor warns of delays building Plant Vogtle", 23 June 2014, see http:/m.onlineathens.com/local-news/2014-06-23/monitor-warns-delays-building-plant-vogtle, accessed 17 July 2014.

[33] Delayed numerous times. This date from TVA, "Watts Bar Unit 2 Project Ready for Open Vessel Testing", 2 May 2014, see http://www.tva.com/news/releases/aprjun14/wb2_open_vessel_testing.htm, accessed 3 June 2014.