



World Nuclear Industry Status Report 2012

By Mycle Schneider
and Antony Froggatt
with Julie Hazemann

A Mycle Schneider Consulting Project
Paris, London, July 2012

With the support of

LE MONDE
diplomatie

SCHWEIZERISCHE ENERGIE-STIFTUNG
FONDATION SUISSE DE L'ENERGIE

Hatzfeldt
Foundation

The World Nuclear Industry Status Report 2012

By

Mycle Schneider

Independent Consultant, Paris, France
Project Coordinator and Lead Author

and

Antony Froggatt

Independent Consultant, London, U.K.
Author

With

Julie Hazemann

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

Paris, London, July 2012

A

MYCLE SCHNEIDER CONSULTING
Project

With the support of

Le Monde
diplomatique



Hatzfeldt Foundation

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, USA. He has provided information and consulting services to the Belgian Energy Minister, the French and German Environment Ministries, the U.S. Agency for International Development, the International Atomic Energy Agency, Greenpeace, the International Physicians for the Prevention of Nuclear War, the Worldwide Fund for Nature, the European Commission, the European Parliament's Scientific and Technological Option Assessment Panel and its General Directorate for Research, the Oxford Research Group, and the French Institute for Radiation Protection and Nuclear Safety. Mycle has given evidence and held briefings at Parliaments in thirteen countries. 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 fourteen universities 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.

Acknowledgments

The authors wish to thank Amory B. Lovins, Chris Paine, Hermann Hatzfeldt, Yves Marignac, Reiner Metzger, Bernhard Piller, Philippe Rekacewicz, Philippe Rivière, Luis Speciale, Le Monde Diplomatique, Paris, Die Tageszeitung, Berlin, Swiss Renewable Energy Foundation and the Natural Resources Defense Council (NRDC), Washington, D.C. for their support for this project.

A big thank you to John Corbett for his extensive research assistance on finances and to Jörg Kohn for designing the original cover page.

The report has greatly benefitted from proof-reading, editing suggestions and comments by Shaun Burnie, Amory B. Lovins, Lutz Mez, Walt Patterson, MV Ramana, Sabine von Stockar and Steve Thomas.

Special thanks to Julie Hazemann, for—besides everything else—repeatedly making extra time available while there was none left to begin with.

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 suggestions of improvement.

Authors' Contacts

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

Antony Froggatt
53a Nevill Road
London N16 8SW
United Kingdom
Ph: +44-20-79 23 04 12
E: a.froggatt@btinternet.com

Table of Contents

Executive Summary & Conclusions.....	4
Introduction	9
General Overview Worldwide.....	10
Overview of Operation, Power Generation, Age Distribution	11
Overview of Current New Build	14
Potential Newcomer Countries.....	21
Projects and programs officially abandoned in 2011	28
Unfulfilled Promises	29
Unrealistic Projections.....	29
Construction Times of Past and Currently <i>Operating</i> Reactors.....	30
Construction Times and Costs of Reactors Currently <i>Under Construction</i>	32
Watts Bar-2 – 43 Years Construction.....	32
EPR – European Problem Reactor	32
Financial Markets and Nuclear Power.....	35
Financial Institutions’ Views of Nuclear Power	35
Credit Rating Agencies and Nuclear Power	36
Market Value	38
Book Value.....	39
Nuclear Power vs. Renewable Energy Deployment	41
Investment	41
Installed Capacity	42
Electricity Generation.....	45
The Renewables and Nuclear Cost Cross-Over	48
Grid Parity	48
Nuclear vs. Renewable Costs	49
Annexes.....	51
Annex 1. Overview by Region and Country	52
Africa.....	52
The Americas.....	53
United States Focus	56
Asia.....	59
China Focus.....	59
Japan Focus	63
European Union (EU27) and Switzerland.....	68
Western Europe	70
France Focus.....	72
Germany Focus.....	74
U.K. Focus.....	78
Central and Eastern Europe	81
Former Soviet Union	86
Annex 2: Reactor Construction Times 1992-2012.....	90
Annex 3: Construction and Operating License (COL) Applications in the U.S.	91
Annex 4: Construction Times in the U.S. and France	92
Annex 5: Definition of Credit Rating by the Main Agencies.....	93
Annex 6: Abbreviations.....	94
Annex 7. Status of Nuclear Power in the World (1 July 2012).....	96
Annex 8. Nuclear Reactors in the World Listed as “Under Construction” (1 July 2012).....	97

Executive Summary & Conclusions

Twenty years after its first edition, *World Nuclear Industry Status Report 2012* portrays an industry suffering from the cumulative impacts of the world economic crisis, the Fukushima disaster, ferocious competitors and its own planning and management difficulties.

The report provides a global overview of the history, the current status and trends of nuclear power programs in the world. It looks at units in operation and under construction. Annex 1 also provides detailed country-by-country information. A specific chapter assesses the situation in potential newcomer countries. For the first time, the report looks at the credit-rating performance of some of the major nuclear companies and utilities. A more detailed chapter on the development patterns of renewable energies versus nuclear power is also included.

The performance of the nuclear industry over the 18 months since the beginning of 2011 can be summed up as follows:

Reactor Status and Nuclear Programs

- **Startups and Shutdowns.** Only seven reactors started up, while 19 were shut down in 2011¹ and to 1 July 2012, only two were started up, just compensating for two that were shut down so far this year. As of end of June 2012 no reactor was operating in Japan and while two units at Ohi have got restart permission, it remains highly uncertain, how many others will receive permission to restart operations.
- **Nuclear Phase Out Decisions.** Four countries announced that they will phase out nuclear power within a given timeframe: Belgium, Germany, Switzerland and Taiwan.
- **Newcomer Program Cancellations.** At least five countries have decided not to engage or re-engage in nuclear programs, although they had previously planned to do so: Egypt, Italy, Jordan, Kuwait, and Thailand.
- **New Nuclear Countries.** Iran became the first country to start commercial operation of a new nuclear power program since Romania in 1996.

Construction & New Build Issues

- **Construction Cancellation.** In both Bulgaria and Japan two reactors under construction were abandoned.
- **Construction Starts.** In 2011, construction began on four reactors and two so far in 2012.
- **New Build Project Cancellation.** In Brazil, France, India and the United States new build projects were officially cancelled. In the Netherlands, the U.K. and the U.S. key utilities withdrew leaving projects in jeopardy.
- **Certification Delays.** The certification of new reactor technologies has been delayed numerous times. The latest announcement concerns the certification in the U.S. of the Franco-German designed EPR² that was pushed back by 18 months to the end of 2014.
- **Construction Start Delays.** In various countries firmly planned construction starts were delayed, most notably in China, where not a single new building site was opened, but also in Armenia, Finland and the U.S.

¹ We define shut down as definitively taken off the grid. This includes the 10 Fukushima reactors, of which four are destroyed; units 5 and 6 at Daiichi and the four reactors at Daiini remain in cold shutdown and are almost certain never to operate again. However, their definitive closure has not yet been officially confirmed.

² European Pressurized Water Reactor (in Europe) or Evolutionary Pressurized Water Reactor (in the U.S. and elsewhere).

- **Construction License Delays.** In the U.S. licensing applications for 28 reactors were received for the first time in over three decades in a two-year period between July 2007 and June 2009, but nothing since. Of the 28 applications, 16 were subsequently delayed and eight were suspended indefinitely or officially cancelled. However, for the first time in over 30 years two construction licenses were issued.
- **Construction Delays.** Of the 59 units under construction in the world, at least 18 are experiencing multi-year delays, while the remaining 41 projects were started within the past five years or have not yet reached projected start-up dates, making it difficult to assess whether they are running on schedule. On construction delays the U.S. Watts-Bar-2 project holds the record. Construction started in 1973 and grid connection was finally planned for 2012, but was delayed again until “late 2015 or 2016”.
- **Newcomer Countries.** The analysis of a number of potential newcomer countries³ shows that few, if any, new members of the nuclear operators club to be expected over the next few years. No financing agreements are in place for any of the cases studied, many of them have to deal with significant public opposition, especially after the Fukushima accident and often they lack a skilled workforce and appropriate legal framework. Some countries have to deal with particularly adverse natural conditions (earthquake and flooding risks, lack of cooling water access, etc.). Finally, nuclear power’s principle competitors, mainly renewables and natural gas on the production side, increasingly are more affordable and much faster to install.

Economics & Finances

- **Cost Increases.** Construction costs are a key determinant of the final nuclear electricity generating costs and many projects are significantly over budget: The U.S. Watts-Bar-2 reactivation project alone increased by 60 percent over the past five years; the EPR cost estimate has increased by a factor of four (adjusted for inflation) over the past ten years.
- **Credit Rating.** Of eleven assessed nuclear companies and utilities, seven were downgraded by credit rating agency Standard and Poor’s over the past five years; four companies remained stable, while none were upgraded over the same period. Rating agencies consider nuclear investment risky and “a nuclear project could be the thing that pushes [the utility] over the edge—it’s just another negative factor”, explains Moody’s. On the contrary, the rating agency welcomed the decision by German utilities RWE and E.ON to pull the plug on their U.K. new build plans as they “can instead focus on investment in less risky projects”. Similarly, electronics giant Siemens announcement to entirely withdraw from nuclear power “frees up funds that Siemens can redeploy in businesses with better visibility”. Both decisions are consequently considered “credit positive”.
- **Share Value.** The assessment of a dozen nuclear companies reveals that all performed worse than the UK FTSE100 index, the only exception being Scottish SSE, which has recently pulled out of plans to build nuclear plants in the UK. TEPCO, owner of the devastated Fukushima site, lost 96% of its share value since 2007. Over the same time period, more surprisingly, the shares of the world’s largest nuclear operator, French state utility EDF, lost 82 percent of their value, while the share price of the world’s largest nuclear builder, French state company AREVA, fell by 88 percent.

³ Bangladesh, Belarus, Indonesia, Jordan, Poland, Saudi Arabia, Thailand, Turkey, United Arab Emirates, and Vietnam. As indicated, programs were officially abandoned in Egypt, Italy and Kuwait.

Nuclear Power vs. Renewable Energy Deployment

In contrast to many negative indicators for nuclear power renewable energy development has continued with rapid growth figure. This has taken place during the ongoing international economic crisis, significant cuts in guaranteed feed-in tariffs and worldwide manufacturing overcapacities.

- **Investment.** Global investment in renewable energy totaled US\$260 billion in 2011, up five percent from the previous year and almost five times the 2004 amount. Considering a 50 percent unit price drop over the past year, the performance of solar photovoltaics (PV) with US\$137 billion worth of new installations, an increase of 36 percent, is all the more impressive. The total cumulative investment in renewables has risen to over US\$1 trillion since 2004, according to Bloomberg New Energy Finance, this compares to our estimate of nuclear power investment decisions of approximately \$120 billion over the same time period. The rise and fall of nuclear investments is essentially due to the evolution of the Chinese program, with 40 percent of current worldwide construction.
- **Installed Capacity.** Installed worldwide nuclear capacity decreased in the years 1998, 2006, 2009 and again in 2011, while the annual installed wind power capacity increased by 41 GW⁴ in 2011 alone. China constitutes an accelerated version of this global pattern. Installed wind power capacity grew by a factor of 50 in the past five years to reach close to 63 GW, five times more than the installed nuclear capacity and equivalent to the French nuclear fleet.⁵ Solar capacity was multiplied by a factor of 47 in those five years to reach 3.8 GW, while nuclear capacity increased by a factor of 1.5 to 12 GW. Since 2000, within the European Union nuclear capacity decreased by 14 GW, while 142 GW of renewable capacity was installed, 18 percent more than natural gas with 116 GW.⁶
- **Electricity Generation.** The quantity of electricity produced by nuclear power plants globally has been increased only slightly over the past decade and as a result its contribution to the global energy mix is decreasing as other sources accelerate production. In 2011 wind turbines produced 330 TWh more electricity than it did at the turn of the century, which is a four times greater increase than was achieved by the nuclear sector over the same period. The growth in solar PV generated power has been impressive in the last decade and especially in the past few years, with a tenfold increase in the past five years. In Germany, for the first time, power production from renewables at 122 TWh (gross), only second to the contribution of lignite 153 TWh, exceeded coal's 114.5 TWh, nuclear power's 102 TWh and natural gas' 84 TWh. The German renewable electricity generation thus corresponded to 29 percent of French nuclear production. One should recall that France generates almost half of the European Union's nuclear electricity. In China, just five years ago, nuclear plants were producing ten times as much electricity as wind, by 2011 the difference had shrunk to less than 30 percent.
- **Grid Parity.** Grid parity occurs when the unit costs of renewable energy is equal to the price that end users pay for their electricity. Grid parity for solar photovoltaic power has already happened in a number of markets and regions with particular conditions. Several assessments expect that this will become a worldwide phenomenon within less than a decade. This will radically change the incentives for further large scale expansion of solar facilities around the world.

Lifetime Extensions and Stress Tests

As a result of insufficient new capacities coming online, the average age of the world's operating nuclear fleet continues to increase and now stands at 27 years. Assuming a 40-year lifetime, 67 additional units or 35 GW would have to be ordered, built and commissioned by 2020, beyond the units already under construction, just to maintain the status quo. This is an unlikely scenario,

⁴ GW stands for gigawatt or thousand megawatt.

⁵ Note that nuclear plants usually generate between two and five times more electricity per installed GWe than wind turbines.

⁶ Note that the electricity generation per installed GWe varies considerably between energy sources.

although not entirely impossible, if China were to restart building large numbers of reactors. Furthermore, as our lifetime extension projections illustrate, the systematic prolonged operation of reactors up to licensed limits (up to 60 years) would not fundamentally change the problem of the industry.⁷ An additional 19 reactors would have to begin operation in order to break even by 2020, but the installed capacity would be slightly positive (+4 GW). This scenario is possible, but will require a number of specific conditions including that the generalized lifetime extension is technically feasible, economically attractive and publicly and politically acceptable.

Plant life extension seems the most likely survival strategy of the nuclear industry at this point. The French case illustrates this. As the French Court of Audits has calculated, eleven EPRs would have to be built in France by the end of 2022 in order to maintain the current nuclear share. “This seems highly unlikely, if not impossible, including for industrial reasons”, the Court comments and concludes: “This implies one of two things: a) either it is assumed that plants will operate for more than 40 years (...); b) or the energy mix will move towards other energy sources. However, no clear public decision has been made concerning these major strategic issues, even though they call for short-term action and major investments.” An appropriate description for the situation in many nuclear countries.

Serious questions need to be raised about the extent to which the lessons of Fukushima are being even considered by today’s nuclear operators. There are around 400 nuclear power reactors in operation and in the absence of a major new build the nuclear industry is pushing to keep those units operating as long as possible. The fact that one third of the nuclear countries generated their historic maximum of nuclear electricity in 2011⁸ raises the troubling question of the depth of the nuclear safety assessments or so-called “stress tests” carried out around the world after 3/11. This study did not assess safety issues, but if plant life extension becomes the only future for the industry, the pressure on safety authorities will grow substantially.

Conclusion

Prior to the March 2011 (3/11) Fukushima disaster, the nuclear industry had made it clear that it could not afford another major accident. Over the past ten years the industry has sold a survival strategy to the world as the nuclear revival or its renaissance. In reality many nuclear companies and utilities were already in great difficulties before the triple disaster hit the Japanese east coast in 2011.

Fifteen months after 3/11, it is likely that the decline of the industry will only accelerate. Fukushima continues to have a significant impact on nuclear developments everywhere. Fifteen years ago, nuclear power provided over one third of the electricity in Japan, but as of May 2012 the last operating reactor was closed. The Japanese government is facing massive opposition to nuclear power in the country, thus making the restart of any reactors difficult. The controversy over the restart permission for the Ohi reactors in the Kansai region illustrates the dilemma. Germany shut down half of its nuclear fleet after 3/11. Japan and Germany could be leading a new trend. The German direction is clear with the possibility of Japan following: an electricity system based on highly efficient use and renewable energy technologies, even if many questions remain, including the timescale, local versus centralized, grid transformation and smart system development. It appears increasingly obvious that nuclear systems are not competitive in this world, whether from systemic, economic, environmental or social points of view.

The nuclear establishment has a long history of failing to deliver. In 1973-1974, the International Atomic Energy Agency (IAEA) forecasted an installed nuclear capacity of 3,600-5,000 GW in the world by 2000, ten times what it is today. The latest example was from Hans Blix, former Director General of the IAEA, who stated two months after 3/11: “Fukushima is a bump in the road...”. The statement is both crass and far from today’s reality.

⁷ It raises a whole range of safety related issues that we have not analyzed in this report.

⁸ Brazil, China, Czech Republic, Hungary, India, Iran, South Korea, Pakistan, Russia, Taiwan

Operation and Construction Data as of 1 July 2012⁹

Operation. There are 31 countries operating nuclear power plants in the world¹⁰, one more than a year ago, with Iran finally starting up the Bushehr reactor that had been under construction since 1975. A total of 429 reactors combine an installed capacity of 364 GWe¹¹. These figures assume the final shutdown of the ten Fukushima reactors. It should be noted that as of 5 July 2012 only one (Ohi-3) of the 44 remaining Japanese reactors is operating and their future is highly uncertain. This compares to the historical maximum of 444 reactors in 2002. Installed capacity peaked in 2010 at 375 GWe before declining to the level of a decade ago. Nuclear electricity generation reached a maximum in 2006 with 2,660 TWh and dropped to 2,518 TWh in 2011 (down 4.3 percent compared to 2010), while the nuclear share in the world's power generation declined steadily from a historic peak of 17 percent in 1993 to about 11 percent in 2011.

Construction. There are 13 countries currently building nuclear power plants, two fewer than a year ago with Iran starting up its plant and Bulgaria abandoning construction at the two Belene units where work had started in 1987. Japan halted construction at two sites (Ohma and Shimane-3) and Pakistan started construction on two units (Chasnupp-3 and -4). There are currently 59 reactors under construction with a total capacity of 56 GW. However:

- Nine reactors have been listed as “under construction” for more than 20 years.
- Four additional reactors have been listed for 10 years or more.
- Forty-three projects do not have an official (IAEA) planned start-up date.
- At least 18 of the 59 units listed by the IAEA as “under construction” have encountered construction delays, most of them multi-annual. Of the remaining 41 reactor units construction began either within the past five years or they have not reached projected start-up dates yet. This makes it difficult or impossible to assess whether they are on schedule or not.

Nearly three-quarters (43) of the units under construction are located in three countries: China, India and Russia.

⁹ See table in 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.

¹⁰ Unless otherwise noted, the figures indicated are as of 1 July 2012.

¹¹ All figures are given for nominal net electricity generating capacity. GW stands for gigawatt or thousand megawatt.

Introduction

The Chernobyl disaster "*caused such a negative opinion of nuclear energy that, should such an accident occur again, the existence and future of nuclear energy all over the world would be compromised.*"

World Association of Nuclear Operators (WANO), 1996

The triple disaster earthquake-tsunami-nuclear accident that hit Japan on 11 March 2011 had a profound impact on environmental, economic and energy policy not just in Japan but far beyond. The Japanese people were and are deeply traumatized by the aftermath of the tragedy now widely known as 3/11. Trust in political leaders was shaken, confidence in apparently superior technology destroyed. In China the government froze all new nuclear projects and the public became aware of the nuclear power issue through the disastrous events in its neighbouring country. In South Korea public support for nuclear power plummeted. Governments in many countries are reviewing their nuclear plans. Belgium and Germany confirmed nuclear phase-out legislation by 2025 and 2022 respectively. The Netherlands and Switzerland have abandoned new reactor build projects.

The expression of opposition to nuclear programs is changing. In Japan, on 28 April 2012, 64 mayors and 6 former mayors from 35 prefectures have started a network with the aim of creating communities that do not rely on nuclear energy, with the ultimate aim of achieving a nuclear-free Japan. Members include the heads of the cities of Sapporo, Nagoya, the 3/11-stricken town of Minamisoma and Tokyo's Setagaya Ward as well as Tokai-mura's mayor. Tokai-mura hosts the nuclear power plant closest to Tokyo, which has not operated since 3/11.

On 5 May 2012, the last operating reactor went offline in Japan. The local authorities play a key role in preventing the restart of nuclear plants in Japan as an unwritten law requires their approval prior to operating. Local authorities have increasingly raised their voices in other countries. In South Korea the mayor of Seoul has vowed to reduce energy consumption of the city in order to save the equivalent of the output of a nuclear reactor. Even in China, a local authority has voiced opposition to the construction of the Pengze nuclear plant in a neighboring district. In France, several dozen municipalities, including the city of Strasbourg, have voted a motion requesting the closure of the Fessenheim nuclear plant.

In 1992, in order to assess the impact of the Chernobyl disaster on the global nuclear industry and the resultant trends, Greenpeace International, WISE-Paris and the Washington based Worldwatch Institute jointly published the first *World Nuclear Industry Status Report*. "Many of the remaining plants under construction are nearing completion so that in the next few years worldwide nuclear expansion will slow to a trickle", we wrote. "It now appears that in the year 2000 the world will have at most 360,000 megawatts of nuclear capacity – only ten percent above the current figure." The actual figure for 2000 was an installed capacity of 356,600 MW. "Not only coal plants, but also new, highly efficient natural gas plants, and new technologies such as wind turbines and geothermal energy, are all substantially less expensive than new nuclear plants. The market niche that nuclear power once held has in effect gone", we concluded twenty years ago. In 2012, reality has confirmed that assessment and nuclear power's competitors have most definitely taken over as this latest report demonstrates.

General Overview Worldwide

*Even before the Fukushima disaster,
the long-awaited nuclear renaissance in the West
seemed to be running out of steam.*

Energy Economist
February 2012

As of the middle of 2012, a total of 31 countries were operating nuclear fission reactors for energy purposes—one more than in 2010–11, with Iran finally starting up its Bushehr reactor, construction of which began in 1975. Nuclear power plants generated 2,518 Terawatt-hours (TWh or billion kilowatt-hours) of electricity in 2011¹², the same as in 2001 and a 112 TWh or 4.3 percent decrease compared to 2010, which is 5.3 percent less than the historic maximum in 2006. The maximum share of nuclear power in commercial electricity generation worldwide was reached in 1993 with 17 percent (see figure 1). It has dropped to 11 percent in 2011, a level last seen in the early 1980s.

This decline in 2011 corresponds to more than the annual nuclear generation in all but five of the nuclear countries. The decline is exclusively caused by the substantial drop in Japan (124 TWh or 44 percent), Germany (31 TWh or 23 percent) and the United States (17 TWh or 2 percent), since in all but five countries nuclear generation actually increased or remained stable in 2011. Ten countries¹³ even generated their historic maximum in 2011. Considering the decision in many countries to carry out “stress tests” or other nuclear safety audits at their facilities following the 3/11 events, this is a rather surprising result. It indicates that inspection and analysis did not have any operational impact in most cases, which might suggest the assessments were brief and limited in scope.¹⁴

The “big six” countries—France, Germany, Japan, Russia, South Korea, and the United States—generated over 70 percent of all nuclear electricity in the world. Two thirds of the 31 countries operating reactors are nevertheless past their nuclear generation peak. The three countries that have phased-out nuclear power (Italy, Kazakhstan, Lithuania), and Armenia, generated their historical maximum of nuclear electricity in the 1980s. Several other countries’ nuclear power generation peaked in the 1990s, among them Belgium, Canada, Japan, and the UK. And six additional countries peaked generation between 2001 and 2005: Bulgaria, France, Germany, South Africa, Spain, and Sweden. Among the countries with a steady increase in nuclear generation are China, the Czech Republic and Russia. However, even where countries are increasing their nuclear electricity production this is often not keeping pace with overall increases in electricity demand leading to a reduced role for nuclear power.

In fact, all nuclear countries—with the exception of Iran that started up its first nuclear plant only in 2011—reached the maximum share of nuclear power prior to 2010. While five countries peaked in 2008 (China) or 2009 (Armenia, Czech Republic, Romania, Russia), the other 25 countries saw their largest nuclear share up to 2005. In total, nuclear power in nine countries played its largest role during the 1980s¹⁵, in twelve countries in the 1990s and in thirteen countries in the 2000s.

Increases in nuclear generation are mostly as a result of higher productivity and uprating¹⁶ at existing plants rather than to new reactors. According to the latest assessment by *Nuclear Engineering International*¹⁷, the global annual load factor¹⁸ of nuclear power plants decreased from 77 to

¹² 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, www.iaea.org/programmes/a2/index.html.

¹³ Brazil, China, Czech Republic, Hungary, India, Iran, South Korea, Pakistan, Russia, Taiwan

¹⁴ The so-called “stress tests” have been subject to multiple criticisms, however, they are not the subject of analysis in this report.

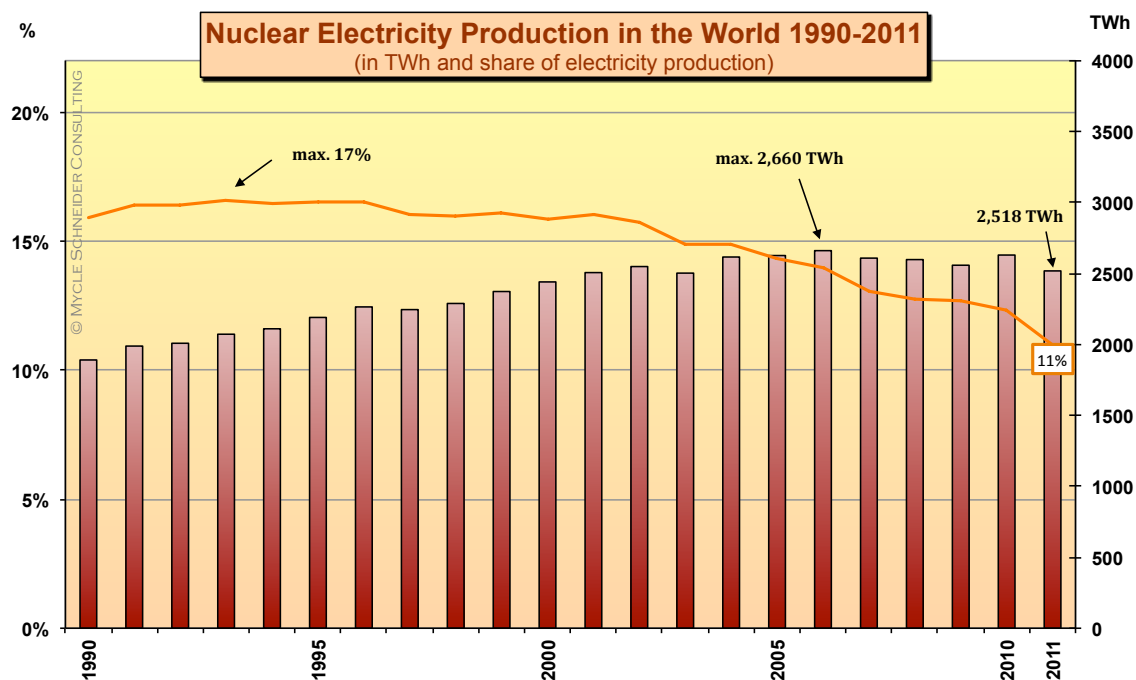
¹⁵ Belgium, Finland, Germany, Italy, Netherlands, South Africa, South Korea, Spain, Taiwan.

¹⁶ Increasing the capacity of nuclear reactors by engineering changes like more powerful steam generators or turbines.

¹⁷ Nuclear Engineering International, “Load Factors to end December 2011”, May 2012.

76 percent in 2011. Not surprisingly the biggest change was seen in Japan, where the load factor plunged from an already modest 69.5 percent to 39.5 percent. This is also due to the fact that officially 50 of the 54 pre-3/11 units in Japan are still counted as operational—even though some reactors have not generated electricity for years.¹⁹ In Germany eight units have been officially closed very quickly and thus do not appear in the year-end load factor of 85 percent anymore.

Figure 1: Nuclear Electricity Generation in the World



Source : IAEA-PRIS, BP, MSC, 2012

Taiwan and Romania had the highest load factors in 2011 with 95.5 and 95.4 percent respectively. Russia is generally on an upward trend (now 80 percent) with load factors of the 15 operating Chernobyl-type RBMK (light water cooled, graphite moderated) reactors rising from 60 percent to 81 percent between 2010 and 2011. South Korea is fluctuating at a very high level (90 percent). The U.S. is continuing an excellent average load factor of 86 percent, especially considering its large operating fleet. France at a load factor of 76 percent has increased productivity but remains on the lower end of the performance indicator.

Overview of Operation, Power Generation, Age Distribution

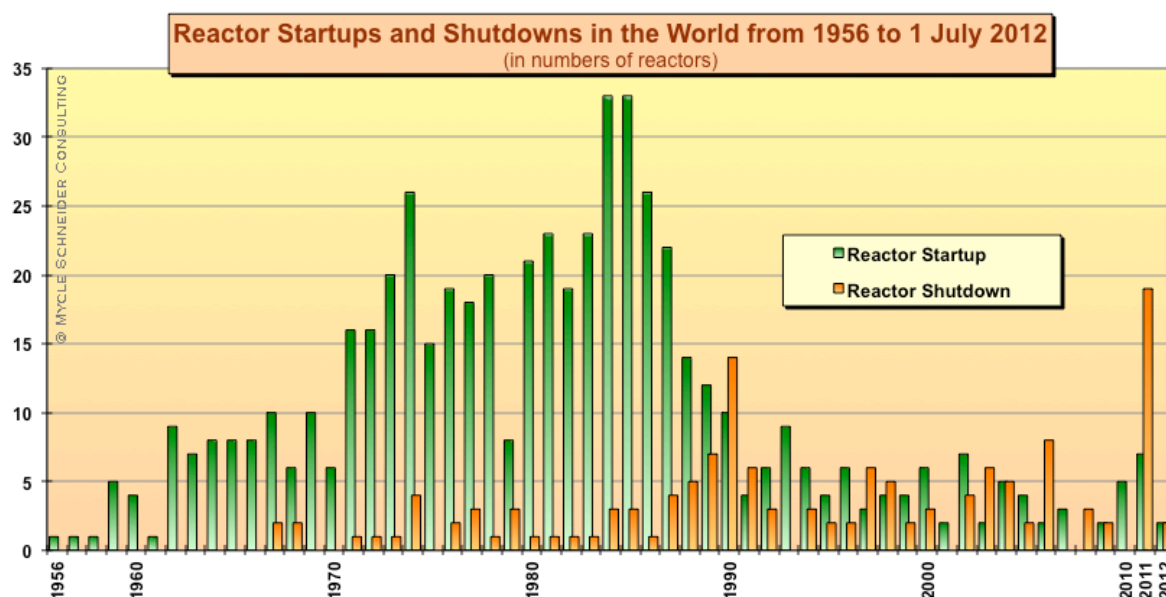
There have been two major waves of grid connections since the beginning of the commercial nuclear age in the mid-1950s. (See Figure 2.) A first wave peaked in 1974, with 26 reactor startups. The second wave occurred in 1984 and 1985, the years preceding the Chernobyl accident, reaching 33 grid connections 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 1992-2001 decade showed almost twice as many startups than shutdowns

¹⁸ 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.”

¹⁹ Three units of the Kashiwazaki Kariwa plant, for example, have been off-line since the earthquake in 2007.

(50/26), while in the past decade 2002-2011 the trend reversed (36/49), notably with 19 units²⁰ closing and only seven starting up in 2011.²¹

Figure 2. Nuclear Power Reactor Grid Connections and Shutdowns, 1956–2012



Source: IAEA-PRIS, MSC, 2012

As of 1 July 2012, under the Baseline Scenario (see hereunder), a total of 429 nuclear reactors were considered operating in 31 countries, down 15 from the maximum of 444 in 2002. The current world reactor fleet has a total nominal capacity of about 362.5 gigawatts (GW or thousand megawatts). However, there are large uncertainties to these figures, mainly stemming from the undefined future of the 50 Japanese nuclear reactors that are officially still operating but are all shut down as of 1 July 2012. We have therefore considered three scenarios:

- **The Baseline Scenario.** Only the 10 Fukushima reactors are permanently closed.
- **The East Coast Scenario.** In addition to the Fukushima units, the seven reactors impacted either directly or indirectly by 3/11 events remain closed. These include three Onagawa reactors that were closest to the 3/11 epicenter, the three remaining Hamaoka units, shut down at the request of former Prime Minister Naoto Kan because of high earthquake risk estimates and the Tokai reactor, the nuclear plant closest to the Tokyo Metropolitan area (ca. 100 km). The total number of operating units in the world would drop to 421 and the installed capacity to 356 GWe.
- **The German Scenario.** In addition to the units considered closed under the Baseline and East Coast Scenarios the 12 reactors with an operational age in excess of 30 years will remain shut down. The German government decided in the wake of 3/11 to shut down for good the eight reactors that had operated for over three decades. That would leave Japan with 25 operating reactors, the worldwide figure would drop to 409, last seen in 1987, and the installed capacity to 348 GWe, not experienced since the middle of the 1990s.

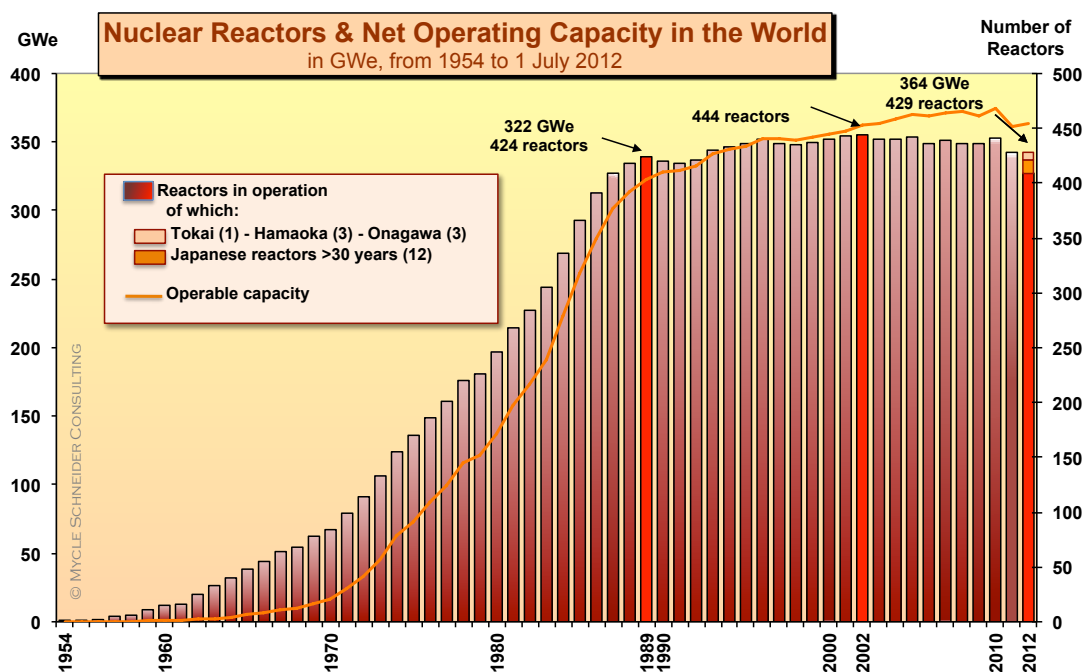
²⁰ Ten in Japan, eight in Germany, one in the UK. In Japan, these are the 10 Fukushima reactors, of which four are destroyed; units 5 and 6 at Daiichi and the four reactors at Daiini remain in cold shutdown and are almost certain never to operate again. However, their definitive closure has not yet been officially confirmed.

²¹ Three in China (including an experimental breeder reactor of 20 MW in China, which is counted by the IAEA, but strangely had never been in its statistics of units “under construction”), plus one each in India, Iran, Pakistan and Russia.

Considering the opposition in Japan, especially by local authorities under the influence of an increasingly vocal public opinion, against the restart of *any* nuclear power plant (see Japan Focus for details), it is possible that there will be the short-term closure of the majority of the nuclear program in the country. This would not be a “phase-out” scenario but rather the simple “abandoning” of nuclear power. Every authorization of restart will be subject to intense battles between promoters and opposition of the nuclear option. Under these circumstances, the scenarios above could prove quite conservative.

The total world installed nuclear capacity has decreased only six times since the beginning of the commercial application of nuclear fission, all in the past 15 years—in 1997, 2003, 2007, 2008, 2009 and 2011. Despite 15 fewer units operating in early 2012 compared to 2002, the generating capacity is still about identical. 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 140 uprates since 1977. These included, in 2011, five uprates between 1.6 percent (Surry 1 and 2) and 17 percent (Point Beach 1 and 2)²². The cumulative approved uprates in the United States total 6.2 GW.²³ Most of these have already been implemented, and applications for an additional 1.5 GW in increases at 20 units are pending.²⁴ 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, but upgrading and extending the operating lives of older reactors will result in lower safety margins than replacement with more modern designs.

Figure 3. World Nuclear Reactor Fleet, 1954–2012



Sources: IAEA-PRIS, MSC, 2012

²² The fifth uprate (15 percent) was authorized at Nine Mile Point 2.

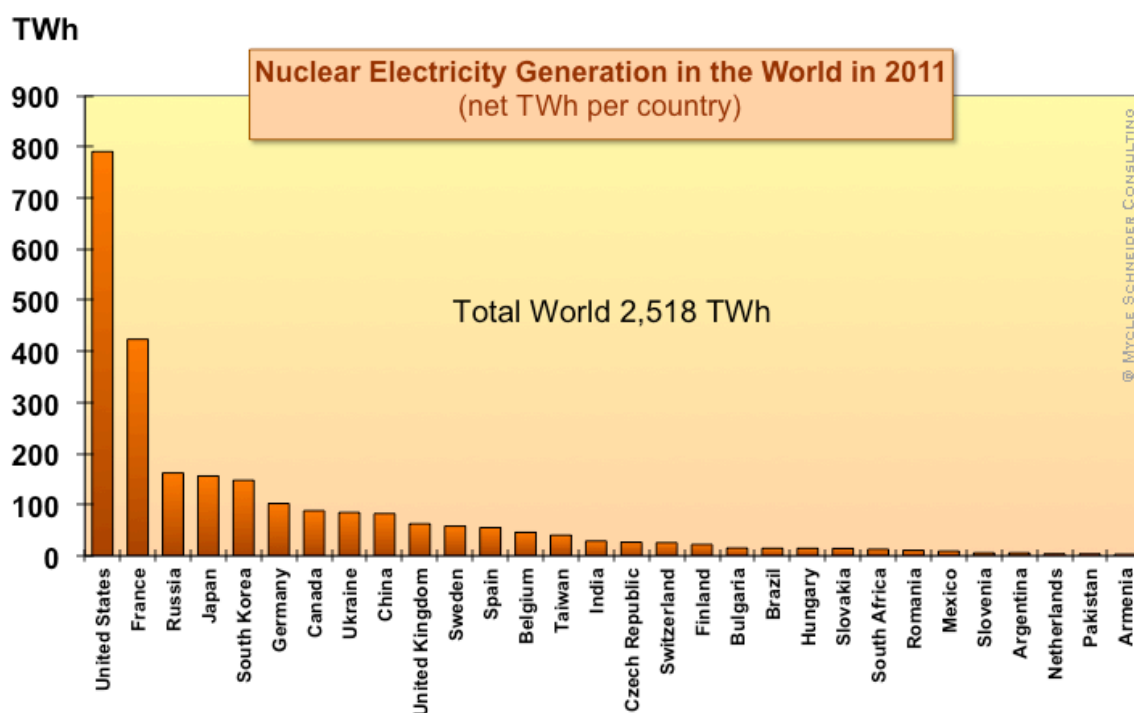
²³ Nuclear Regulatory Commission (NRC), “Approved Applications for Power Uprates”, updated 29 March 2012, at www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/approved-applications, accessed on 2 May 2012.

²⁴ Nuclear Regulatory Commission (NRC), “Pending Applications for Power Uprates”, updated 30 April 2012, at www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/pending-applications.html, accessed on 2 May 2012.

Including uprates in many countries, as well as new-build capacity, net of closures, the capacity of the global nuclear fleet increased by about 30 GWe between 1992 and 2002 to reach 362 GWe; it peaked in 2010 at 375 GWe before falling back to the level achieved a decade ago.

The use of nuclear energy has been 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 in early 2012 (see Figure 4). One new country, Iran, started operating its first nuclear power reactor in 2011. Iran is the first in 15 years to join the list of countries generating electricity from fission since Romania joined the nuclear club in 1996. Half of the world's nuclear countries are located in the European Union (EU), and they account for nearly half of the world's nuclear production. France alone generates about half (49 percent) of the EU's nuclear production.

Figure 4. Nuclear Power Generation by Country, 2011



Source: IAEA-PRIS, MSC, 2012

Overview of Current New Build

Currently, 13 countries are building nuclear power plants, which is two less than a year ago:

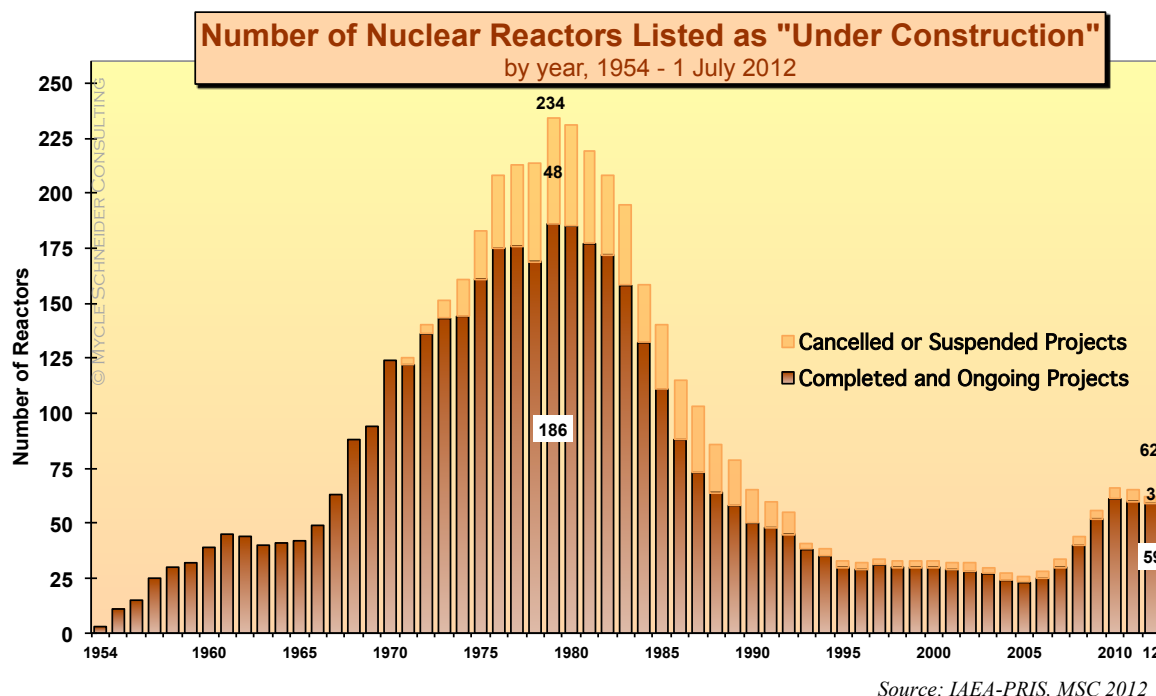
- Iran finally started operating its only reactor that had been under construction at Bushehr since 1975. No further active building is currently ongoing.
- Bulgaria abandoned the construction of the only two units at Belene, which it had been building since 1987.
- Japan halted work at two units following the 3/11 events, Ohma and Shimane-3, which had been under construction since 2007 and 2010 respectively. No further project is underway or planned at this stage.
- Pakistan started construction at Chasnupp-3 in late May 2011, two months after the connection of Chasnupp-2 to the grid in March only three days after 3/11.

In addition we have removed the Russian Kursk-5 unit from the list, following reports that the builder, Rosatom, confirmed abandoning the project. It was intended to be an upgraded version of

the Chernobyl RBMK design.²⁵ As of 1 May 2012, we consider 59 reactors under construction. The current number compares with 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 5.) The year 2004, with 26 units under construction, marked a record low for construction since the beginning of the nuclear age in the 1950s.

Over the past year, the most spectacular construction freeze took place in China. No new concrete base has been poured in the country after 3/11. The *World Nuclear Association* assumes that at least five authorized construction starts did not happen, with at least another ten that were in the pipeline for that year.²⁶

Figure 5. Number of Nuclear Reactors under Construction



The total capacity of units now under construction in the world is about 56 GWe, down by about 6 GWe compared to a year ago, with an average unit size of around 955 MW. (See Table 1 and Annex 4 for details.) A closer look at currently listed projects illustrates the level of uncertainty associated with reactor building, especially given that most constructors assume a five year construction period:

- Nine 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 has now failed to meet the latest startup date in 2012 and is now scheduled to be connected to the grid in 2015. Other long-term construction projects include three Russian units, two Mochovce units in Slovakia, and two Khmelnytski units in Ukraine. The construction of the Argentinian Atucha-2 reactor started 31 years ago.
- Four reactors have been listed under-construction for 10 years or more. These are two Taiwanese units at Lungmen for about 13 years and two Indian units at Kudankulam for around 10 years.
- Forty-three projects do not have an IAEA planned start-up date, including nine of the 10 Russian projects and all of the 26 Chinese units under construction.

²⁵ The WNA states on its website: “In February 2012 Rosatom confirmed that the project was terminated.” see <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

²⁶ www.world-nuclear.com/info/inf63.html, accessed 3 May 2012.

- At least 18 of the units listed by the IAEA as “under construction” have encountered construction delays, most of them significant. All of the 41 remaining units were started within the last five years or have not reached projected start-up dates yet. This makes it to assess whether they are on schedule.
- Nearly three-quarters (43) of the units under construction are located in just three countries: China, India and Russia. Furthermore, there are only these three countries, plus South Korea, that have construction taking place at more than one power plant site. None of these countries has historically been very transparent or reliable about information on the status of their construction sites. It is nevertheless known that half of the Russian units listed are experiencing multi-year delays.

The geographical distribution of nuclear power plant projects is concentrated in Asia and Eastern Europe, continuing a trend from earlier years. Between 2009 and 1 May 2012, a total of 14 units were started up, all in these two regions.

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.

In most cases the grid system will also have to be upgraded—often using new high-voltage power lines, which bring their own planning and licensing difficulties. In some cases, public opposition is significantly higher for the long-distance power lines than for the nuclear generating station itself. Projected completion times should be viewed skeptically, and past nuclear planning estimates have rarely turned out to be accurate.

Table 1: Nuclear Reactors “Under Construction” (as of 1 July 2012)²⁷

Country	Units	MWe (net)	Construction Start	Grid Connection
China	26	27,400	2007-2010	2012-2016
Russia	10	8,258	1983-2012	2013-2017
India	7	4,824	2002-2011	2013-2016
South Korea	3	3,640	2008-2009	2013-2014
Pakistan	2	630	2011	2016-2017
Slovakia	2	782	1985	2012-2013
Taiwan	2	2,600	1999	2016
Ukraine	2	1,900	1986-1987	2015-2016
Argentina	1	692	1981	2012
Brazil	1	1,245	2010	2018
Finland	1	1,600	2005	2014
France	1	1,600	2007	2016
USA	1	1,165	1972	2015
Total	59	56,336	1972-2012	2012-2018

Source : IAEA-PRIS, MSC, 2012

Past experience shows that simply having an order for a reactor, or even having a nuclear plant at an advanced stage of construction, is no guarantee for grid connection and power supply. 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 5.) The United States alone account for 138 of these cancellations.²⁸ Many U.S. utilities incurred significant financial harm because of cancelled reactor-building projects.

In the absence of any significant new build *and* grid connection over many years, the average age (since grid connection) of operating nuclear power plants has been increasing steadily and now

²⁷ For further details see Annex 8.

²⁸ CEA, “Elecnucl – Nuclear Power Plants in the World”, 2002.

stands at about 27 years.²⁹ 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 a period of 40 years. Nuclear operators can request a license renewal for an additional 20 years from the Nuclear Regulatory Commission (NRC). As of March 2012, 72 of the 104 operating U.S. units have received an extension, another 15 applications are under review by the NRC.

Many other countries, however, have no time limitations to 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 on a reactor-by-reactor basis whether a unit can operate for more than 30 years. At this point, ASN considers the issue of lifetimes beyond 40 years to be irrelevant, although the French utility EDF has clearly stated that, for economic reasons, it plans to prioritize lifetime extension over large-scale new build. In fact, only two plants (Fessenheim, Tricastin) have so far received a permit to extend operational life from 30 to 40 years, but only under the condition of significant upgrading. President François Hollande vowed during his election campaign, to close down the Fessenheim reactors during his term of office. However, even 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 reach that age by 2020. The French Cour des Comptes (Court of Audits) has calculated that 11 EPRs would have to be built by the end of 2022, if the same level of nuclear generation was to be maintained. "This seems highly unlikely, if not impossible, including for industrial reasons", the Cour des Comptes comments before concluding: "This implies one of two things: a) either it is assumed that plants will operate for more than 40 years (...); b) or the energy mix will move towards other energy sources. However, no clear public decision has been made concerning these major strategic issues, even though they call for short-term action and major investments."³⁰ It remains to be seen how the incoming administration will deal with the issue in France.

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 6 and 7.) At present, 20 of the world's operating reactors have exceeded the 40-year mark.³¹ As the age pyramid illustrates, that number will rapidly increase over the next few years. Twelve additional units have reached age 40 in 2011 (one of which is now retired), and two in the beginning of 2012, while a total of 159 units have reached age 30 or more, and 17 more will do so in 2012.

The age structure of the 145 units already shut down confirms the picture. In total, 43 of these units operated for 30 years or more; and within that subset, 19 reactors operated for 40 years or more. (See Figure 7.) The majority of these were Magnox reactors located in the U.K.. As they had been designed to produce weapons-grade plutonium, these were all small reactors (50–490 MW) that had operated with very low burn-up fuel. Therefore there are significant differences from the large 900 MW or 1,300 MW commercial reactors that use high burn-up fuel that generates 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 145 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 seem rather optimistic.

²⁹ Here, reactor age is calculated from grid connection to final disconnection from the grid. In this report, "startup" is synonymous with grid connection and "shutdown" with withdrawal from the grid.

³⁰ Cour des Comptes, "The costs of the nuclear power sector", Summary of the Public Thematic Report, January 2012.

³¹ We count the age starting with grid connection, and figures are rounded by half years.

Figure 6. Age Distribution of Operating Nuclear Reactors, 2012

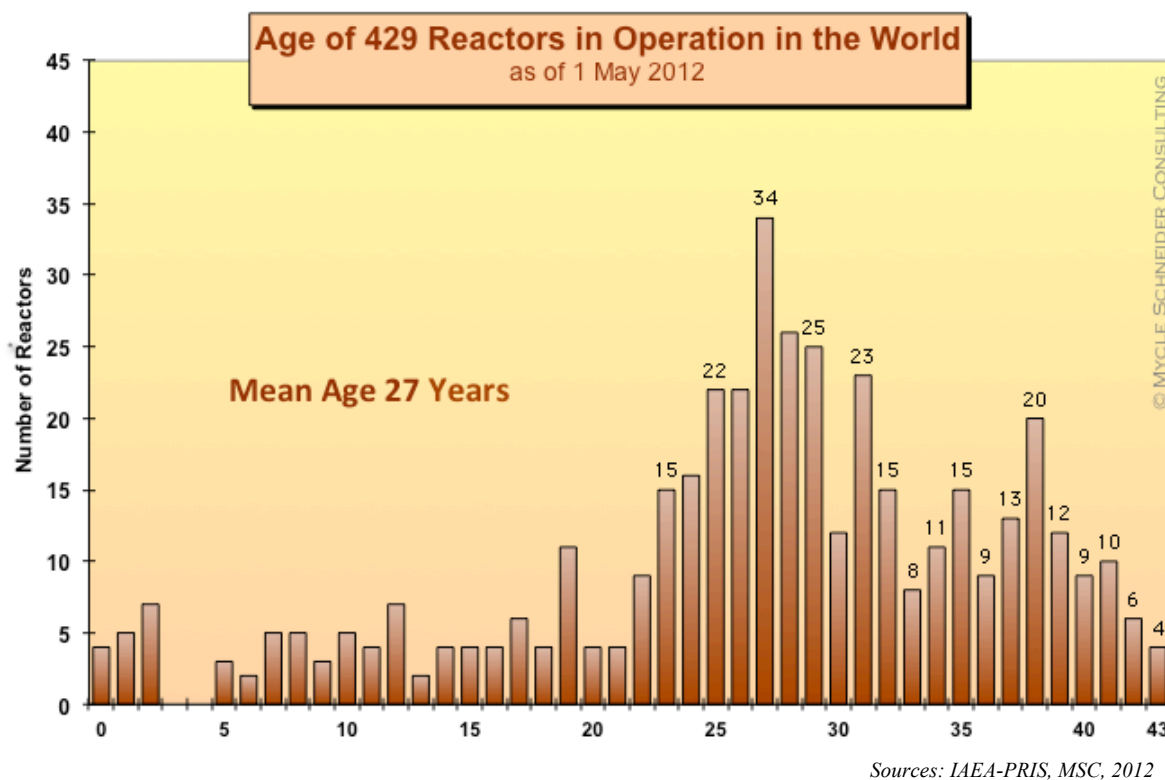
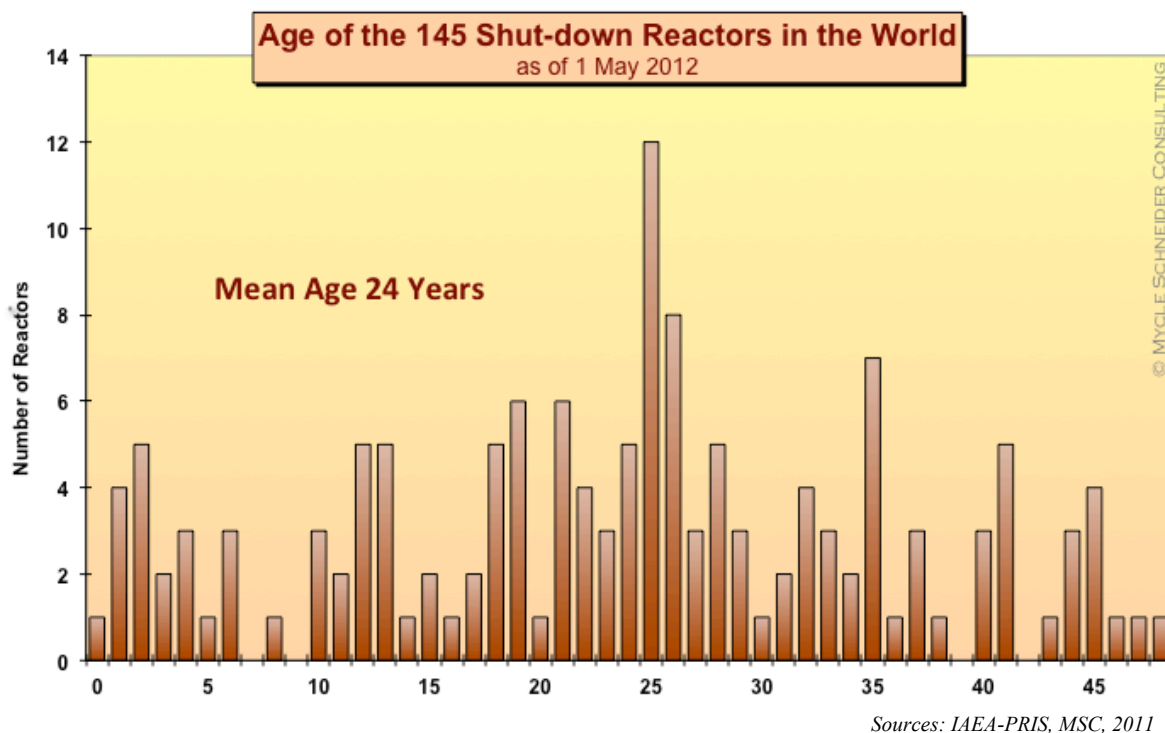


Figure 7. Age Distribution of Shutdown Nuclear Reactors, 2012

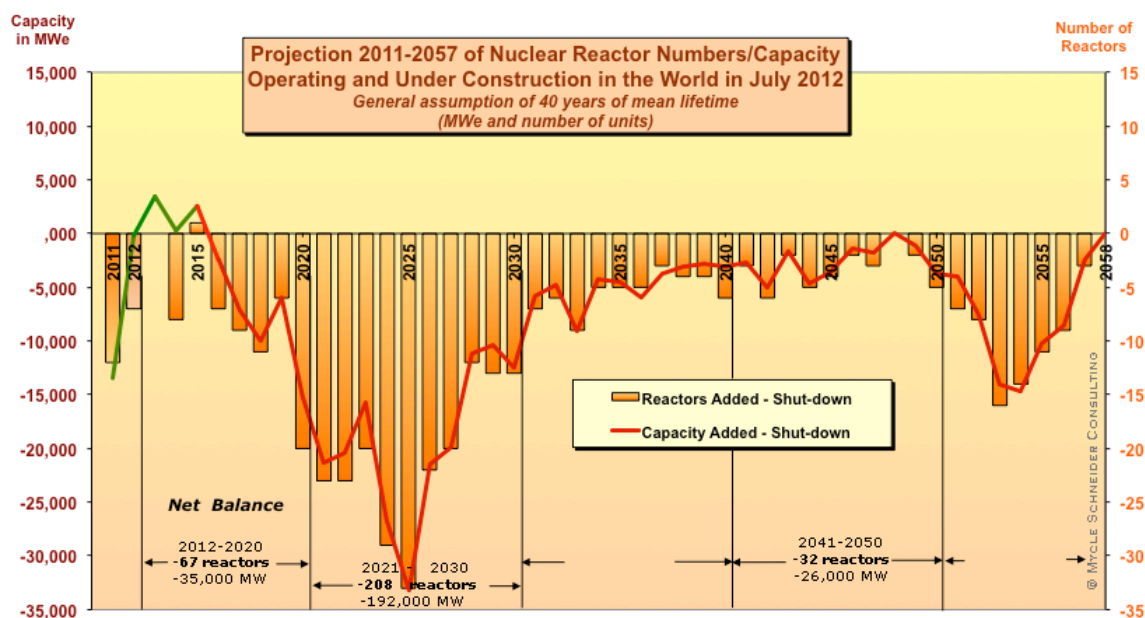


After the Fukushima disaster questions have been raised about the wisdom of operating older reactors. The Fukushima-I units (1 to 4) were connected to the grid between 1971 and 1974. The license for unit 1 was extended for another 10 years in February 2011. Four days after the accidents in Japan, the 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 exclusive selection criterion was operational age. Other countries did not follow the same way, but it is clear that the 3/11 events had an impact on previously assumed extended lifetimes also in other countries, including Belgium, Switzerland and Taiwan.

For the purposes of capacity projections, in a first scenario (40-Year Lifetime Projection), we have assumed a general lifetime of 40 years for worldwide operating reactors, with a few adjustments, while we take into account authorized lifetime extensions in a second scenario (PLEX Projection). In our scenarios in the previous report, in order to remain conservative, we had assumed, for example, that all 17 German units would be operated with remaining lifetimes between 8 and 14 years. Eight of these have now been shut down definitively. Similarly, in the present projections there are several individual cases where continued operation or lifetime extensions are in question and earlier shutdowns have been officially decided.³² (See Figure 8.)

Figure 8. The 40-Year Lifetime Projection



Sources: IAEA-PRIS, WNA, MSC 2012

The lifetime projections make possible an evaluation of the number of plants that would have to come on line over the next decades to offset closures and maintain the same number of operating plants. In spite of the 59 units under construction—as of 1 July 2011, all of which are considered online by 2020—installed nuclear capacity would drop by 35 GW. Therefore in total 67 additional reactors would have to be finished and started up prior to 2020 in order to maintain the status quo.³³ This corresponds to two new grid connections every three months, with an additional 209 units (192 GW) over the following 10-year period—one every 19 days.

This achievement of the 2020 target appears unlikely given existing constraints on the manufacturing of key reactor components, the difficult financial situation of the world's main reactor builders and utilities, the general economic crisis and generally hostile public opinion—aside from any other specific post-Fukushima effects. As a result, the number of reactors in operation will decline over the coming years unless lifetime extensions beyond 40 years becomes widespread. The scenario of such generalized lifetime extensions is in our view even less likely after Fukushima, as many questions

³² The Japanese reactors constitute the largest contingency of uncertainty. In this scenario all but the 10 Fukushima reactors would return to operation.

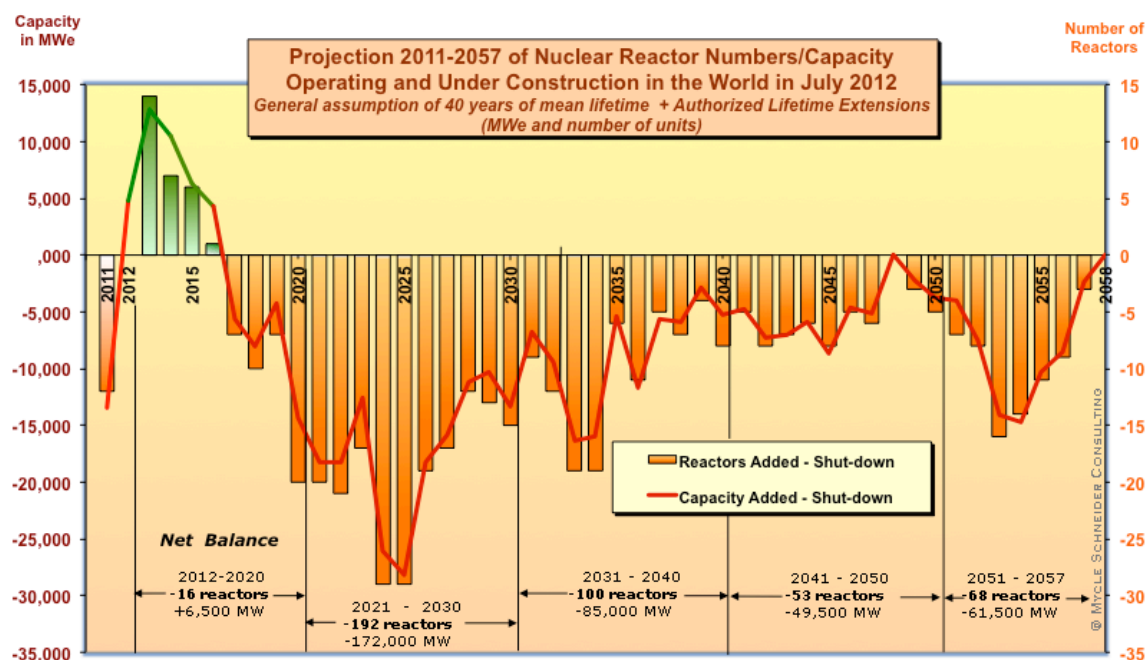
³³ We decided to adjust the scenarios to 2020 and ten-year intervals after that, while previous scenarios started at the time horizon of 2015.

regarding safety upgrades, maintenance costs, and other issues would need to be much more carefully addressed.

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. However, the average construction time for the first 15 operating units was 5.8 years. At present, about 27 GW are under construction. While there has been considerable acceleration of construction starts in the past—with 18 new building sites initiated in 2009 and 2010—not a single new construction site was initiated since 3/11. The prospects for significantly exceeding the original 2008 target of 40 GW for 2020 now seems unlikely, even if an 80 GW target has resurfaced recently (see China Focus). China has reacted surprisingly rapidly and strongly to the Fukushima events by temporarily suspending approval of nuclear power projects, including those under development.

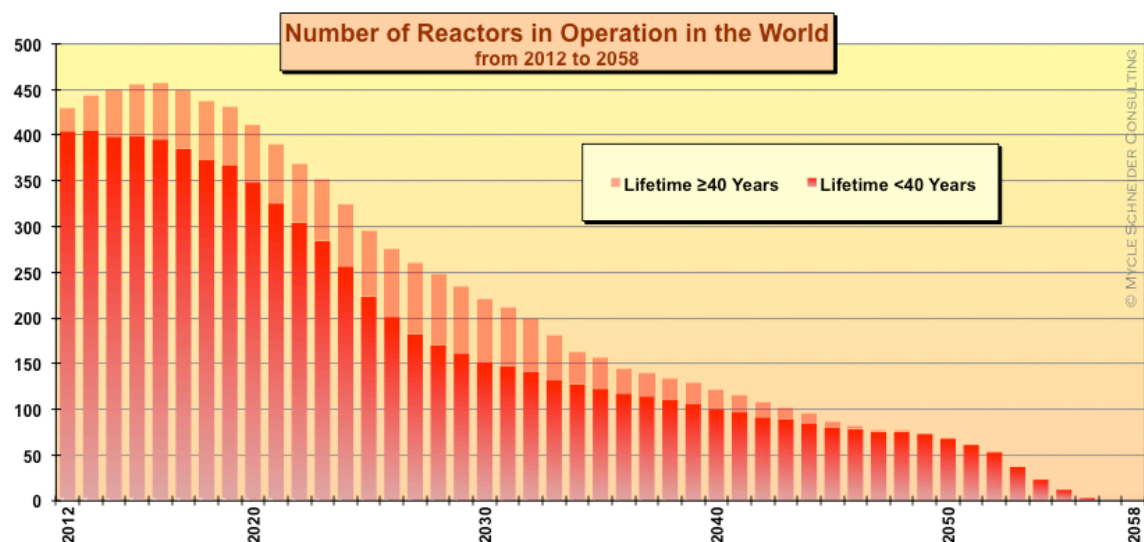
We have modeled a scenario in which all currently licensed lifetime extensions and license renewals (mainly in the United States) are maintained and all construction sites are completed. For all other units we have maintained a 40-year lifetime projection, unless a firm earlier or later shutdown date has been announced. The net number of operating reactors would still decrease by 16 units even if installed capacity would grow by 6.5 GW in 2020. The overall pattern of the decline would hardly be altered, it would merely be delayed by some years. (See Figures 9 and 10).

Figure 9. The PLEX Projection



Sources: IAEA-PRIS, US-NRC, WNA, MSC 2012

Figure 10. Forty-Year Lifetime Projection versus PLEX Projection (in numbers of reactors)



Sources: IAEA-PRIS, US-NRC, MSC 2012

Potential Newcomer Countries

In 2010, the IAEA announced that 65 countries had expressed an interest, were considering, or were actively planning for nuclear power, up from an estimate of 51 countries in 2008.³⁴ Since 2010 the IAEA has not published a comprehensive updated analysis, but it stated it expects Vietnam, Bangladesh, United Arab Emirates, Turkey and Belarus to start building their first nuclear power plants in 2012 and that Jordan and Saudi Arabia could follow in 2013³⁵. This would seem extremely optimistic given the current situation in these countries.

In the 25 years since the accident at Chernobyl, only four countries—Mexico, China, Romania and Iran—have started new nuclear power programs³⁶. (See Figure 11.) While over the same period three others—Italy, Kazakhstan, and Lithuania—have closed all their reactors.

The IAEA continues its activities to support the introduction of nuclear power programs and tries to overcome the negative Fukushima impact on public opinion. Participants from 43 countries attended the Sixth Annual Workshop on Nuclear Power Infrastructure at the IAEA in January 2012. “Those countries with a strong national position on introducing nuclear power, however, are still committed to developing their national nuclear infrastructure” said Masahiro Aoki³⁷ from the IAEA’s Integrated Nuclear Infrastructure Group (INIG)³⁸, and the Scientific Secretary of the meeting. “The factors that contribute to interest in nuclear power in these countries have not changed, such as energy demand,

³⁴ IAEA, “International Status and Prospects of Nuclear Power,” Report by the Director General, Board of Governors General Conference (Vienna: 2 September 2010); IAEA, “International Status and Prospects of Nuclear Power,” Report by the Director General, Board of Governors General Conference (Vienna: 12 August 2008).

³⁵ Enformable.com, “IAEA – Vietnam and 4 other countries to incorporate nuclear energy after Fukushima”, Lucas W Hixson, February 24th 2012, <http://enformable.com/2012/02/iaea-vietnam-and-4-other-countries-to-incorporate-nuclear-energy-after-fukushima/>; accessed 5 May 2012.

³⁶ Armenia closed its two reactors in 1989, following a referendum, but re-opened unit 2 in 1995.

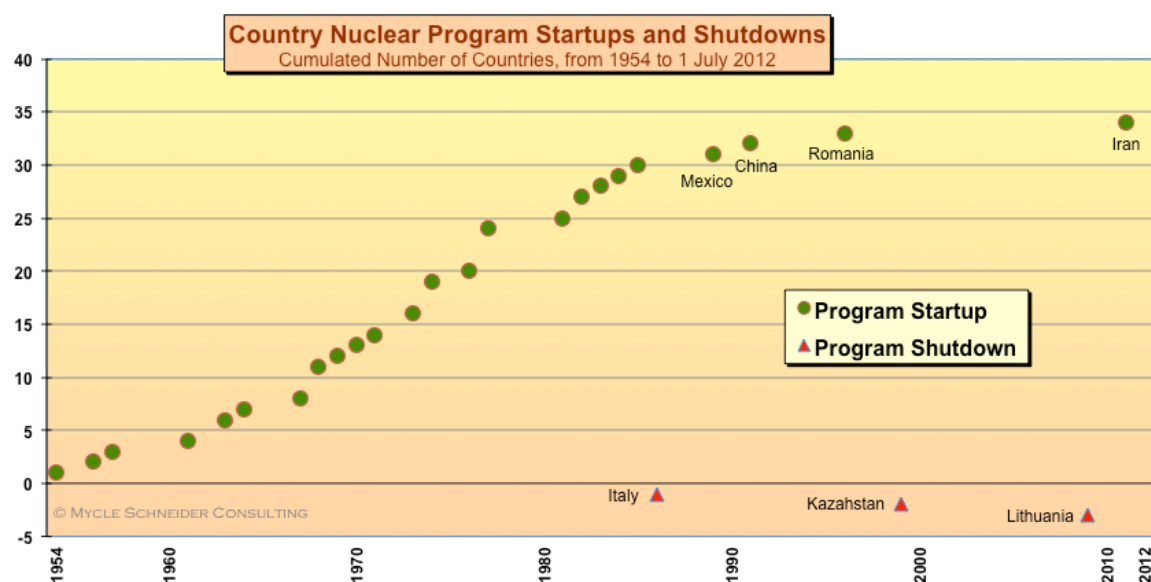
³⁷ Aoki is the former Director of the Radiation Protection and Accident Management Division of the Japanese Nuclear Safety Commission.

³⁸ INIG was set up in 2010 in order to improve development and delivery of IAEA nuclear infrastructure related guidance and support.

concerns about climate change, volatile fossil fuel prices and security of the energy supply”, Aoki explained.³⁹ There are many stages to the development of nuclear power and many countries that propose or even embark upon nuclear construction, such as Austria and the Philippines, which in the end do not start up a reactor. In fact, under the headline “what are the problems we are trying to solve?”, INIG’s Aoki in a 2011 presentation⁴⁰ appropriately lists:

- Never moving beyond planning stage
- Focusing on specific issues but missing the big picture
- Inviting bids with no appropriate response
- Developing unsustainable nuclear power programme

Figure 11. Start-ups and Closures of National Nuclear Power Programs, 1950–2011



Sources: IAEA-PRIS 2012, MSC, 2012

Below is an assessment by country of the status of the projects that the IAEA has referred to, which indicates that most are much further from the launch of their program than the IAEA frequently suggests.

Press reports indicate that **Bangladesh** has agreed to build two nuclear power plants with Russian assistance; they quote Science Minister Yeafesh Osman as saying “we have signed the deal... to ease the power crisis”. He said that construction of the plants would start by 2013 and would take five years to complete⁴¹. The agreement is for two 1 000 megawatt-electric (MWe) units as well as fuel supply, take-back of spent fuel, training and other services. The Government of Bangladesh is considering either a government-owned turnkey project or a Build-Own-Operate-Transfer (BOOT) contract⁴². The Russian contractor would be Rosatom subsidiary Atomstroyexport and the Bangladesh Atom Energy Commission the client. No information is available on the value of the

³⁹ Nuclear Power Newsletter, “IAEA Annual Workshop on Nuclear Power Infrastructure”, IAEA, May 2012.

⁴⁰ Masahiro Aoki, “IAEA Milestone Approach and Recent Developments”, INIG, 27 July 2011.

⁴¹ BBC, “Bangladesh agrees nuclear power deal with Russia”, 2nd November 2011, <http://www.bbc.co.uk/news/world-asia-15552687>, accessed 5 May 2012.

⁴² IAEA, “Bangladesh Progresses Towards Nuclear Power”, 21 November 2011, <http://www.iaea.org/newscenter/news/2011/bangladeshprog.html>; accessed 5 May 2012.

contract. Negotiations started in February 2012.⁴³ The trade journal *Nuclear Intelligence Weekly* reported the same month that there was “no financing yet” for implementing the agreement.⁴⁴

In mid-2006, the government of **Belarus**, which, 20 years before, was heavily impacted by the Chernobyl accident, approved a plan for construction of a nuclear power plant in the Mogilev region in the country’s east. An agreement with Russia on cooperation in the construction of a nuclear power plant in Belarus was signed on 15 March 2011, four days after 3/11. Expressions of interest were sought from international companies, and, not surprisingly given the existing economic and political ties, a bid from Russia’s Atomstroyexport was taken forward. Under a financing agreement, Russia would provide a \$9 billion⁴⁵ loan. Prior to 3/11, the two countries reportedly aimed at the signature of an agreement on plant construction in spring 2011, with construction starting that September.⁴⁶ In November 2011 it was agreed that Russia would lend up to \$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 Russian state-owned Vnesheconombank (VEB) and Belarusian commercial bank Belvnesheconombank signed an agreement needed to implement the Russian export credit facility⁴⁷. A contract has reportedly been signed for the design of the nuclear power plant with Atomstroyexport starting working on the design. This phase is scheduled to be completed by mid-2013 with concreting work to start in September 2013. The first unit is to be operational in 2017.⁴⁸ 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. Both would be of the Generation-3+ VVER “NPP-2006” type with a capacity of 1170 MW each.⁴⁹ Apparently, Rosatom has offered 100 percent financing.⁵⁰ Opposition to the project is increasing. On the 26th anniversary of the Chernobyl catastrophe, about one thousand people demonstrated in the Belarussian capital Minsk against the nuclear project.⁵¹

Turkey has a long history of attempting to build a nuclear power program, starting in the early 1970s. In 1996, a call for tender was launched for the construction of 2 GW of nuclear capacity at the Akkuyu site along the eastern Mediterranean. Several international bids were received, including from Westinghouse, AECL, Framatome, and Siemens. In 2000, however, the bid was abandoned.⁵² In 2006, the government revised the nuclear initiative and announced plans for up to 4.5 GW of capacity at Akkuyu and at the Black Sea site of Sinop. The plans met with large-scale local protests.

The following year, Turkey approved a bill introducing new laws on the construction and operation of nuclear power plants, which led in March 2008 to a revised tender process for the Akkuyu plant. Only one bid was received jointly from Atomstroyexport and Inter RAO (both from Russia) and Park Teknik (Turkey) for an AES-2006 power plant with four 1200 MW reactors. In May 2010, the Russian and Turkish heads of state signed an intergovernmental agreement for Rosatom to build, own, and operate the Akkuyu plant with four 1200 MW AES-2006 units—a project reported to be

⁴³ Nucleonics Week, “Russia develops plan for Bangladesh’s first nuclear plant”, 8 March 2012.

⁴⁴ Nuclear Intelligence Weekly, “Newbuild – Fighting Over Risk”, 13 February 2012.

⁴⁵ All dollar (equivalent) amounts are expressed in U.S. dollars unless indicated otherwise.

⁴⁶ Voice of Russia, “Belarus Nuclear Deal to be Signed on March 15,” 16 February 2011.

⁴⁷ World Nuclear Association, “Nuclear Power in Belarus”, February 2012.

⁴⁸ Itar-Tass, “Belarus NPP cost should not exceed funds for Kaliningrad NPP construction – Semashko”, 17 February 2012, see <http://www.itar-tass.com/en/c154/346054.html>, accessed 1 June 2012.

⁴⁹ 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.

⁵⁰ Nucleonics Week, “Rosatom offers up to 100 percent financing for Temelin plant expansion: VP”, 22 March 2012.

⁵¹ Nuclear Intelligence Weekly, 17 April 2012.

⁵² World Nuclear Association, “Nuclear Power in Turkey”, December 2011; see http://www.world-nuclear.org/info/inf128-nuclear_power_in_turkey.html, accessed 5 May 2012.

worth \$20 billion.⁵³ In December 2011, the project company filed applications for construction permits and a power generation license, as well as for an environmental impact assessment, with a view to starting construction in 2013. The reactors are planned to enter service at yearly intervals in the period 2018–21.⁵⁴ If this project was fully realized, then nuclear power would represent five percent of the installed electricity generating capacity by 2023. In March 2010, Turkey also signed an agreement with Korea Electric Power Corporation (KEPCO) to prepare a bid for the Sinop plant. However, the parties failed to reach an agreement because of “differences in issues including electricity sales price.”⁵⁵ Negotiations switched to Toshiba, with the support of the Japanese government, and in December 2010 the parties signed an agreement to prepare a bid for development. A French consortium of AREVA and GDF Suez has also indicated an intention to bid for the project, as has French state utility EDF and the Chinese Guangdong Nuclear Power Company (CGN). In November 2011 the prime minister requested the South Korean president to renew the KEPCO bid⁵⁶. Yet another candidate entered the process when, on 24 April 2012, Turkish state utility EUAS signed a memorandum of understanding with the Canadian firm CANDU –AECL (now owned by SNC-Lavalin) that covers a feasibility study for a 4-unit nuclear plant at Sinop. There are still ongoing discussions about the reactor technologies involved in the various offers. However, as the trade journal *Nuclear Intelligence Weekly* points out, “the deciding factor in Ankara will almost certainly not be the technology as much as the financing that comes with it”.⁵⁷ After all, even 100 percent pre-financing arrangements have not allowed for the decades long nuclear project in Turkey to be implemented. In addition, state owned utility EUAS could very well suffer from the downgrading by credit-rating agency Standard & Poor’s of Turkey’s credit rating BB long-term outlook from positive to stable.

Opposition to nuclear power in Turkey remains very high. In June 2011, 80 percent of people polled were in favour of abandoning all new nuclear construction, with 77 percent considered nuclear power only a “limited and soon obsolete” option.⁵⁸

To date, **Jordan** has signed nuclear cooperation agreements with 12 countries. In February 2011, the country’s energy minister announced that the Jordan Atomic Energy Commission (JAEC) had preselected designs from AECL of Canada, Atomstroyexport of Russia, and a joint venture between AREVA and Mitsubishi—called ATMEA—for the country’s first nuclear reactor, located at Majdal. On 30 June 2011, JAEC accepted the technical bids and the winning firm was supposed to be announced in December 2011⁵⁹. On 1 May 2012, JAEC issued a statement saying it had “concluded that ATMEA-1 and AES-92 [Atomstroyexport] technologies are the best two evaluated contenders in meeting the requirements and needs of Jordan”, as specified in the terms of the tender.⁶⁰ A potential site, located in the Mafraq Governorate, 40 km from the capital, was announced in February 2012⁶¹.

However, on 30 May 2012, the Jordanian parliament voted a recommendation to shelve the program, which “will 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

⁵³ WNN, “Russia’s Plans for Akkuyu,” 13 May 2010.

⁵⁴ WNN, “Site Work to Start for Turkish Plants,” 25 February 2011.

⁵⁵ Bloomberg, Tsuyoshi Inajima, “Turkey Holds Nuclear Talks With Japan After South Korean Discussions Fail,” Bloomberg.com, 23 December 2010.

⁵⁶ World Nuclear Association, “Nuclear Power in Turkey”, December 2011.

⁵⁷ Nuclear Intelligence Weekly, “Candu Down in Jordan, Up in Turkey”, 4 May 2012.

⁵⁸ IPSOS, “Global Citizen Reaction to the Fukushima Nuclear Plant Disaster”, June 2011.

⁵⁹ Jordan Times, “Jordan receives nuclear reactor bids”, Taylor Luck, Jordan Times, 21 December 2011.

⁶⁰ JAEC, “JAEC Concludes Technology Evaluation Phase for Jordan Nuclear Power Plant”, 1 May 2012; see <http://www.jaec.gov.jo/News/NewsDetails.aspx?nid=30>, accessed on 6 May 2012.

⁶¹ MENAFN.com “Jordan selects nuclear reactor site”, Jordan Times, 14 February 2012, http://www.menafn.com/qn_news_story_s.asp?storyid=1093483594, accessed 6 May 2012.

feasibility study is done.⁶² Prior to the vote, the Parliament's Energy Committee had published a report accusing JAEC of deliberately "misleading" the public and officials over the program by "hiding facts" related to costs⁶³. Nuclear power has the highest water consumption of all electricity generating technologies, while Jordan is amongst the world's most water poor nations. The Jordanian electricity grid is far below the minimum size necessary to be able to take up a large power plant. Total installed generating capacity was 2,750 MW by the end of 2010. Financing remains unclear and opposition to the project reaches into the royal family⁶⁴.

In August 2009 the **Kingdom of Saudi Arabia** announced that it was considering launching a nuclear power program, and 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."⁶⁵ The King Abdullah City for Atomic and Renewable Energy (KA-CARE) is being set up in Riyadh to advance this agenda and to be the competent agency for treaties on nuclear energy signed by the Kingdom. It is also responsible for supervising works related to nuclear energy and radioactive waste projects. In June 2010 it appointed the Finland- and Switzerland-based Pöyry consultancy firm to help define "high-level strategy in the area of nuclear and renewable energy applications" with desalination. 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 (\$80 billion).

The first two reactors would be planned to be on line in ten years and then two more per year until 2030.⁶⁶ However, according to a World Energy Council survey, "Saudi Arabia reported that using nuclear is still under consideration and that the WNA figures given above [16 reactors, 20 GW] are speculative."⁶⁷ The assessment confirms reports that the KA-CARE nuclear proposal has still not been approved by the country's top economic board, headed by King Abdullah.⁶⁸

Saudi Arabia has very large electricity expansion projects. It plans to double installed capacity to 100 GW by 2021, mainly through fossil fuels, but with a 10 percent renewable target by 2020. There is a US\$100 billion state spending commitment over the next ten years on renewables and nuclear combined.⁶⁹

Senior Saudi Arabian diplomats have reportedly stated that "if Iran develops a nuclear weapon, that will be unacceptable to us and we will have to follow suit", and officials in Riyadh have said that the country would reluctantly push ahead with their own civilian nuclear program.⁷⁰ Independent experts have suggested that the drive for civil nuclear power in the region is seen by some as a "security hedge", and that "if Iran was not on the path to a nuclear weapon capability you would probably not see this [civil nuclear] rush".⁷¹

⁶² 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.

⁶³ Idem.

⁶⁴ On 28 June 2011, Princess Basma bint Ali gave a stinging anti-nuclear speech in a public event in Amman, Jordan, entitled "Pros and Cons of Nuclear Energy".

⁶⁵ World Politics Review, "Saudi Arabia's Nuclear Ambitions Part of Broader Strategy", 16th June 2011, <http://www.worldpoliticsreview.com/articles/9186/saudi-arabias-nuclear-ambitions-part-of-broader-strategy>, accessed 6 May 2012.

⁶⁶ World Nuclear Association, "Emerging Nuclear Energy Countries", February 2012, see <http://www.world-nuclear.org/info/inf102.html>, accessed 7 May 2012.

⁶⁷ WEC, "World Energy Perspective: Nuclear Energy One Year After Fukushima", 9 March 2012.

⁶⁸ Nuclear Intelligence Weekly, "Saudi Arabia – Nuclear Plans Remain Stalled", 13 February 2012.

⁶⁹ Ernst&Young, "Renewable energy country attractiveness indices", February 2012.

⁷⁰ Guardian, "Riyadh will build nuclear weapons if Iran gets them, Saudi prince warns", Jason Burke, 29 June 2011.

⁷¹ The Times, "Six Arab States join rush to go nuclear", Richard Beeston, 4 November 2006.

Saudi public opinion remains surprisingly critical and 70 percent oppose nuclear construction. However, a majority of 54 percent considers nuclear power a viable long-term option, only one of two countries (with Russia) with an optimistic majority in a 24-country opinion survey.⁷²

In October 2010, **Vietnam** signed an intergovernmental agreement with Russia's Atomstroyexport to build the Ninh Thuan 1 nuclear power plant, using 1200 MW sized reactors. Construction is slated to begin in 2014, and the turnkey project will be owned and operated by the state utility Electricity of Vietnam (EVN), with operations beginning in 2020.⁷³ Rosatom has confirmed that Russia's Ministry of Finance is prepared to finance at least 85 percent of this first plant, and that Russia will supply the new fuel and take back used fuel for the life of the plant. An agreement for up to \$9 billion finance was signed in November 2011 with the Russian government's state export credit bureau, and a second agreement covered the establishment of a nuclear science and technology center.⁷⁴

Vietnam has also signed an intergovernmental agreement with Japan for the construction of a second nuclear power plant in Ninh Thuan province, with its two reactors to come on line in 2024–25. The agreement calls for assistance in conducting feasibility studies for the project, low-interest and preferential loans for the project, 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 government issued a master plan specifying Ninh Thuan 1 & 2 nuclear power plants with a total of eight 1000 MWe-class reactors, one coming on line each year 2020-27, then two more larger ones to 2029 at a central location. By 2020 nuclear power is supposed to represent 1 percent of the Vietnamese electricity production. However, already in November 2010, Wood Mackenzie analysts stated that the lack of finances and skilled labor would delay the first plants to come online to 2028 at the earliest.⁷⁵

The **United Arab Emirates** (UAE) has the most advanced new nuclear development plans in the Middle East. In April 2008, the UAE published a nuclear energy policy that stated that nuclear power was a proven, environmentally promising and commercially competitive option that “could make a significant base-load contribution to the UAE's economy and future energy security.”⁷⁶ The policy proposed installing up to 20 GW of nuclear energy capacity, including 5 GW by 2020, which would then represent about 22 percent of total planned installed power generating capacity. This would require the operation of four reactors, two between Abu Dhabi city and Ruwais, one at Al Fujayrah, and possibly one at As Sila.

A joint-venture approach, similar to that developed for the water and conventional power utilities, was proposed in which the government would retain a 60 percent share and a private company a 40 percent share. A call for bids in 2009 resulted in nine expressions of interest and the short listing of three companies: AREVA (France) with GDF-SUEZ, EDF, and Total, proposing EPRs; GE-Hitachi (U.S.-Japan), proposing ABWRs; and a South Korean consortium, proposing APR-1400 PWRs. In December 2009, the Korean consortium was awarded the \$20 billion contract for the construction and first fuel loads of four reactors, reportedly because the consortium could demonstrate the highest capacity factors, lowest construction costs, and shortest construction times. The trade press considers that “it remains to be seen whether South Korea's bid was realistic, or whether it was seriously

⁷² IPSOS, op. cit.

⁷³ Global Energy Magazine, “Japan and Russia to Build Ninhthuan Nuclear Power Plants for Vietnam,” 3 November 2010.

⁷⁴ World Nuclear Association, “Nuclear Power in Vietnam”, January 2012 http://world-nuclear.org/info/vietnam_inf131.html

⁷⁵ Bloomberg, “Thai, Vietnamese Nuclear Plans Face Delays on Labor, Wood Mackenzie Says”, 18 November 2010, see <http://www.bloomberg.com/news/2010-11-18/thai-vietnamese-nuclear-plans-face-delays-wood-mackenzie-says.html>, accessed 10 May 2012.

⁷⁶ ArabianOilandGas.com “Abdullah Al Mutawa Explains How the UAE is Preparing to Meet Future Power Demands,” 10 June 2008.

under-priced". The outcome might be fatal: "If things go wrong, Korea's entry to the nuclear export market could be short-lived."⁷⁷ Indeed, updated cost estimates are reportedly already skyrocketing between \$36 billion and "closer to \$40 billion".⁷⁸ Financing negotiations have been delayed into the second half of 2012 and a final approval for construction is now unlikely before the end of the year.

The public in the UAE has raised almost no objection to the announced nuclear energy policy, which has been sold as a way to relieve pressure on the country's fossil fuel resources, increase the security of electrical power supply, create employment and a high-tech industry, and reduce carbon emissions. In July 2010, a site-preparation license and a limited construction license were granted for four reactors at a single site at Braka, along the coast 53 kilometers from Ruwais.⁷⁹ The application is based substantially 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 put into question since, projects that Braka-1 will start commercial operation in 2017 with unit 2 operating from 2018. In March 2011 a groundbreaking ceremony was held to mark the start of construction.

Other countries that have undertaken steps to develop a nuclear program include:

Since the mid-1970s, **Indonesia** has discussed and brought forward plans to develop nuclear power, releasing its first study on the introduction of nuclear power, supported by the Italian government, in 1976. The analysis was updated in the mid-1980s with help from the IAEA, the United States, France and Italy. Numerous discussions took place over the following decade, and by 1997 a Nuclear Energy Law was adopted that gave guidance on construction, operation, and decommissioning. A decade later, the 2007 Law on National Long-Term Development Planning for 2005–25 stipulated that between 2015 and 2019, four units should be completed with an installed capacity of 6 GW.⁸⁰ Discussions with nuclear vendors have included the possibility of using Russian floating reactors but appear to be dominated by Japanese and South Korean companies; however, neither financing nor detailed planning appear to be in place. In contrast to this nuclear stasis, in 2011, Indonesia showed the fastest growth rate—520 percent—in clean energy investments of any G20 country, exceeding the \$1 billion mark for the first time. Much of the investment went into the exploitation of the country's vast resources in geothermal energy (40 percent of the world's known resources).⁸¹

Poland planned the development of a series of nuclear power stations in the 1980s and started construction of two VVER 1000/320 reactors in Zarnowiec 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. In November 2010, the government adopted the Ministry of Economy's Nuclear Energy Program, which was submitted to a Strategic Environmental Assessment. Poland aims to build 6 GW of nuclear power with the first reactor starting up by 2020. Officials have revised the planning in the meantime targeting 2022-23 for the startup of the first reactor. Financing of the ambitious project remains unclear and public opinion is highly uncertain. While Poland was the only country showing a majority in favor of nuclear new build in a 24-country opinion survey in June 2011⁸², a local referendum in February 2012 in Mielno, one of three pre-selected, potential sites, showed a surprising 94 percent opposed to the plan. The Polish government reacted by starting a \$6 million public propaganda campaign, labeled "Meet the

⁷⁷ Energy Economist, "Prospects for Nuclear Power in 2012", Platts, February 2012.

⁷⁸ Nuclear Intelligence Weekly, "United Arab Emirates: No Plans for Second NPP", 20 April 2012.

⁷⁹ ArabianBusiness.com, "ENEC Welcomes Regulator's License Approval," 11 July 2010.

⁸⁰ Hanan Nugroho, "Development of Nuclear Power in Indonesia: Stop or Go?" *Jakarta Post*, 5 May 2010.

⁸¹ PEW, "Who's winning the clean energy race? – 2011 Edition", 2012.

⁸² IPSOS, op. cit.

Atom”. “We want to make sure that the first Polish nuclear power plant is established with the approval of Polish society”, Hanna Trojanowska, vice minister and government commissioner for nuclear energy stated late March 2012.⁸³ The director of external relations for the state utility PGE, that promotes the project, stated that “obviously we will not proceed against the will of local people”.⁸⁴ The technology selection process is supposed to reduce the choice to three potential designs by the end of 2012 with first concrete to be poured by 2017. Potential vendors are expected to present “an optimum mix of ECA [Export Credit Agency] support and local delivery of the project”.⁸⁵

In its Power Development Plan for 2010–30, approved in 2010, **Thailand** proposes the construction of 5 GW of nuclear capacity. Currently, five locations are being considered as part of a feasibility study that was supposed to be completed by the end of 2010 but which has now been delayed. This may be due in part to “vociferous opposition”⁸⁶ to proposed plant sitings, which reportedly have reduced the number of possible locations to two or three areas.⁸⁷ Consultancy firm Wood Mackenzie estimates that Thailand will not even be able to introduce a nuclear safety regulatory framework until 2026. Other key problems are the lack of financing and skilled personnel.⁸⁸ Following the Fukushima accident, plans were put on hold so that the first reactor would now be expected on line in 2023⁸⁹. In reality, prospects for Thailand building a nuclear plant seem to be finished. “Prospects for nuclear power likely saw the final nail in the coffin with the Fukushima disaster”, concludes *Power Engineering International*.⁹⁰

While public opposition and financing remain two of the key problems of any new-build projects, it is remarkable that the Russian group Rosatom has offered up to 100 percent financing at least in the cases of new build projects in Belarus, Czech Republic, Turkey and Vietnam. Rosatom remains also a contender in Jordan. It remains to be seen whether cross-subsidization from the gas sector will be sufficient to finance the Russian nuclear ambitions inside and outside the country. Given the past history of nuclear ambitions not materializing, there are serious doubts as to how much of these will be realized.

Projects and programs officially abandoned in 2011

In **Egypt**, the government’s Nuclear Power Plants Authority was established in the mid-1970s, and plans were developed for 10 reactors by the end of the twentieth century. Despite discussions with Chinese, French, German, and Russian suppliers, little specific development occurred for several decades. In October 2006, the Minister for Energy announced that a 1,000 MW reactor would be built, but this was later expanded to four reactors by 2025, with the first one coming on line in 2019.

⁸³ Nucleonics Week, “As Polish nuclear plans progress, government seeks public support”, 5 April 2012.

⁸⁴ Idem.

⁸⁵ Idem.

⁸⁶ PEI, “Thailand” Country Profile, in “Global Power Review 2012”, Pennwell, 2012.

⁸⁷ WNA, “Emerging Nuclear Energy Countries,” February 2012 <http://www.world-nuclear.org/info/inf102.html>

⁸⁸ Bloomberg, “Thai, Vietnamese Nuclear Plans Face Delays on Labor, Wood Mackenzie Says,” Bloomberg.com, 18 November 2010.

⁸⁹ WNA, “Emerging Nuclear Energy Countries,” February 2012 <http://www.world-nuclear.org/info/inf102.html>

⁹⁰ PEI, “Thailand” Country Profile, in “Global Power Review 2012”, Pennwell, 2012.

In early 2010, a legal framework was adopted to regulate and establish nuclear facilities; however, an international bidding process for its construction was postponed indefinitely in February 2011 due to the political situation in the country.

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 national nuclear research and development entity, to expedite licensing of new reactors at existing nuclear power plant sites, and to facilitate licensing of new reactor sites. ENEL and EDF had 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 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.⁹¹ The referendum motion was supported by 94 percent of the population, ending Italy's new nuclear ambitions.

Kuwait country had announced plans to invest in nuclear energy as far back as 2009, signing accords with the U.S., France and Russia to boost cooperation in atomic energy. In September 2010, Kuwait's National Nuclear Energy Committee told Reuters it was considering options for four planned 1,000 megawatt reactors, and would release a "roadmap" for developing atomic power in January 2011⁹². One year later it was announced that Kuwait had abandoned its nuclear program according to officials from a Kuwaiti government research quoted in the *Japan Times*⁹³.

Unfulfilled Promises

The nuclear establishment, industry, utilities and their promoters in business and politics have a long history of over selling their technology and 'promising the impossible'. As a result the history of the nuclear age is littered of examples of fantasy projections for installed nuclear capacity and failures to construct to time and budget.

Unrealistic Projections

In 1973-1974, the IAEA gave a forecast of installed nuclear capacity of 3,600-5,000 GW worldwide by 2000.⁹⁴ Two years later the French Atomic Energy Commission (CEA) estimated the share of nuclear power in the world's primary *energy* balance at 22-35 percent by the turn of the century.⁹⁵ These optimistic projections were soon to be confronted reality and in 1982, Hans-Jürgen Laue, the Director of the IAEA's Nuclear Power Division, lamented:

⁹¹ GreenOptimistic.com "Italy's Nuclear Power Comeback, Facing Strong Opposition and Referendum," 13 January 2011.

⁹² Asian Business.com "Kuwait abandons nuclear programme after Fukushima fallout", Elizabeth Broomhall, 23 February 2012 <http://www.arabianbusiness.com/kuwait-abandons-nuclear-programme-after-fukushima-fallout-446709.html>

⁹³ The Japanese Times, "Kuwait scraps nuclear power in light of 3/11", 23 February 2012

⁹⁴ H.J. Laue, "Nuclear energy: facing the future", IAEA Bulletin Supplement, 1982.

⁹⁵ Dominique Finon, "Le nucléaire entre l'espoir et la résignation", in "Energie Internationale 1987/1988", Institut économique et politique de l'énergie, 1988

There has been a steady decline in projections for the short-term (1975 and 1980) and since 1975, a dramatic decrease in the projections for the longer term (1990 and 2000).

Although the 1990 capacity projections show signs of ‘bottoming out’, some recent studies indicate that the actual turnout in 2000 could be as much as 20 percent lower than the projection reported by the Agency in 1980.⁹⁶

However, no “bottoming out” took place and the IAEA’s 1980 projections of 740-1,075 GWe installed nuclear power capacity for the year 2000 were a factor of two to three above the actual figure of 356 GWe. Current operation remained a factor of 10 to 14 below the 1973-74 projections. Even after Chernobyl, the OECD Nuclear Energy Agency forecasted an installed nuclear capacity of 497-646 GWe for the year 2000, still between 40 and over 80 percent above reality.⁹⁷ Considering the long lead times of nuclear projects of 10 to 15 years, the failure of these specialized international agencies to develop accurate short-term projections casts doubt on their analytic capability or independence or both.

Projections from the 1970s and 1980s seem a long time ago and one might wonder about their relevance for the present industrial reality. However, projections by these same organizations continue to this day seem to be overly optimistic.

In this context it is also important to remember that a significant share of the world’s current nuclear fleet was planned in the 1960s and 1970s. For example, all of the 104 currently operating reactors of the U.S. nuclear program were ordered between 1963 and 1973. It was this atmosphere of enthusiasm that led to a large part of the nuclear programs that are still in place today.

In 1986 the only reactor to be permanently closed was unit number 4 at Chernobyl, while 26 new reactors were connected to the grid. However, in 2011, at least 19 reactors (depending on the number of closures in Japan considered definitive) were shut down definitively, of which 18 are a direct consequence of 3/11, and only seven reactors were started up. While after Chernobyl, Germany was the first country to start up a new reactor, after Fukushima that same country shut down eight reactors. Only 14 months after 3/11, Japan does not have a single reactor operating any more—at least temporarily. Times have indeed changed.

Construction Times of Past and Currently Operating Reactors

There has been a clear global trend towards increasing construction times since the beginning of the nuclear age. Apparently national building programs are faster in their early years. As Figure 12 illustrates, in the 1970s and 1980s construction times were quite homogenous, while in the past two decades they have been varied. The two South Korean reactors that were connected to the grid in 2012 averaged a 4.4 year construction time, while, worldwide, it took an average of 13.8 years to build the seven units started up in 2011 and 9.5 years for the five reactors that began operating in 2010.

The reasons for gradually increasing construction times are not always well understood. It is clear that continuously increasing safety requirements and 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 had an impact on costs.

“Forgetting by doing”, the IIASA analyst Arnulf Grübler called the phenomenon of increasing construction times and costs.⁹⁸ Most of the nuclear countries have been struck by this symptom. The latest generation of operating units provides an illustration of this. Over a 20-year period between 1992 and May 2012 a total of 89 reactors started up, accounting for about one fifth of the total

⁹⁶ H.J. Laue, op.cit.

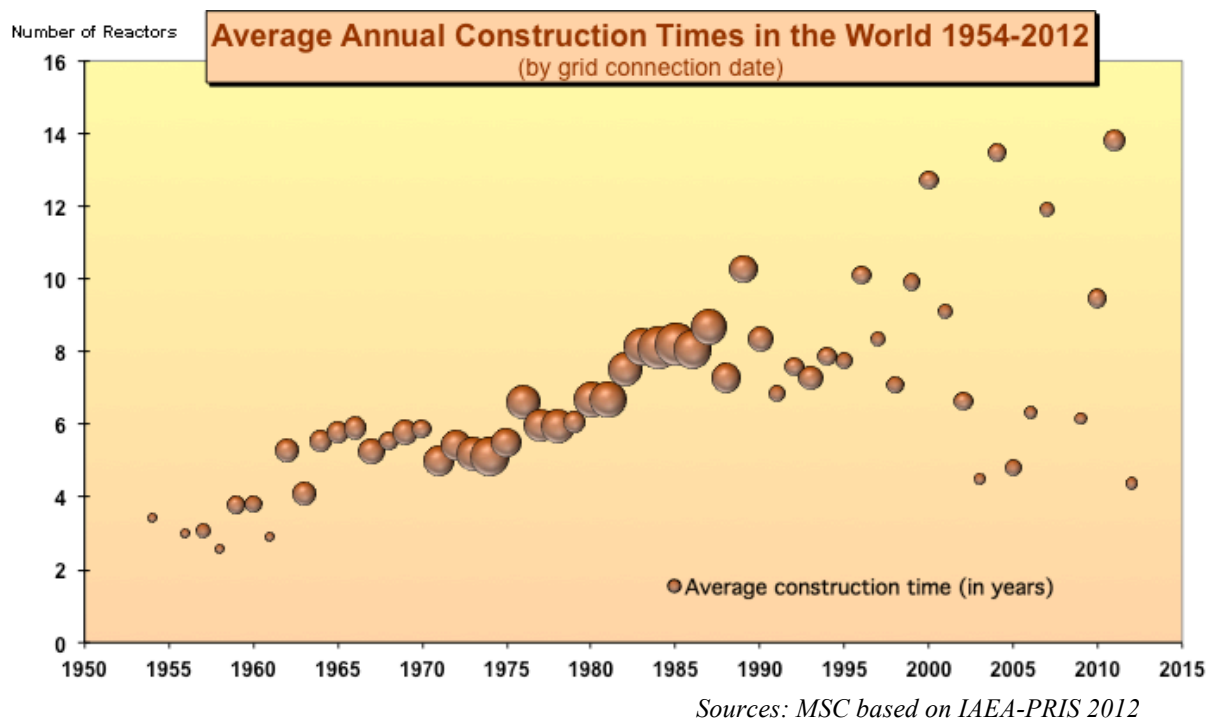
⁹⁷ OCDE-AEN, “Perspectives de l’énergie nucléaire jusqu’en 2025”, 1 June 1987.

⁹⁸ This is obviously contrary to the usual development patterns, whereby technology learning curves show declining costs over time, see section on nuclear versus renewables.

operating nuclear plants (implying that four fifths are over 20 years old). Average construction time was almost nine years with a large range from 3.2 to 36.3 years. There are significant differences between the 17 countries that started up reactors during that period.

Only three countries clearly stand out with low average construction times for significant numbers of plants. With 17 units Japan started up the largest fleet over the past two decades, followed by South Korea (14), China (15) and India (13). Almost two thirds of all new startups in the world in that period were concentrated in those four countries. Average construction times in the first three countries were impressive, compared to performance in other countries. Over the past two decades, Japan averaged 4.4, South Korea 4.6 and China 5.8 years building prior to grid connection. India with 8.7 years average took twice as long as Japan to finish a reactor. (See Annex 2 for details). It is remarkable to compare this with the performance of the older large nuclear countries. The UK only started up one unit over the time period and it took 6.1 years. France started up six units after an average of 9.4 years (and a maximum of 12.6 years), Russia with five reactors after a 20 year average and the U.S. needed 18.5 and 23.2 years respectively to complete the last two units that started up in 1993 and 1996.

Figure 12: Average Annual Construction Times in the World 1954-2012



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

After the Three Mile Island accident in 1979, construction times in the U.S. escalated from an average of six years to almost 12 years. (See Annex 4, Figure 27a.). In France, construction times were five to six years between 1970 and 1985. In the second half of the 1980s they doubled due to a range of factors (design changes, upgrading, upcoming overcapacity). (See Annex 4, Figure 27b.).⁹⁹ The increase in construction times is considered the primary driver of rising costs.

⁹⁹ Mark Cooper, "Nuclear Safety and Nuclear Economics, Fukushima Reignites the Never-Ending Debate: Nuclear Safety at an Affordable Cost, Can We Have Both? Is Nuclear Power Not Worth the Risk at Any Price?", Institute for Energy and the Environment, Vermont Law School, March 2012.

Construction Times and Costs of Reactors Currently *Under Construction*

As indicated in the General Overview section, at least 18 of the units listed by the IAEA as “under construction” have encountered costly multi-year construction delays. All of the 41 remaining units were started within the last five years or have yet to reach their projected start-up date, making it difficult to assess whether they are running on schedule. Average construction time of the 59 listed projects currently stands at 7.4 years, ranging from the Baltiisk project in Kaliningrad, which was only launched in February 2012, to the Watts Bar-2 site in the U.S. with almost 40 years.

The eternal TVA project Watts Bar-2 in Tennessee and the EPR building sites in Finland and France are interesting cases of dramatically longer construction times and therefore increasing costs.

Watts Bar-2 – 43 Years Construction

The Tennessee Valley Authority (TVA) ordered the Watts Bar-2 reactor in 1970. It was expected to enter commercial operation in 1976. Construction started in 1973 and by 1976 the project was 43 percent complete and four years behind schedule.¹⁰⁰ Despite waning enthusiasm for atomic energy elsewhere in the country and numerous other nuclear plant orders being cancelled, it took until 1985, twelve years after construction start, to officially suspend work on the project.

In 1996, Watts Bar-1 was connected to the grid after 23 years of construction, the latest of the currently operating nuclear plants in the U.S.

In 2000 the NRC granted the first extension of the 1973 construction permit for Watts Bar-2 to the end of 2010. In 2007, the TVA board approved a 5-year plan to complete Watts Bar 2 at a cost of about \$2.5 billion. At this point the plant was about 60 percent complete and commercial operation planned for 2012. In 2008, the NRC extended the construction permit for a second time, to March 2013, and construction resumed. In March 2009, TVA provided an update to its original license application from June 1976, which is still under review by the NRC.¹⁰¹

As of April 2012, almost forty years after the original construction start, four years after reactivation work started, Watts Bar-2 was about 70 percent complete. An updated cost estimate identified additional funding needs to \$1.5 billion to \$2.0 billion, bringing the total reactivation cost to between \$4 billion and \$4.5 billion. TVA’s new “estimated time to complete is between September and December of 2015.”¹⁰² One month later, the NRC stated that “TVA plans to complete construction in late 2015 or 2016”.¹⁰³

EPR – European Problem Reactor

In April 1989, the German reactor builder Siemens and its French counterpart Framatome (now integrated into AREVA) signed an agreement for the development of Pressurized Water Reactors (PWRs). In November 1989, the two companies formed a consortium called Nuclear Power International (NPI) (which was later turned into Framatome ANP and then AREVA NP) for the development and marketing of the “European Pressurized Water Reactor (EPR)”. In 1992 NPI projected a license application by 1995 and construction start in 1998.¹⁰⁴ Nineteen years have past

¹⁰⁰ W. David Montgomery, James P. Quirk, “Cost Escalation in Nuclear Power”, California Institute of Technology, January 1978.

¹⁰¹ Detailed information on the licensing aspects and history of the reactivation project is available on the NRC website at <http://www.nrc.gov/info-finder/reactor/wb/watts-bar.html>, accessed on 17 May 2012.

¹⁰² TVA, “TVA Releases Cost, Schedule Estimates for Watts Bar Nuclear Unit 2”, 5 April 2012.

¹⁰³ NRC, “NRC Schedules Public Meeting for May 22 to Discuss Watts Bar Nuclear Unit 2 Construction Project”, NRC News, 15 May 2012.

¹⁰⁴ The Guardian, “Partners put safety first”, 15 October 1992.

since Siemens deposited a patent for the EPR pressure vessel¹⁰⁵, which illustrates the long period required from development to implementation that today is still years away. By 1998, the “green-red” coalition governments, which had been elected in France and Germany, led to the freezing of plans for an EPR in France, and the preparation for a nuclear phase-out agreement in Germany. It took until August 2005 for the first concrete for an EPR to be poured—in Finland.

The Olkiluoto-3 unit was planned to start-up in 2009. In October 2008 the project was two years late and about €1 billion over budget. Analyst Pierre Bucheny of Paris based Landsbanki Kepler estimated that the cost overrun had already wiped out the profit margin on AREVA’s next ten reactor sales.¹⁰⁶ By early 2012, following a long series of management problems, quality-control issues, component failures and design difficulties, Olkiluoto-3 is about five years behind planning and cost estimates rose to between €6 and €6.6 billion or 100-120 percent over budget.

The French equivalent project Flamanville-3 is not doing any better. Construction started in December 2007 with startup originally planned for 2012, but as of today is scheduled for 2016. Delays and cost overruns are increasing even faster than in the Finnish case and estimates are already at about €6 billion. Standard & Poor’s has noted:

We consider the hold-up at Flamanville as much more significant than the one at Olkiluoto because it implies that EDF, even with its vast experience, hasn't been able to maintain civil works on schedule.¹⁰⁷

In an unprecedented move, the three nuclear safety regulators from Finland, France, and the United Kingdom issued a joint statement on 2 November 2009 raising concern about the EPR’s Instrumentation and Control (I&C) system, noting that AREVA’s design “doesn’t comply with the independence principle, as there is a very high degree of complex interconnectivity between the control and safety systems.”¹⁰⁸ Full system independence is fundamental to guarantee plant safety in case the control system fails. While the UK authorities stated that they had resolved the regulatory issue in November 2010, it took the French safety authority until April 2012 to consider the suggested solutions satisfactory. The Finnish regulator STUK has still not validated the system.

Meanwhile, design certification of the EPR has been delayed in the U.S.. The NRC has told AREVA that completion of the rulemaking by the end of 2014, rather than June 2013, “will still present a challenge” and that there was “no margin” in the new schedule.¹⁰⁹

The following table gives a historic overview of the cost estimates for the EPR. In 2003, the French Ministry for Industry estimated the construction cost at €1,043 per installed kilowatt (€/kW) and production costs at €28.4 per MWh for the reference year 2015.¹¹⁰ This assessment served as the basis for the decision to go ahead with the Flamanville-3 investment, arguing that an EPR would generate cheaper power than the existing French nuclear fleet. The French Nuclear Energy Society (SFEN) still presents these 10-year-old figures on its website.¹¹¹

The first detailed assessment independent of the builder, the utility and the government was published in early 2012 by the Court of Accounts (Cour des Comptes). Construction costs were put at €3,700 per kW and power generating costs of 70-90 Euro₂₀₁₀, roughly three times the original 2003

¹⁰⁵ “Reaktordruckbehälter mit limitierten Versagenszonen”, filed on 15 March 1993, see <http://www.patent-de.com/19940922/DE4308207A1.html>, accessed on 13 May 2012.

¹⁰⁶ Anne-Sylvaine Chassany, “AREVA to Settle Finnish Project Loss With Client TVO (Update 2)”, Bloomberg, 16 October 2012; see <http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aNHcrUQUJmu0>, accessed 16 May 2012.

¹⁰⁷ Standard & Poor’s, “Construction Track Records For New Nuclear Plants Around The World So Far Are Mixed”, 16 August 2010.

¹⁰⁸ ASN/HSE/STUK, “Joint Regulatory Position Statement on the EPR Pressurised Water Reactor,” press release, 2 November 2009.

¹⁰⁹ David B. Matthews, NRC, Letter to Anthony Robinson, AREVA NP, 21 May 2012.

¹¹⁰ For detailed references for all cost estimates see Table 2.

¹¹¹ SFEN, “Comment calcule-t-on le coût du kWh nucléaire”, see <http://www.sfen.org/Comment-calcule-t-on-le-cout-du>, accessed 17 May 2012.

government estimate. Finally, with an estimated £14 billion projected for its two-unit EPR project at Hinkley Point in the UK, the highest cost figure yet was calculated by EDF itself. This would bring the investment cost to €5,400 per kW, a staggering 4.2-fold increase from the 2003 estimate (adjusted for inflation). The MWh cost range would be 110-166 Euro₂₀₁₂ per MWh, depending on the rate of return required (10-15 percent return). This is between two and three times the current average baseload power price in the UK, which is around 51 Euro per MWh.

Table 2: Evolution of EPR Cost Estimates 2003-2012

Origin of Estimate	Construction Costs (€/kW) ¹¹²	Production Costs (€/MWh)
DGEMP 2003 ¹¹³	1,043 (1,274 € ₂₀₁₂)	28.4 ¹¹⁴ Euro ₂₀₀₁
EDF 2005 ¹¹⁵	?	(33-)41 ¹¹⁶ Euro ₂₀₀₄
EDF 2005 ¹¹⁷	?	(35-)43 ¹¹⁸ Euro ₂₀₀₄
EDF 2006 ¹¹⁹	2,063 (2,331 € ₂₀₁₂)	46 Euro ₂₀₀₅
AREVA 2007 ¹²⁰	1,300–1,800 (1,498–2,074 € ₂₀₁₂)	29.9 ¹²¹ Euro ₂₀₀₄
DGEC 2007 ¹²²	?	44.9 Euro ₂₀₀₇
EDF 2008 ¹²³	2,500 (2,677 € ₂₀₁₂)	54-60 ¹²⁴ Euro ₂₀₀₈
Cour des Comptes 2012 ¹²⁵	3,700 (3,874 € ₂₀₁₂)	70-90 Euro ₂₀₁₀
EDF 2012 ¹²⁶	5,400	110-166 ¹²⁷ Euro ₂₀₁₂

Sources: As indicated, assembled by MSC¹²⁸.

The UK government is considering guaranteeing a profit range for nuclear investors in the form of a “Contract for Difference” (CfD). However, making up for the difference between the current baseload power on the market and the estimated cost range of 110-166 Euro per MWh (the “strike price”) would be difficult to sell for the government. A Citigroup analysis wonders:

Transfer Construction Risk?: if construction costs are rising, then the only way to contain the rise in the strike price is to reduce the risk faced by the developer and thereby lower their cost of capital. In practice this means transferring the construction risk to the taxpayer / consumer. On the face of it the CfD arrangement is not designed to tackle construction risk allocation so some other mechanism will be needed alongside the CfD. If the government shoulders all of the construction risk then a cost of capital

¹¹² Figures in brackets are adjusted for inflation.

¹¹³ DGEMP, “Coûts de référence de la production d’électricité”, Ministère de l’Industrie, 2003.

¹¹⁴ Equivalent to 29.9€₂₀₀₄/MWh, according to EDF.

¹¹⁵ Serge Massart, Goulven Graillat, “La place d’EPR dans la stratégie d’EDF”, EDF, in Revue Contrôle, May 2005.

¹¹⁶ 41€ pour la tête de série, 33€ pour une série de 10 réacteurs.

¹¹⁷ EDF, “Projet Flamanville 3 – Construction d’une central électronucléaire ‘tête de série EPR’ sur le site de Flamanville”, Dossier Débat Public, CPDP, July 2005.

¹¹⁸ 43€ pour la tête de série, 35€ pour une série de 10 réacteurs.

¹¹⁹ EDF, “Investor Day”, London, 4 December 2008.

¹²⁰ Anne Lauvergeon, “Le nucléaire, un des atouts maîtres dans la nouvelle donne énergétique mondiale”, Réalités Industrielles, February 2007.

¹²¹ Equivalent to 28.4€₂₀₀₁/MWh.

¹²² According to Cour des Comptes, “Les coûts de la filière électronucléaire”, January 2012.

¹²³ EDF, “Investor Day”, London, 4 December 2008.

¹²⁴ Low estimate Flamanville-3 case; high estimate potential additional costs inherent to the site.

¹²⁵ Cour des Comptes, “Les coûts de la filière électronucléaire”, January 2012.

¹²⁶ The Times, “Soaring costs threaten to blow nuclear plans apart”, 7 May 2012.

¹²⁷ Citigroup, “New Nuclear in the UK – It isn’t getting any easier”, 8 May 2012.

¹²⁸ Thanks to Yves Marignac for his input.

below 10 percent is feasible; but the government would be taking on a huge risk over which it has little control.

Conclusion: if construction costs are indeed anything like £7bn per reactor, then an already very challenging programme may be reaching the point of impossibility in our view¹²⁹.

It is difficult to see how the Citigroup's analysis will fit with the statement by Energy Secretary Ed Davey when introducing the draft energy bill that would pave the way for a CfD scheme, in May 2012 when he said:

Unless nuclear can be price competitive, as the industry says it can be, unless it can be price competitive, these nuclear projects won't proceed.¹³⁰

Financial Markets and Nuclear Power

Power sector investment requirements globally are expected to be in the order of \$16.9 trillion by 2035, according to the New Policy Scenario of the IEA, of which 58% will be required to build power stations and the rest for the networks. The majority of this, nearly \$10 trillion will be required outside the OECD, in particular to meet rising demand and urbanisation trends¹³¹. Within the OECD the retirement of existing capacity coupled with the move towards a decarbonised power sector have increased the forecasted investment requirements over current levels.

Financial Institutions' Views of Nuclear Power

Given its higher construction costs and longer lead times coupled with its history of cost overruns and delays, nuclear power is perceived by many financial institutions as a higher risk investment than other conventional electricity-generating sources, particularly gas. The perception of a higher risk is important as it can lead to a higher interest rate at which utilities can borrow, and therefore significantly raises the final cost of a nuclear construction. This is why investment institutions, such as Citibank, have stated that "Due to the uncertainties on timing and cost, we believe nuclear projects should have a higher ERP [Equity risk premium] than the overall market."¹³²

However, the financial risk is not limited to an individual project, but it can affect the utility itself. Citibank states that "three of the risks faced by developers—Construction, Power Price, and Operational—are so large and variable that individually they could each bring even the largest utility company to its knees".¹³³

In the weeks and months following the nuclear meltdowns at Fukushima many in the financial community made clear their views on the expected impact on the development of the global nuclear sector. The financial institution UBS stated very clearly:

We believe the Fukushima accident was the most serious ever for the credibility of nuclear power.¹³⁴

In their April 2011 analysis they highlighted the impact of the accident on TEPCO and the lessons that this might have for other utilities:

Before the Fukushima accident, TEPCO was viewed as a low risk regulated utility, mainly bought for its stable earnings and dividends. However, the events at Fukushima have led to an 80% decline in its

¹²⁹ Citigroup; "New Nuclear in the UK – It isn't getting any easier", 8 May 2012.

¹³⁰ BBC, "Energy bill avoids carbon pledge", 22 May 2012, see <http://www.bbc.co.uk/news/science-environment-18146940>, accessed 22 May 2012.

¹³¹ IEA, "World Energy Outlook 2011", International Energy Agency, November 2011

¹³² CitiBank, "New Nuclear – The Economics Say No", November 2009

¹³³ CitiBank, "New Nuclear – The Economics Say No", November 2009

¹³⁴ UBS Investment Research, "Q-Series: Global Nuclear Power, Can nuclear power survive Fukushima ?", 4 April 2012

share price and discussions about the future viability of the company. Such a quick change in prospects would have been unlikely if Fukushima had been a traditional thermal generation plant. This additional risk linked to nuclear exposure has not, it seems to us, been properly priced in by the market.¹³⁵

While HSBC stated in March 2011: “Overall, we expect a number of impacts from the public and political backlash against nuclear, which could mean the focus switches to renewables”.¹³⁶ They further listed the series of existing problems for the further deployment of nuclear power:

We note that the build-out of new nuclear facilities in most nuclear countries is contingent on some form of subsidy/loan guarantee/ financing from governments and as such are deeply political issues with an increasingly skeptical public. Hence safety is likely to be the latest black mark to be put against the nuclear industry, on a list that includes water intensity (versus expected future water scarcity), slow build times, cost overruns, waste disposal and proliferation.¹³⁷

After Fukushima, Moody’s prepared a special note on nuclear power, which highlighted the global impact of the accident. Moody’s stated that it had created “a material credit negative for all issuers that own and operate nuclear generation due to increased political intervention; emboldened opposition forces; intensified regulatory scrutiny and higher costs”. On the question of costs they stated that “issuers pursuing the construction of new nuclear generation are already being ascribed a higher risk profile. The potential for delays during construction can increase costs, which could raise regulatory prudence/disallowance risks. This scenario was last evidenced in the U.S. in the 1980’s, following the Three Mile Island accident”.¹³⁸

Predictions on the possible importance and impact of Fukushima have been borne out over the past fifteen months, with little global appetite for construction of new nuclear reactors. As has been shown in other sections of this report, only in three countries has new build begun, in India, Pakistan and Russia. There is no single reason for the lack of new orders, but it is clear that in those parts of the world that have more liberalized electricity markets, an important factor is the rising financial costs that are affecting the economics of new build. The Chief Executive of E.ON, one of the largest nuclear operators in Europe, said:

Ultimately the driver for investment [in new reactors] will be the cost of capital, not politics. Definitely, the cost of capital will be higher after Fukushima.¹³⁹

Credit Rating Agencies and Nuclear Power

Rating agencies, of which there are three major institutions, Moody’s, Standard and Poor’s and Fitch, assess the financial strength of companies and governmental entities and their ability to meet the interest and principal payments on their bonds and other debt. (See Annex 5 for the definitions of rating levels.) The ratings given can affect the interest rates at which a company is able to borrow and therefore is an important factor for utilities needing external investment for nuclear projects.

Table 3 highlights the range of current ratings of a number of major nuclear vendors and utilities and thus the views that the rating agencies, in this case Standard & Poor’s (S&P), have of different companies with nuclear interests. The impact of Fukushima on the nuclear companies is obvious. TEPCO has moved from an AA rating prior to the event to a B+ rating today. The world’s largest reactor builder AREVA, as noted in the France Focus section of this report, started declining long before 3/11 and plunged from an A rating in 2009 to BBB-, only one notch above ‘junk’ status. AREVA’s credit rating problems are in part as a result of the delays and cost overruns at the French and Finish EPR construction projects.

¹³⁵ Ibidem.

¹³⁶ HSBC, “Climate Investment Update: Japan’s nuclear crisis and the case for clean energy”, 18 March 2010

¹³⁷ Ibidem.

¹³⁸ Moody’s 2011, “Re-evaluating Creditworthiness for Global Nuclear Generators: Moody’s Investor Service, Special Comment, 7 April 2011.

¹³⁹ Platts, “Europe will return to nuclear power some day, Enel chief says”, Nucleonics Week, 16th June 2011

Table 3: Long Term Credit Ratings of Nuclear Related Companies

Standard and Poor's Long-Term Credit Rating (year end or as noted)							
<i>Company</i>	2012 June	2011 June	2011 April	2010	2009	2008	2007
EDF	A+	AA-	AA-	A+	A+	AA-	AA-
KEPCO	A	A	A	A	A	A	A
E.ON	A	A	A	A	A	A	A
CEZ	A-	A-	A-	A-	A-	A-	A-
Iberdrola	A-	A-	A-	A-	A-	A-	A-
RWE	A-	A-	A-	A	A	A	A+
ENEL	BBB+	A-	A-	A-	A-	A-	A-
Exelon	BBB	BBB	BBB	BBB	BBB	BBB	BBB+
TVO	BBB	-	-	-	-	-	-
AREVA	BBB-	BBB+	BBB+	BBB+	A	-	-
TEPCO	B+	B+	BBB+	AA	AA	AA	AA

Sources: S&P, Financial Times, Reuters, Company websites and Annual Reports 2011¹⁴⁰

Further strengthening the view that engagement in nuclear can harm the credit rating of a company was the decision by the German engineering company Siemens to exit its nuclear business in September 2011, which was seen by Moody's to be credit positive. The reasons given by Moody's were:

First, financial returns on this complex technology are risky as during the construction phase customers often expand safety specifications, which then may trigger disputes between suppliers and clients. Second, research and development (R&D) requirements are high at a time when future demand for new facilities is increasingly uncertain owing to recent safety concerns (e.g., Japan's Fukushima nuclear accident) and political intervention. Third, the exit frees up funds that Siemens can redeploy in businesses with better visibility, like power transformation.¹⁴¹

These delays are also affecting the credit rating of the Finnish utility Teollisuuden Voima Tyj (TVO), which was downrated by Fitch to a BBB+ due to concerns over the current delays at Olkiluoto-3 (OL3). The credit agency further warned:

The ratings would come under pressure if further OL3 delays materially impact TVO's production costs, or litigation costs were to materialize with the construction contract supplier, AREVA.¹⁴²

A few days later, Standard & Poor's rated TVO BBB, even lower than Fitch, and argued that risk was linked as well to operating as new build reactors: TVO's dependence on its current two nuclear plants in Finland exposes the company to asset concentration risk, primarily disruption of operations" and "we expect that TVO's financial risk profile will continue to be negatively affected in the near to medium term by the large investment in the new nuclear plant" Olkiluoto-3.

Standard & Poor's does not exclude further down-rating, arguing that

ratings could be negatively affected if TVO's liquidity position weakened, for example if the company's net cash outflows were higher than expected primarily related to the construction of Olkiluoto-3¹⁴³ (See EPR—European Problem Reactor).

¹⁴⁰ Based on research by John Corbett, London, commissioned by MSC.

¹⁴¹ Wolfgang Draack, "Siemens Exit from Nuclear is Credit Positive", in Moody's, Weekly Credit Outlook, 26 September 2011.

¹⁴² FitchRatings, "Fitch Downgrades Teollisuuden Voima Oyj to 'BBB+', Outlook Stable", 1 June 2012, http://www.fitchratings.com/creditedesk/press_releases/detail.cfm?pr_id=751432

¹⁴³ Standard & Poor's,

None of the eleven companies we looked at has improved its rating levels over the past five years, while four remained stable and seven were downgraded. This is an indication of the problems faced by many general energy utilities, but also mirrors the views of the agencies on nuclear investments.

A Moody's analyst was quoted in the energy trade press in March 2012 as stating:

The risks are writ larger when you think of a nuclear project [than for other forms of generation], because construction and planning is that much more tortuous, construction risk is higher and from an operational point of they have a high fixed cost base.¹⁴⁴

It was further stated:

If [a utility] is already on the edge of a ratings band, a nuclear project could be the thing that pushes them over the edge—it's just another negative factor.¹⁴⁵

In April 2012, RWE and E.ON announced that they would no longer proceed with their plans to build nuclear power in the UK. The reaction of Moody's investor service was again credit positive:

The companies' decision to pull out of their UK nuclear joint venture, known as Horizon Nuclear Power, is credit positive for both German utilities, which can instead focus on investment in less risky projects.¹⁴⁶

Market Value

Many of the major electrical power utilities are now fully or partially owned, often through shares, by the private sector. Consequently, macro trends, such as the development in national policies, global fuel prices and international nuclear developments, along with individual company management issues can, and do, affect share prices. Figure 13 compares the share value of a number of utilities, mainly those involved in nuclear power, with the U.K. FTSE100¹⁴⁷. Interestingly, these have all performed worse than the FTSE 100 average, the only exception being SSE, which has recently pulled out of plans to build nuclear plants in the UK. The figure also, not surprisingly, shows the fall in the share price of TEPCO, which has lost 96% of its share value since 2007. The shares of the world's largest nuclear operator EDF have lost 82 percent of their value over the same period, while the largest nuclear builder AREVA has lost 88 percent.

Nuclear companies are not the only energy sector whose share prices have fallen. Changes in government policies have had a significant impact on the prices of renewable energy companies. Uncertainties over the relative prices of fossil fuels, particularly relating to reductions in demand resulting from the economic downturn, have led to reductions in the values of many other major energy companies. However, as the next chapter illustrates, the renewable energy sector is rather subject to a shift between companies and continues to retain overall very substantial growth figures.

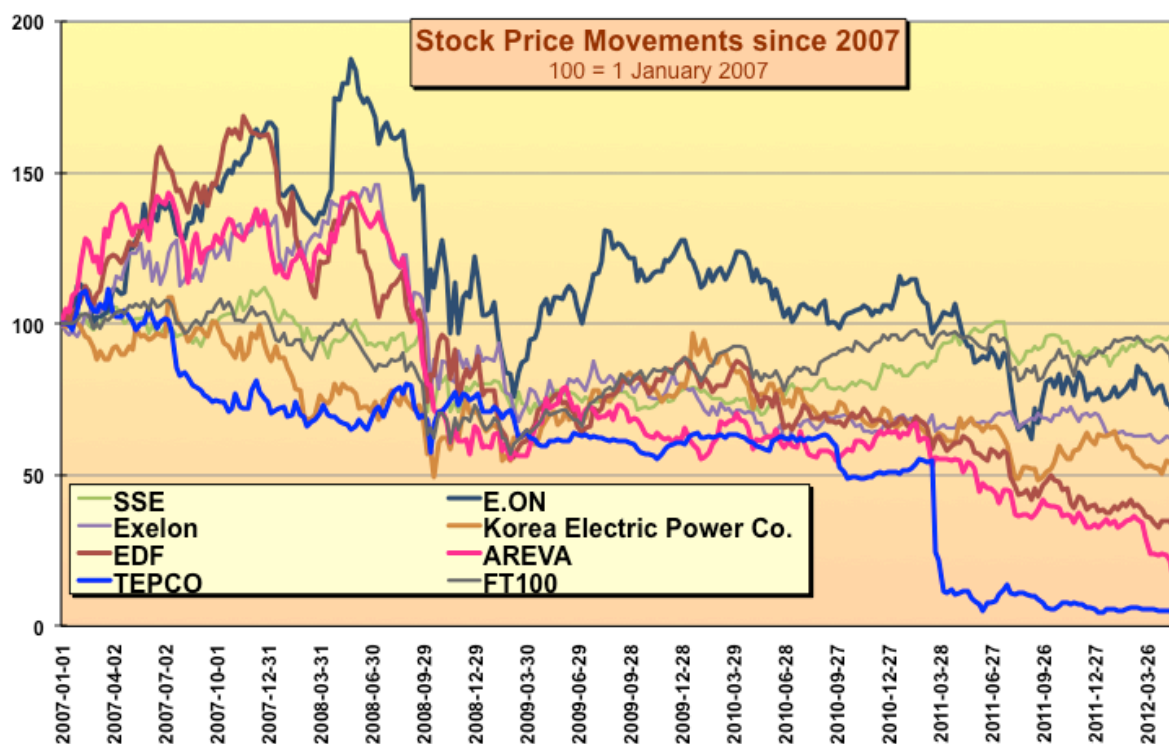
¹⁴⁴ ICIS Heren, "New nuclear electricity costs hit utility ratings - Moody's", 27 March 2012, <http://www.icis.com/heren/articles/2012/03/27/9545356/power/edem/new-nuclear-electricity-costs-hit-utility-ratings---moody's.html>

¹⁴⁵ ICIS Heren, "Nuclear electricity investment could risk utility credit ratings – analysts", 20 March 2012, <http://www.icis.com/heren/articles/2012/03/20/9543406/power/edem/nuclear-electricity-investment-could-risk-utility-credit-ratings--analysts.html>

¹⁴⁶ I-nuclear, "Moody's says German withdrawal 'credit positive'; decision gives EDF bargaining power", 2 April 2012, <http://www.i-nuclear.com/2012/04/02/moodys-says-german-withdrawal-credit-positive-decision-gives-edf-bargaining-power/>

¹⁴⁷ The FTSE is the share index of the 100 companies with the highest market capitalization on the London Stock Exchange.

Figure 13: Share Prices of Major Utilities 2007-June 2012 compared to FTSE100



Source: Financial Times, Accessed June 2012

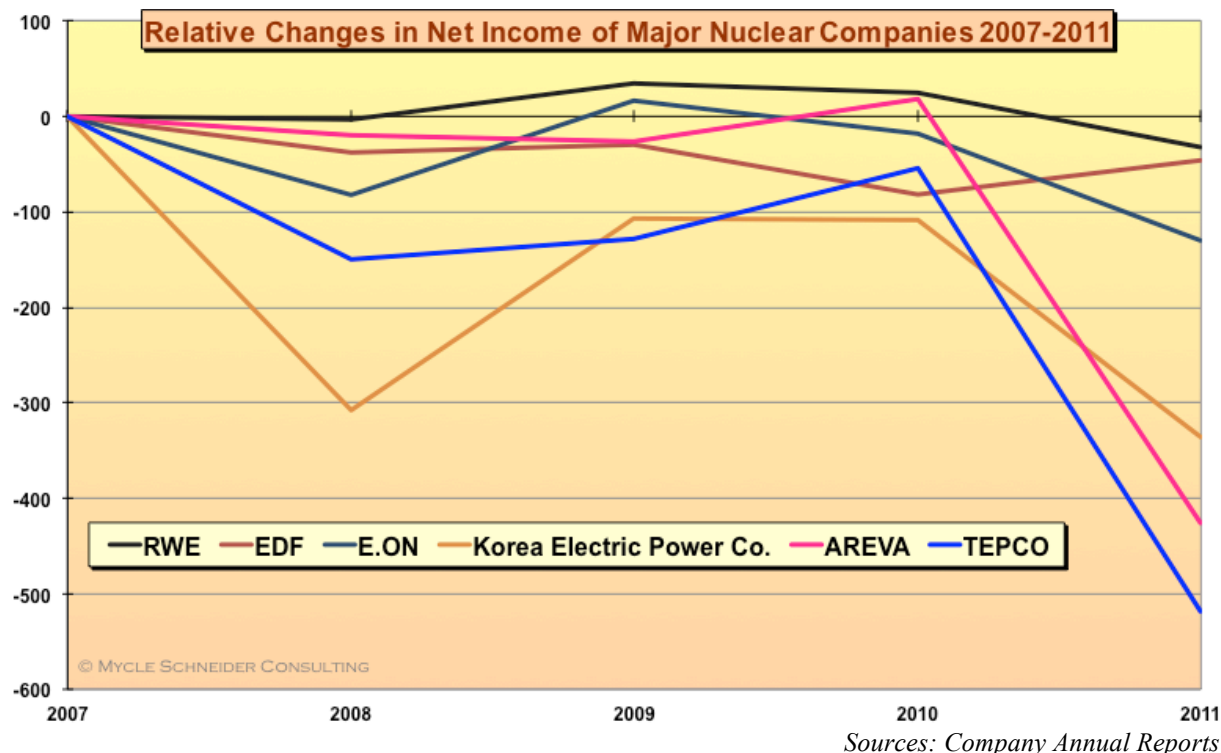
Book Value

The figure below shows the relative net income of major utilities and vendors involved in nuclear power since 2007, with none of the companies surveyed considerably increasing their income over the period. While the loss of TEPCO, as the operator of Fukushima, would be expected, the performance of other major nuclear companies is surprising. As reflected in the declining credit rating, AREVA is doing particularly badly over the last year, with a net income of €883 million in 2010¹⁴⁸ shifting to a loss of €2.4 billion in 2011. The South Korean KEPCO has also experienced significant losses in the past few years and has stated that electricity prices are so low that it cannot cover its operating costs. Consequently, it is beholden to national policy both as the Government controls 51% of the shares and in order to increase electricity prices.

The past five years have seen the decline in the fortunes of many of the major nuclear vendors and utilities. This is in part due to the uncertainties in the electricity markets, due to uncertainty over fossil fuel, particularly gas prices, the continual rise in the deployment of renewable energy, restricted access to capital and demand uncertainty. These macro issues are creating insecurities for all electricity producers and “under normal circumstances” particularly negatively affect nuclear power, due to its large upfront construction costs and long lead times. Fukushima has added another layer of ambiguities for the nuclear sector, including doubts over the required long term public and political support, questions on the future direction of reactor designs and safety requirements and the cost of attracting private capital into an increasingly regulated electricity market.

¹⁴⁸ It should be noted though that, already in pre-Fukushima 2010, AREVA registered an operational deficit of €423 million.

Figure 14: Relative Changes in Net Income of Major Nuclear Companies 2007-2011



Given the extent that these risks are now understood by the utilities and the financial sector, it is clear that nuclear will not be built without significant government support. In a revealing presentation on nuclear, a representative of the French Corporate and Investment Bank BNP-Paribas concluded that “significant Government sponsorship will be required in most markets to implement new nuclear”. The economic reasons for this were given as:

- Most nuclear projects are financed either by Governments or by very large utilities
- They are at high risk of being completed late and significantly over budget.
- Nuclear projects face heightened political risk relative to other energy assets.
- Public acceptance is not assured and this brings reputational risk.
- No clear idea about the economics¹⁴⁹.

Interestingly, BNP-Paribas is one of the few Banks that has a policy specifically on the conditions on which it will fund nuclear projects.

In the UK an analysis by Citigroup in May 2012 on nuclear costs made clear that the governments proposed mechanisms for supporting the construction of new nuclear will “will transfer revenue risk from the developer to the consumer”. Furthermore, Citibank noted that in the event of higher construction costs “the only way to contain the rise in the strike price is to reduce the risk faced by the developer and thereby lower their cost of capital. In practice this means transferring the construction risk to the taxpayer / consumer.”¹⁵⁰ (See EPR-European Problem Reactor).

¹⁴⁹ BNP-Paribas 2012, “How will financing be secured in the future?”, Mark Muldowney, Presented at the European Nuclear Forum, Brussels, 19 March 2012.

¹⁵⁰ Citigroup; “New Nuclear in the UK – It isn’t getting any easier”, 8 May 2012.

Nuclear Power vs. Renewable Energy Deployment

As a consequence of climate change, the move towards a low or zero carbon and non-fossil fuel dependent energy sector must be both rapid and global. Given the diversity of energy services—cooking, heating and cooling, lighting, communication, mobility, motor torque—there is no silver bullet or single technology that will create a low carbon energy future. Therefore a number of factors will determine the relative roles and ranking of different technologies, notably: potential for rapid global deployment, other non-fuel and CO₂ resource constraints, the compatibility with existing systems and other technologies, public and political support and the relative and projected economics.

Investment

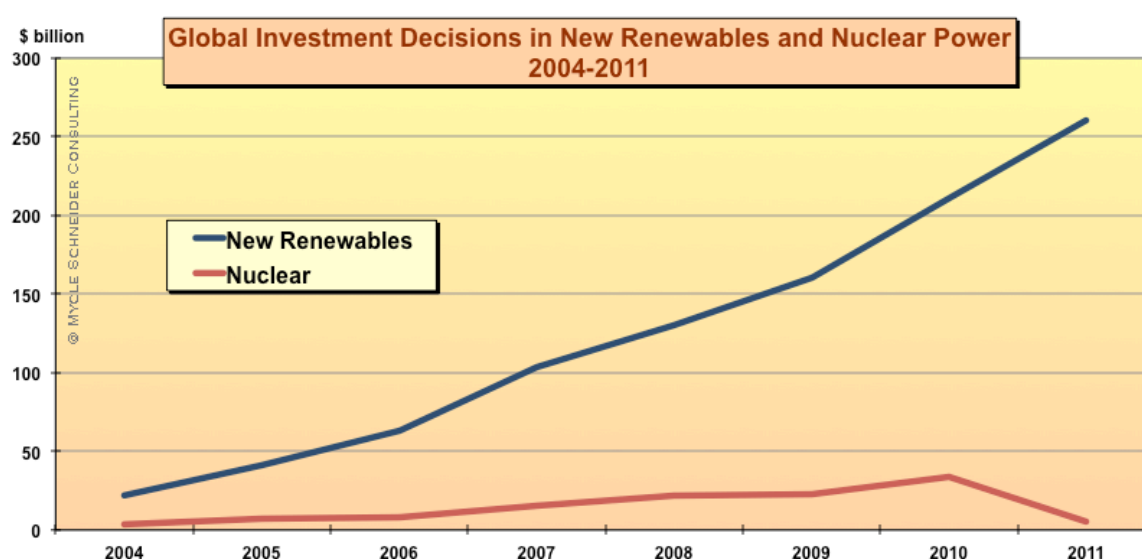
The last few years have seen an unprecedented growth in the deployment of renewable energy, particularly solar photovoltaics (PV) and wind power. According to an assessment by Bloomberg New Energy Finance, global investment in clean energy reached a new record of \$260 billion in 2011, up 5 percent on 2010 and almost five times the 2004 total of \$53.6 billion. Within the 2011 figures were two linked but important factors. Michael Liebreich, CEA of Bloomberg New Energy Finance, stated:

Firstly, a 36 percent increase in investment in solar technology, to \$136.6 billion, which was nearly double the \$74.9 billion investment in wind power.

The performance of solar is even more remarkable when you consider that the price of photovoltaic modules fell by close to 50 percent during 2011, and now stands 75 percent lower than three years ago, in mid-2008.¹⁵¹

Secondly, while the largest single type of investment was the asset finance of utility scale renewable energy projects, the second biggest category of investment was the finance of distributed renewable power technology, notably rooftop PV. This reached \$73.8 billion.

Figure 15: Global Investment Decisions in New Renewables and Nuclear Power 2004-11



Source: Bloomberg New Energy Finance (2012) and WNISR original research (2012)

¹⁵¹ BNEF, 2012, “Solar surge drives record clean energy investments in 2011”. 12 January 2012, Bloomberg New Energy Finance, <http://www.newenergyfinance.com/free-publications/press-releases/>

Figure 15 compares global investment allocation since 2004 in new nuclear power plants and new renewable energy (which excludes large hydro). For nuclear power all the investment costs 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. However, the figures demonstrate the extent of the difference in investment between nuclear and new renewables in the past seven years.

Table 4: Renewable Energy Investment in Top 10 Countries 2009-2011 (in billion US\$)

Country	2011	2010	2009
United States	48.1	34.0	22.5
China	45.5	54.4	39.1
Germany	30.6	41.2	20.6
Italy	28.0	13.9	6.2
India	10.2	4.0	3.2
UK	9.4	7.0	N/A
Japan	8.6	7.0	N/A
Spain	8.6	4.9	10.5
Brazil	8.0	7.6	7.7
Canada	5.5	5.6	3.5

Source: BNEF 2012

The gradual increase in investment for nuclear power is primarily due to the Chinese nuclear programme, which accounts for almost 40 percent of the reactors under-construction worldwide. Following the accident at Fukushima there has been a rapid decline in new investment, again primarily due to China. This contrasts with the continual rise in renewable investment, despite the global economic downturn.

Table 4 shows the national investment levels in clean energy (which does not include nuclear power) of the last three years and interestingly, in 2011, the U.S. overtook China with a total investment of nearly \$50 billion. The other notable change between 2010 and 2011, was the rapid rise in Italy, which once again more than doubled its expenditure, with a similar scaleup from India.

Installed Capacity

The commissioning of new electricity-generating facilities involves two major phases, pre-development and construction. Both affect the speed of technology deployment. The pre-development phase can include a wide range of activities such as conducting extensive consultations, obtaining the necessary construction and operating licenses, including public consent, and creating the financing package. In some cases, technology deployment may be sped up through the use of generic safety assessments. Alternatively, pre-development may take longer than expected because of local site conditions, lack of available skilled workforce or new issues coming to light.

The IAEA estimates that starting a new nuclear program in a country without experience can take between 11 and 20 years, and the French safety authorities assume a minimum of 15 years to set up an appropriate framework. Even where countries have nuclear experience the IEA has estimated a pre-development phase of approximately eight years for nuclear power.¹⁵² This includes the time it takes to gain political approval but assumes an existing industrial infrastructure, workforce, and regulatory regime. Given the uncertainty of electricity demand forecasts, matching these with the long lead times required for nuclear development is a potentially high-risk venture. The long lead times and complexity of the commissioning and construction period for nuclear power create additional risk for the technology compared to other technologies. The history of the global nuclear industry is littered with examples of projects that have been proposed or even begun which have

¹⁵² IEA, "Nuclear Power in the OECD", Paris, 2001.

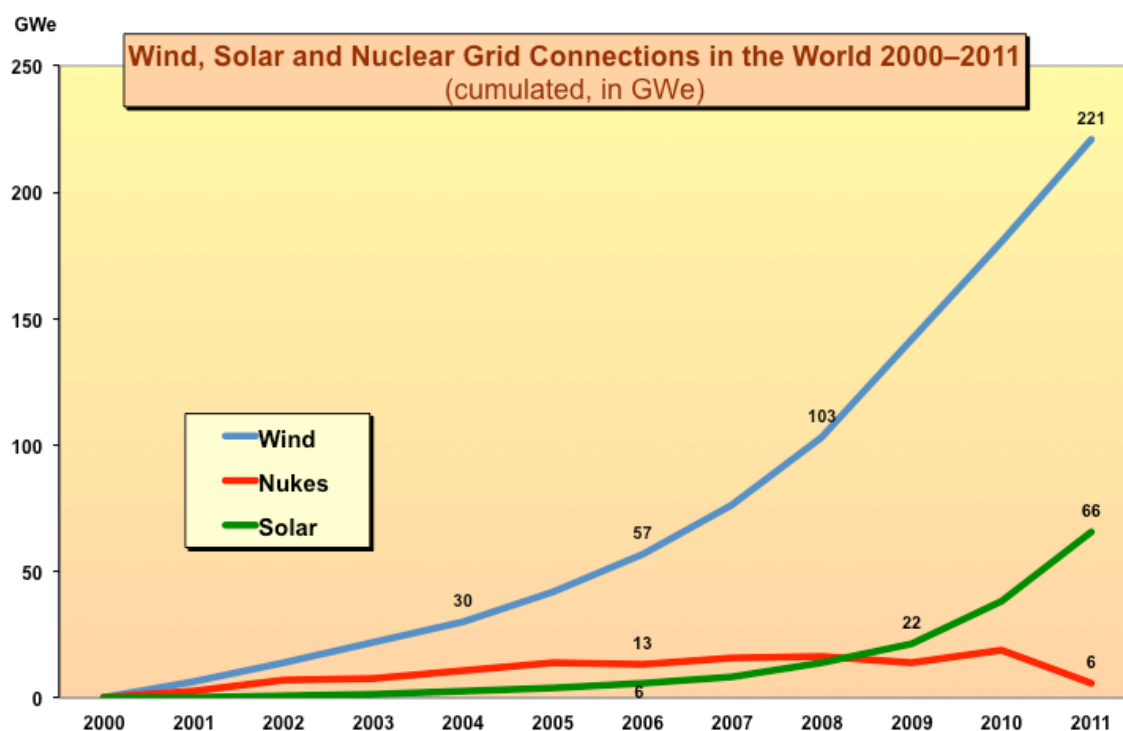
never led to an operating facility. For example in the United States 138 reactors were ordered but never completed.

It is important to note the differences in construction of a wind farm, and many other renewable energy schemes, compared to large fossil-fueled or nuclear power stations. The European Wind Energy Association (EWEA) likens building a wind farm to the purchase of a fleet of trucks: the turbines are bought at an agreed fixed cost and on an established delivery schedule, and the electrical infrastructure can be specified well in advance. Although some variable costs are associated with the civil works, these are very small compared to the overall project cost.¹⁵³ The construction time for onshore wind turbines is relatively quick, with smaller farms being completed in a few months, and most well within a year. The contrast with nuclear power, and even conventional fossil fuel power plants, is significant.

Looking at the net additions to the global electricity grid over the past two decades, nuclear power added some 2 GW annually on average during the beginning of this period, compared with a global installed nuclear capacity of some 360 GW today. However, this trend on new additions has stagnated or decreased since 2005. installed nuclear capacity actually decreased in the four years 2007-2009 and 2011. Over the same period, global installed wind power capacity increased more than 10 GW annually on average, rising steadily to more than 37 GW in 2009, 35 GW in 2010 and 41 GW in 2011.

Figure 16 compares the net added capacity of nuclear (grid connections minus shutdowns), wind and solar since 2000. As can be seen, over the last decade, the deployment of net new nuclear capacity (+6 GW) has been outpaced by wind power by a factor of 37 (+221 GW) and even the volume of solar PV added during the decade (+66 GW) has overtaken nuclear on the global level by a factor of ten.

Figure 16: Increases from 2000 of the Global Installed Nuclear, Wind and Solar Capacity (GW)



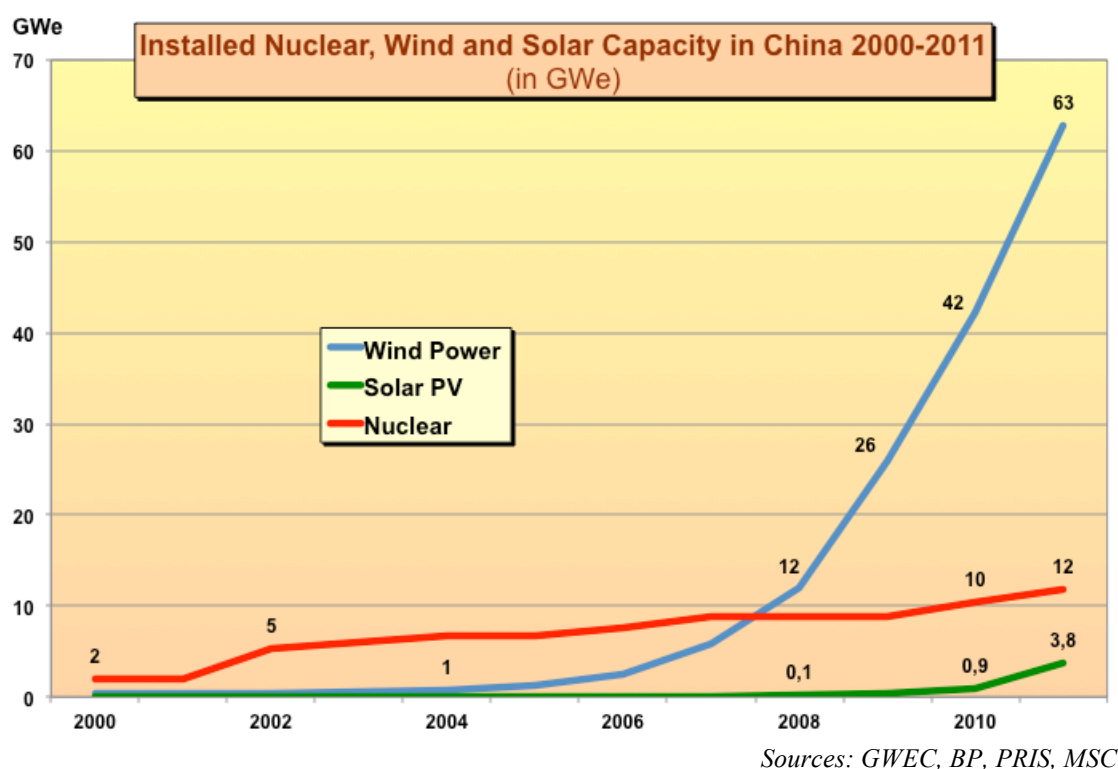
Source: IAEA-PRIS, Global Wind Energy Council, JRC, 2012

¹⁵³ European Wind Energy Association (EWEA), “Wind Energy, The Facts: Volume 1, Technology”, Brussels, 2003.

Part of this rapid scale-up is due to the geographical diversity of renewable energy deployment. According to the Global Wind Energy Council, about 75 countries worldwide have commercial wind power installations, with 22 of them already passing the 1 GW level by 2011, compared to 31 countries operating commercial nuclear reactors. Although the majority of renewable energy countries are in Europe, there is widespread deployment of wind power in Egypt (550 MW), New Zealand (622 MW), Morocco (291 MW), and the Caribbean (99 MW). Markets in emerging and developing countries now determine growth in wind power, and in 2011 alone, China installed 18 GW and India 3 GW.¹⁵⁴

China reflects an accelerated version of the global situation. Installed windpower capacity grew by a factor of 25 in five years to reach close to 63 GW, equivalent to the French nuclear fleet¹⁵⁵ and 5 times more than the Chinese nuclear capacity. Solar capacity was multiplied by a factor of 47 in those five years to reach 3.8 GW, while nuclear capacity just increased by a factor of 1.5 to 11.8 GW.

Figure 17: Nuclear, Wind and Solar Capacity Increases in China 2000-2011

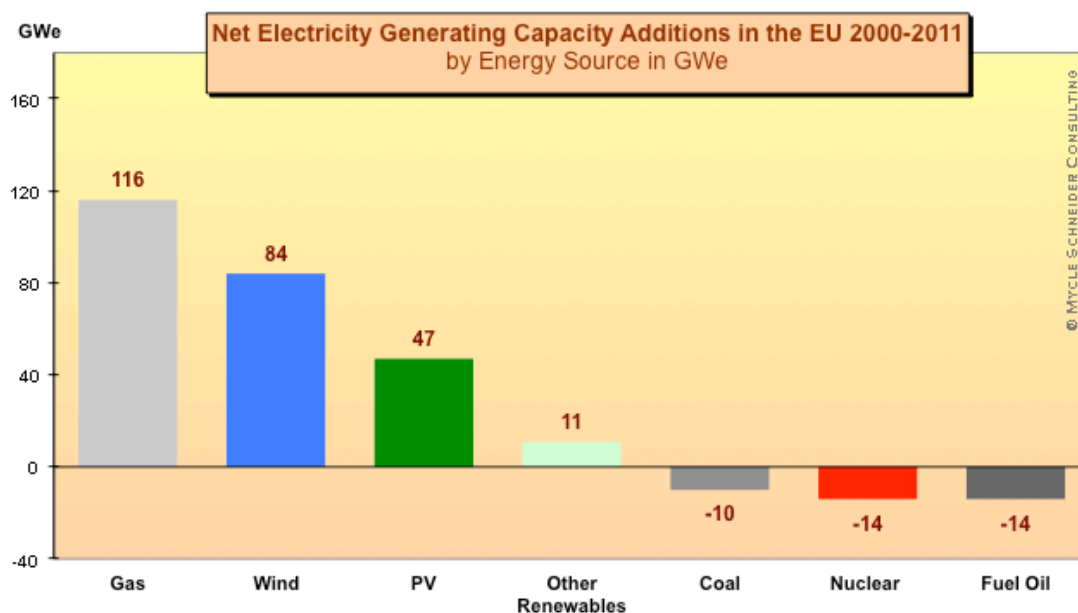


An analysis by the European Wind Energy Association (EWEA) shows that, while more than 120 GW of wind and solar were added to the EU power grid between 2000 and 2011—outpacing the 116 GW of natural gas additions—total installed nuclear capacity in the EU declined by 14 GW, joining the rapidly declining trend of coal- and oil-fired power plants. (See Figure 18.)

¹⁵⁴ GWEC, “Release of Global Wind Statistics: Wind Energy Powers Ahead Despite Economic Turmoil” Global Wind Energy Council, 7th February 2012.

¹⁵⁵ However, nuclear power plants generate between two and five times more than wind turbines per installed MW.

Figure 18: Electricity Capacity Additions in the EU27 in 2000-11



Source: MSC, based on EWEA 2012¹⁵⁶

Note: Other Renewables include large hydro (4 GW), biomass (3 GW), waste (2 GW), concentrated solar power (1 GW), small hydro (0.3 GW), geothermal (0.3 GW), peat (0.2 GW) and tidal/wave (0.01 GW).

Electricity Generation

Skeptics of renewable energy highlight the variable output of some technologies. A consequence of variability is the lower output per installed MW than that of traditional power stations. But despite this, electricity generated by non-hydro renewable generation is now becoming significant, both nationally and globally.

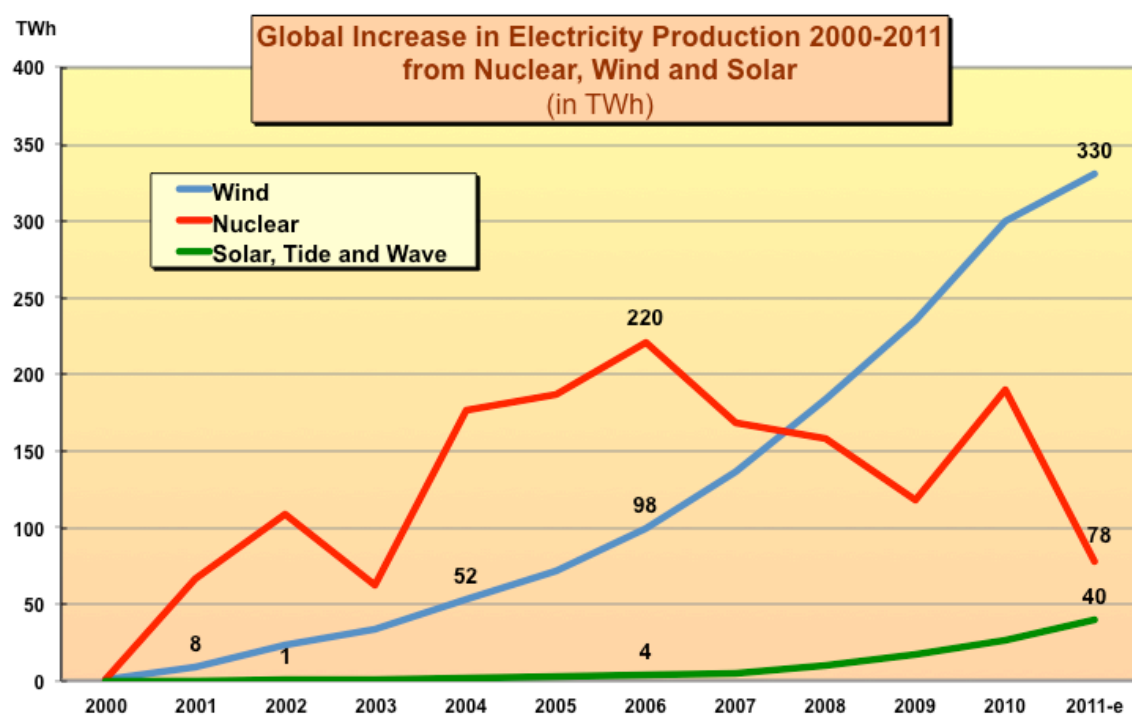
Figure 19 shows the additional electricity production from nuclear power, wind and solar¹⁵⁷ since 2000. As can be seen, in 2011 wind power produced 330 TWh more electricity than it did at the turn of the century, which is a four times greater increase than was achieved by the nuclear sector over the same period. The growth in solar PV has been impressive in the last decade and especially in the past few years, with a tenfold increase in the past five years. While the overall global contribution of nuclear power still exceeds, by a factor of six, that of solar and wind power, this gap is rapidly closing.

The growing importance of wind power is particularly striking in China, which also has by far the largest share of the global number of reactors under construction and is seen as the world leader in nuclear deployment. The pace of deployment of wind is such that not only has the rate of installation long outpaced nuclear but wind power generation is rapidly catching up to nuclear power. Just five years ago nuclear was producing 14 times as much electricity as wind, but by 2011 the difference was less than 30 percent.

¹⁵⁶ EWEA 2012, "Wind in Power, 2011 European Statistics", European Wind Energy Association, February 2012

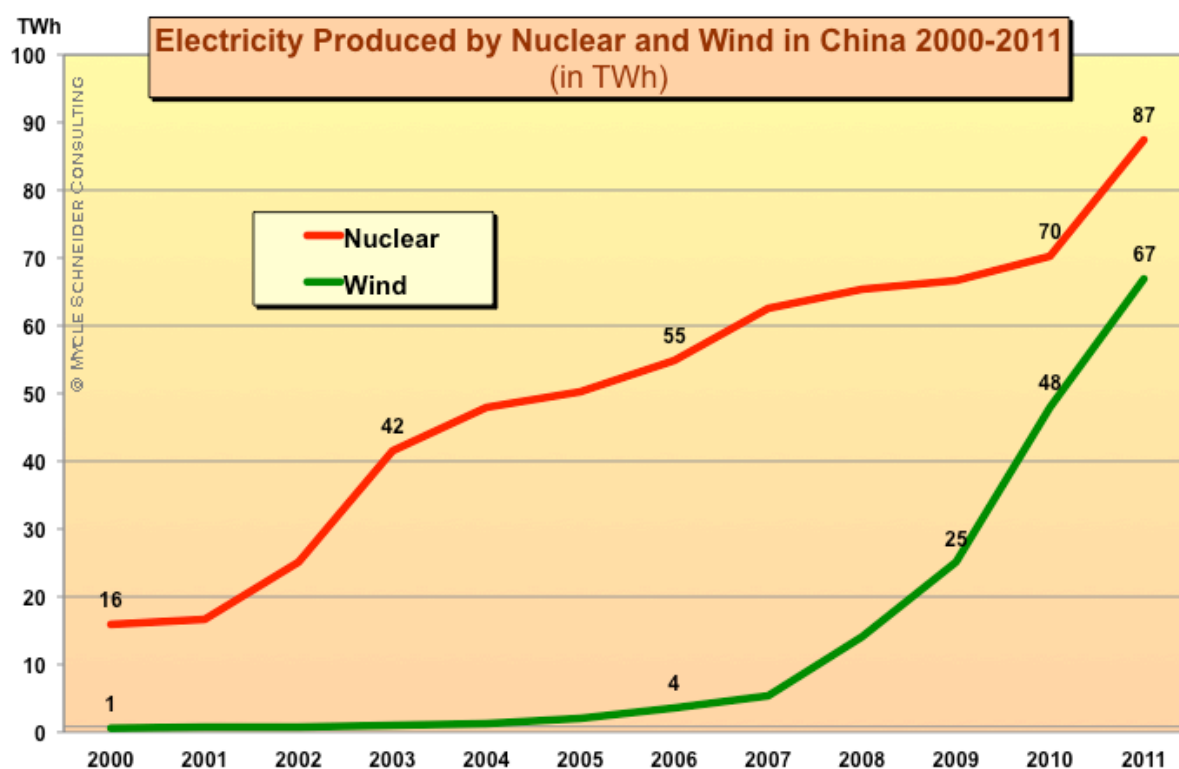
¹⁵⁷ The numbers for solar include tidal and wave power, but with only 300 MW of installed capacity globally their contribution is negligible.

Figure 19: Global Electricity Production from Nuclear and Selected Renewables



Source: US-EIA 2012, IAEA-PRIS 2012, various, MSC 2012.

Figure 20: Electricity produced by Nuclear Power and Wind in China



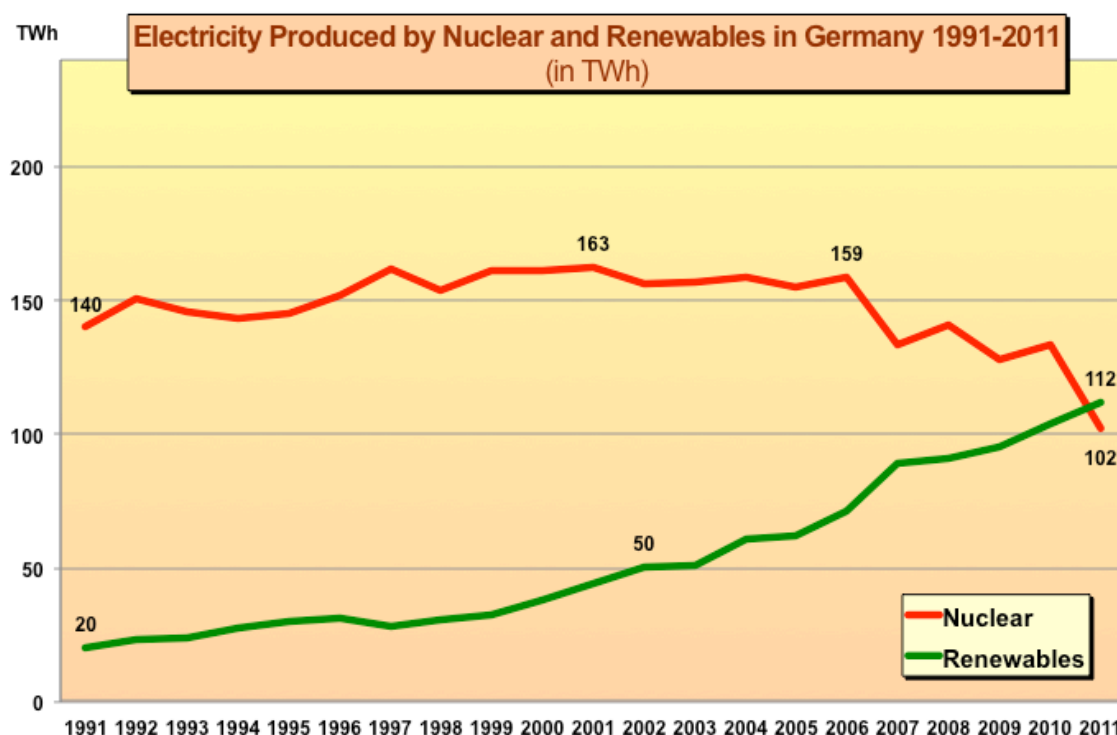
Source: US EIA, IAEA-PRIS, WNISR, 2012

In many countries and regions a historic crossover is occurring whereby renewable energy is now providing a larger contribution than nuclear power.

Four German states generated more than 45 percent of their electricity from wind turbines alone in 2011.¹⁵⁸ As of the end of 2011, the combined installed renewable electricity capacity in Germany totaled 65.4 GW¹⁵⁹, that is more than the available French nuclear capacity (63.1 GW). Of course, French nuclear plants generated 424 TWh, while German renewables generated “only” 122 TWh of electricity or 29 percent of French nuclear power in 2011; but the German renewables growth rate is very significant (+17.3 percent) while French nuclear generation is stagnating at best.¹⁶⁰

In 2011, for the first time since the buildup of the nuclear program in Germany, for the first time, the power production from renewables with 122 TWh (gross) was only second to lignite (153 TWh), exceeded that of coal (114.5 TWh), nuclear power (102 TWh) and natural gas (84 TWh). (See Figure 21). Total renewables output increased by 19 percent over the previous year and represents now one fifth of the German power generation, up from 3 percent in 1991. The growth rate in recent years has been particularly impressive in the solar power sector. Within two years, about 15 GW of photovoltaic capacity got added to the grid bringing the total to 25 GW, and solar power generation tripled to 19 TWh in 2011.

Figure 21: German Power Generation of Nuclear and Renewables



Sources: PRIS 2012, AGEb 2012

¹⁵⁸ J.P. Molly, “Status der Windenergienutzung in Deutschland – Stand 31.12.2011”, Berlin, DEWI, 2012.

¹⁵⁹ Essentially wind (29 GW) and solar plants (24.8 GW), plus biomass (5.5 GW), hydro (4.4 GW), biogenic share of incinerated waste (1.7); see BMU, “Daten des BMU zur Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2011 auf der Grundlage der Angaben der AGEE-Stat”, provisional, 8 March 2012.

¹⁶⁰ French nuclear plants already generated more power in 2004 (427 TWh) than in 2011, while the German renewables more than doubled production over the same period from 56 to 122 TWh.

The Renewables and Nuclear Cost Cross-Over

The rapid development of renewable energy has been driven by recognition that there needs to be radical change in supply for reasons of climate change, resource efficiency and security of energy supply. Furthermore, some governments have seized upon the development of renewables as a means of future economic growth. Government financial support schemes have been introduced to enable renewables to compete in many liberalized energy markets, to balance the lack of inclusion of environmental externalities in the market price, the historic subsidies—for other nascent technologies—and to aid diversification.

These support schemes recognize that the costs of renewable technologies fall, due to technology developments, higher efficiency of installation and managing energy production and economics of scale. The costs of solar PV have fallen most dramatically with a 75 percent drop since 2008 and 45 percent alone in 2011. The wind sector has also seen declines, with an average 7 percent decline in technology costs per year, with an additional 7 percent improvement in costs associated with installation and operation.¹⁶¹ Consequently, the framework for renewable energy support schemes assumes a regression which aims to reward the market pioneers with higher prices, while reducing the level of support as the technologies become more mature to control the overall cost of the support scheme to energy consumers or taxpayers. The clearest example of this is in Germany, which has been at the forefront of renewable energy deployment driven by government policy. This has reduced the feed-in-tariff for roof-top PV installations, between 2008 and April 2012 alone, by 58 percent—from 46.75 Euro-Cent/kWh to 19.5 Euro-Cent/kWh.¹⁶²

Grid Parity

Grid parity occurs when the unit cost of renewable energy is equal to the price that end users pay for their electricity.¹⁶³ On this basis, it makes economic sense, regardless of government support schemes, for consumers to generate their own electricity rather than purchase electricity from the grid. Numerous studies have shown that grid parity has already been achieved in particular countries and regions, such as Germany, Denmark, Italy, Spain and parts of Australia.

A recent detailed study on PV grid parity by Christian Breyer and Alexander Gerlach of Q-Cells SE, the largest producer of solar cells in Europe, examining more than 150 countries covering 98 percent of the world's population, concluded:

Grid parity events will occur throughout the next decade in the majority of all market segments in the world, starting on islands and regions of good solar conditions and high electricity prices. Cost of PV electricity generation in regions of high solar irradiance will decrease from €16 cent/kWh to €6 cent/kWh.¹⁶⁴

While there is some criticism of the term grid parity, what is clear is that the costs of solar PV have fallen dramatically and solar is becoming competitive without subsidies in an ever increasing number of markets and regions. This will have far reaching implications for investors in new generating capacity and for management of the grid systems.

Three years ago, solar PV provided 1 percent of Germany's electricity demand, today it is around 4 percent and is expected to reach 7 percent in 2016. While this may not seem very significant, the major impact of this new capacity can be seen far more clearly at midday, when solar production is

¹⁶¹ Michael Liebreich, Key Note address, Bloomberg New Energy Finance Summit, BNEF, 20 March 2012.

¹⁶² Solar- und Windenergie, "Einspeisevergütungen Solarstrom Deutschland", <http://www.solar-und-windenergie.de/photovoltaik/einspeiseverguetung-photovoltaik.html>, accessed 8 June 2012.

¹⁶³ There are a number of models and definitions for grid parity, depending on the cost and price assumptions and the type of consumer. However, the basic idea is that system costs become lower than the price of the delivered kWh.

¹⁶⁴ Christian Breyer, Alexander Gerlach, "Global overview on grid-parity", in Progress in Photovoltaics: Research and Applications, 2012.

at its maximum, which coincides with the peak of demand and prices. A study by the Institut für Zukunfts Energie Systeme (IZES) compared the prices on the power exchange during the day between 2007 and 2011. This showed that power consumption peaked at around 65 GW at noontime whereas solar power production peaked at around 10 GW shortly thereafter. In other words, PV already provided nearly a sixth of total demand in May 2011 on the average—on some days, peak demand will have been lower and solar power production considerably higher. The study showed the effect of this production on the price of power. In 2007 between 10 AM and 1 PM the price increased with rising demand. But in 2011, the sudden price increase no longer took place even though demand remained largely unchanged. The base and peak prices used to be 20 to 25 percent apart, but that difference has shrunk to around 12 percent.

These are the two years in which the most photovoltaics was installed. At the same time, power demand did not change. We can therefore assume that photovoltaics is the reason why the base and the peak price have approached each other¹⁶⁵.

In the first quarter of 2012, solar panels generated 40 percent and wind turbines 35 percent more than over the same period of the previous year. On 26 May 2012 around noontime, solar power provided a maximum of almost 22 GW to the German grid.

The rapidly increasing contribution of renewable energy to the German power system has had a highly beneficial effect on the market price. Between January and April 2012, the average baseload kWh was negotiated on the spot market at 4.5 cents, that is 13 percent lower than during the first quarter of 2011, despite that fact that while average market price increased by 3.9 percent to 5.4 cents/kWh, a factor connected to the increased production of electricity from solar.¹⁶⁶

Nuclear vs. Renewable Costs

Despite the disproportionately lower support historically, some analysts consider solar PV energy to be competitive with nuclear new-build projects under current real-term prices. The late John O. Blackburn of Duke University calculated a “historic crossover” of solar and nuclear costs in 2010 in the U.S. state of North Carolina. Whereas “commercial-scale solar developers are already offering utilities electricity at 14 cents [US\$] or less per kWh”, Blackburn estimated that a new nuclear plant (none of which is even under construction) would deliver power for 14–18 cents [US\$] per kWh.¹⁶⁷ Solar electricity is currently supported through tax benefits but is “fully expected to be cost-competitive without subsidies within a decade,” he noted.¹⁶⁸ Developments seem to go faster than that. In April 2012, the California PV auction cleared at an average bid price of 8.9 cents (levelized US\$₂₀₁₂).¹⁶⁹

The most recent assessment by Lazard, the global financial advisory and asset management firm, on the unsubsidized levelized costs of energy in the United States shows nuclear power in the range of \$77-114/MWh and therefore more expensive than on shore wind (\$48-95/MWh). While utility scale PV, is currently marginally more expensive—Crystalline in the range of \$101-149/MWh and Thin-film \$102-142/MWh—costs by 2015 are forecasted to be on a par with the lowest nuclear costs¹⁷⁰.

¹⁶⁵ Renewables International, “Merit order effect of PV in Germany”, 2 February 2012, <http://www.renewablesinternational.net/merit-order-effect-of-pv-in-germany/150/510/33011/> citing report by Dr Uwe Leprich

http://www.solarwirtschaft.de/fileadmin/media/pdf/120131_Pr%C3%A4sentation_Preiseffekte_von_PV.pdf

¹⁶⁶ IWR, “Strompreise an der Börse sinken weiter”, 8 May 2012, see <http://www.iwr.de/news.php?id=21115>, accessed 1 June 2012.

¹⁶⁷ John O. Blackburn and Sam Cunningham, “Solar and Nuclear Costs – The Historic Crossover,” prepared for NC WARN Waste Awareness & Reduction Network (Durham, NC: 2010).

¹⁶⁸ Ibid.

¹⁶⁹ Amory B. Lovins, personal communication, 17 June 2012.

¹⁷⁰ Lazard, “Levelized Cost of Energy Analysis – Version 6.0”, June 2012

In France, the Court of Audits estimated, that given the current construction experience, the costs of electricity generated by the Flamanville EPR reactor will be €70-€90/MWh (7–9 Euro Cent/kWh). According to the European Wind Energy Association this is “a level with which onshore wind power could easily compete in most parts of Europe”¹⁷¹. Some of the best U.S. windpower projects contracted in 2011 to sell power for 3 cents/kWh [US\$], net of federal production subsidy.¹⁷²

¹⁷¹ European Voice, 2012, “Blowing Away Nuclear Power”, Christian Kjaer, Chief Executive, European Wind Energy Association, 26 March 2012

¹⁷² Amory B. Lovins, personal communication, 17 June 2012.

Annexes

Annex 1: Overview by Region and Country

Annex 2: Reactor Construction Times 1992-2012

Annex 3: Construction and Operating License (COL) Applications in the U.S.

Annex 4: Construction Times in the U.S. and France

Annex 5: Definition of Credit-Rating by the Main Agencies

Annex 6. Nuclear Reactors in the World Listed as “Under Construction”

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 July 2012) 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, provided in parentheses, 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 2012, 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 TWh or 5.2 percent of the country's electricity in 2011 (the historical maximum was 7.4 percent in 1989). The reactors are the only operating nuclear power plants 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."¹⁷³ In September 2010, the government "[dropped the] final curtain on PBMR," a few months after having terminated all public support.¹⁷⁴ Some \$1.3 billion had been invested in the project, with more than 80 percent coming from the South African government.¹⁷⁵

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 addition to escalating cost projections, Eskom faced a challenge of a falling credit rating, reduced by Moody's in August 2008 to Baa2, the second worst investment grade. In November 2008, Eskom scrapped an international tender because the scale of investment was too high.

In October 2010, facing power shortages in the medium term, the South African government decided to open investment in power generation to private companies. Reportedly, within two weeks in late 2010, the Department of Energy received 384 applications totalling 20 GW, of which 70 percent were wind, 15 percent photovoltaic solar, 10 percent concentrated solar, and the remainder biomass projects. In addition, the department received 20 applications totaling 4 GW of combined heat and power (CHP) projects.¹⁷⁶

Despite this, 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

¹⁷³ *Energy Economist*, "Prospects for nuclear power in 2012", Platts, March 2012.

¹⁷⁴ "Government Drops Final Curtain on PBMR," *World Nuclear News* (WNN), 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.

¹⁷⁵ 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*, ISS Paper 210 (Pretoria: Institute for Security Studies, April 2010).

¹⁷⁶ Department of Energy, Republic of South Africa, "Media Briefing" (Pretoria: 6 December 2010), at [www.energy.gov.za/files/media/presentations/RFI%20Results%20%20Media%20presentation%20%201%20December%202010%20\(2\).pdf](http://www.energy.gov.za/files/media/presentations/RFI%20Results%20%20Media%20presentation%20%201%20December%202010%20(2).pdf).

18 months starting in 2022. The Minister of Energy, Dipuo Peters, signed a foreword to the Plan, stating:

The acute need to secure reliable energy supplies and the urgent requirement to reduce carbon emissions has put nuclear energy firmly on the agenda as a viable option to be pursued in order to achieve energy mix. Nuclear energy is becoming a preferred solution for energy security and in efforts to mitigate climate challenges.¹⁷⁷

Considering the long lead times of nuclear new build, considering the Fukushima effect and the steep cost escalation of nuclear projects (the price tag was raised by 40 percent in South Africa), this is a surprising statement. However, overnight construction costs were still only put at about €2,500 per kW (R26,575/kW), which is less than half the latest EPR cost estimate for the UK. In June 2012, the Energy Minister stated that Government would make a decision on its nuclear future by the end of the year¹⁷⁸.

In the meantime, the CEO of Eskom, Brian A. Dames, stated:

Energy efficiency is probably one of the foundation stones upon which future energy strategies will be based. The world cannot afford the per capita energy densities that are prevalent in industrialised societies and major strides have to be taken to reduce them.¹⁷⁹

The Americas

Argentina operates two nuclear reactors that provided 5.9 TWh or 5 percent of the country's electricity in 2011 (down from a maximum of 19.8 percent in 1990).

Historically Argentina was one of the countries that embarked on an ambiguous nuclear program, officially for civil purposes but backed by a strong military lobby. Nevertheless, the 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.¹⁸⁰ Reportedly, contracts worth US\$440 million were signed in August 2011 with the main work to start by November 2013. Work is expected to take five years at a total cost of US\$1.37 billion.¹⁸¹

Atucha-2 is officially listed as “under construction” since 1981. In 2004, the IAEA estimated that the start-up of Atucha-2 would occur in 2005. But as of June 2012, according to the IAEA, grid connection has been delayed to the admirably precise date of 6 July 2012, exactly 31 years after construction start.

The presidents of Argentina and Brazil, Fernandez de Kirchner and Lula, met in February 2008 and agreed to “develop a program of peaceful nuclear cooperation that will serve as example in this world.”¹⁸² 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.¹⁸³ It did not. Neither a siting decision, nor a call for tender, has been reported to date.

¹⁷⁷ DOE, “Revised Strategic Plan – 2011/120-02015/16”, February 2012.

¹⁷⁸ Business Report, “Nuclear plans ready by year end – Peters”, Business Report, 5 June 2012

¹⁷⁹ PWC, “Perspective: an energy efficient future”, in “The shape of power to come”, PWC, April 2012

¹⁸⁰ “Argentina's Embalse Nuclear Plant to Get 25-year Extension,” PowerGenWorldwide.com, 5 August 2010.

¹⁸¹ Research and Markets, “Nuclear Power Market in Argentina”, May 2012.

¹⁸² “Argentina and Brazil Team Up for Nuclear,” *WNN*, 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.

¹⁸³ “Argentina to Reinforce Nuclear Energy by Adding 700 MW and Building Fourth Nuclear Plant,” Marketwire.com, 7 May 2009.

The Argentinian public's opposition to nuclear power was only reinforced by Fukushima. In a 24-country IPSOS study, 82 percent of the Argentinians polled oppose nuclear new build, a score just below the Italians and the Germans.¹⁸⁴

Brazil operates two nuclear reactors that provided the country with 14.8 TWh (the historic maximum) or 3.2 percent of its electricity in 2011 (down from a maximum of 4.3 percent in 2001).

As early as 1970, the first contract for the construction of a nuclear power plant, Angra-1, was awarded to Westinghouse. The reactor went critical in 1981. In 1975, Brazil signed with Germany 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 license for the building of Angra-3, and the IAEA indicated that a "new" construction start occurred on 1 June 2010. In early 2011, the Brazilian national development bank BNDES approved 6.1 billion reais (\$3.6 billion) for work on the reactor. While some sources indicated a targeted completion date by 2015, in 2011, the IAEA envisaged commercial operation for 30 December 2018 but has withdrawn the date and not replaced it.¹⁸⁵

In January 2011, Brazil's Energy Minister Edison Lobao stated that the government planned to approve the construction of four additional reactors "this year."¹⁸⁶ Right after 3/11, Lobao stated: "We have no need to revise anything, except for learning from what happened in Japan, and taking a look at future proceedings."¹⁸⁷ 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 Marcio Zimmermann stated. "Demand is met with hydro-electrical power and complementary energy sources such as wind, thermal and natural gas." According to press agency AFP, the official also announced that over the coming decade the level of renewable energy would double from 8 to 16 percent.¹⁸⁸ Public opinion is helping the government to look for other solutions than nuclear. In IPSOS' 24-country study Brazil scored lowest in public acceptance with 89 percent against nuclear new build.¹⁸⁹

Canada operates 18 reactors, all of which are Candus (CANadian Deuterium Uranium), providing 88.3 TWh or 15.3 percent of the country's electricity in 2011 (down from a maximum of 19.1 percent in 1994). Four additional units are listed by the IAEA as in "long-term shutdown." There have been significant delays in restarting the reactors, and as of February 2011 only four of originally eight reactors in long-term-shutdown had returned to operation. The two 40-year old Pickering A2 and A3 reactors were scheduled to come back online in 2009 or early 2010, but they

¹⁸⁴ IPSOS, op.cit.

¹⁸⁵ See, for example, "Brazil Commission Gives Go-Ahead for Angra-3 Nuclear Plant," *Dow Jones Newswire*, 31 May 2010.

¹⁸⁶ "Brazil to Approve Construction of Four Nuclear Power Plants in 2011," www.neimagazine.com, 10 January 2011.

¹⁸⁷ Buenos Aires Herald, "Brazil to continue nuclear energy investments despite Japan crisis", 15 March 2012; see <http://www.buenosairesherald.com/article/61644/-brazil-to-continue-nuclear-energy-investments-despite-japan-crisis>, accessed, 25 May 2012.

¹⁸⁸ WNIIR, "Brazil Abandons New Build Plans", 11 May 2012, see <http://www.worldnuclearreport.org/Brazil-Abandons-New-Build-Plans>.

¹⁸⁹ IPSOS, op.cit.

did not. In January 2010, operator Ontario Power Generation (OPG, Ex-Ontario Hydro) requested a five-year license renewal for the four Pickering A reactors, but in July 2010 the Canadian Nuclear Safety Commission (CNSC) decided to limit the license to three years. For both Pickering A and B, the licenses will expire on 30 June 2013.¹⁹⁰ The two other remaining units in long-term shutdown, Bruce-1 and -2, were slated to be back online by 2012. A damaged generator pushed back restart hopes again by several months, likely into 2013.¹⁹¹

On 16 June 2008, the Canadian government announced Darlington in Ontario as the site for a two-unit new-build project. But in early July 2009, the Ontario government shelved the plan and the province's premier, Dalton McGuinty, observed that, "We didn't factor in the single greatest global economic recession in the past 80 years."¹⁹² Ontario's power needs were actually declining rather than increasing as had been forecasted, leaving the province with more time to make a decision on new build. The Darlington project resurfaced in 2010 and in early May 2012 the government accepted the Environmental Impact Assessment report for the construction of up to four units by OPG. However, a joint review panel set up under the Canadian Nuclear Safety Commission issued a list of 67 recommendations that have to be addressed prior to issuing a site preparation license. No decision over a construction license is expected before 2014.¹⁹³ Ontario Energy Minister Chris Bentley stated in March 2012 on new build prospects: "We're working very hard to make sure if we make a decision, it's in the best interests of Ontario ratepayers and taxpayers."¹⁹⁴ Popular daily the *Toronto Sun* commented: "But the financial pressure that caused Ontario to suspend the new build at Darlington has if anything, gotten worse in the past three years and electrical demand has fallen, opening a window for the province to dump its nuke plans and improve its ailing balance sheet."¹⁹⁵

The province of New Brunswick has abandoned the option of adding a second nuclear reactor at its Point Lepreau site; meanwhile, a massive refurbishment project on the first unit is way over budget and running years late. The unit has been down since April 2008, and restart is currently scheduled for fall 2012.¹⁹⁶

In June 2011 the Canadian government sold the commercial reactor division of Atomic Energy of Canada (AECL) to CANDU Energy, a wholly owned subsidiary of engineering company SNC Lavalin for CAD15 million and royalty payments from potential future new build and refurbishment projects.

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 2011, nuclear power produced 9.3 TWh or 3.6 percent of the country's electricity (down from a maximum of 6.5 percent in 1995). An uprating project carried out by Iberdrola between 2007 and early 2011 boosted the nameplate capacity of both units by 20 percent, from 682 megawatts (MW) to 820 MW (gross). The power plant is operated by Iberdrola Ingenieria of Spain (97 percent) and Alstom Mexicana of France (3 percent).¹⁹⁷ The operating license of the two plants expires respectively in 2029 and 2034.

¹⁹⁰ NEI, "Pickering A Gets 3-year Licence Extension," www.neimagazine.com, 2 July 2010.

¹⁹¹ WNN, "Restart of Bruce reactor delayed", 21 May 2012, http://www.world-nuclear-news.org/C-Restart_of_Bruce_reactor_delayed-2105124.html, accessed 25 May 2012.

¹⁹² The (Toronto) Star, "Economy Let Us Delay Nuclear Plan, Premier Says", 7 July 2009.

¹⁹³ WNN, "Canadian new build getting nearer", 3 May 2012.

¹⁹⁴ Toronto Sun, "No new nuclear power if it doesn't make fiscal sense: Bentley", 20 March 2012.

¹⁹⁵ Idem.

¹⁹⁶ NB Power, "Point Lepreau Generating Station Refurbishment Project Update," press release (Fredericton, NB: 3 February 2011).

¹⁹⁷ "Iberdrola Completes Modernization Work on Mexican Nuclear Plant," *European Business Review*, 7 February 2011.

In March 2012, current Energy Minister Jordy Herrera stated: “We have to put the option of building and expanding our nuclear plants on the table”.¹⁹⁸ A draft energy strategy document suggested between two and eight new nuclear plants. However, the current government is likely to be voted out of office in the July 2012 elections. Also, public opinion is a major headache for the nuclear industry with 87 percent opposing nuclear new build, according to IPSOS’ 24-country survey, the second largest score after Brazil.¹⁹⁹

United States Focus

The **United States** has more operating nuclear power plants than any other country in the world, with 104 commercial reactors providing 790.4 TWh in 2011, a 2 percent drop over the previous year when generation had reached an all time high. The production decline is attributed to an unusually high level of outages due to the confluence of refueling with forced outages, in particular due to weather events (like tornadoes and flooding) and competition for supply from the gas sector. Nuclear plants provided 19.2 percent of U.S. electricity in 2011 (down from a maximum of 22.5 percent in 1995).

The last reactor to be completed—in 1996—was Watts Bar-1, near Spring City, Tennessee, and in October 2007 the Tennessee Valley Authority (TVA) announced that it had chosen to complete the two-thirds-built 1.2 GW Watts Bar-2 reactor (see section on Watts Bar-2 in chapter “Unfulfilled Promises”). In August 2011, TVA decided also in principle to complete the Bellefonte-1 reactor at Hollywood, Alabama. However, construction work will not begin prior to the start-up of Watts Bar-2.

The lack of new reactor orders means that over 40 percent of U.S. reactors will have operated for at least 40 years by 2015. Originally it was envisaged that these reactors would operate for a maximum of 40 years; however, projects are being developed and implemented to allow reactors to operate for up to 60 years. As of May 2012, 72 of the 104 operating U.S. units have received an extension, another 15 applications are under review by the NRC and 12 have submitted letters of intent covering a period up to 2017.²⁰⁰

The George W. Bush administration’s National Energy Policy set a target of two new reactors to be built by 2010, but this objective was not met. To reduce uncertainties regarding new construction, a two-stage license process has been developed. This enables designs of reactors to receive generic approval, and utilities will then only have to apply for a combined Construction and Operation License (COL), which does not involve questioning of the reactors’ designs.

Licensing

As of May 2012, the NRC had received 18 licensing applications for a total of 28 reactors. (See detailed list in Annex 3.) All of them have been submitted between July 2007 and June 2009. Of the 28 reactor projects, eight were subsequently suspended indefinitely or cancelled and 16 were delayed.²⁰¹

On 9 February 2012, for the first time in nearly three and a half decades, the NRC granted a COL for Vogtle-3 and -4 units in Georgia. One week later, a coalition of environmental organizations filed a

¹⁹⁸ NIW, “Lame Duck Energy Minister Proposes More Nuclear Power”, 16 March 2012.

¹⁹⁹ IPSOS, op.cit.

²⁰⁰ U.S. Nuclear Regulatory Commission (NRC), “Status of License Renewal Applications and Industry Activities,” see www.nrc.gov/reactors/operating/licensing/renewal/applications.html, viewed 29 May 2012.

²⁰¹ USNRC, “Combined License Applications for New Reactors”, see <http://www.nrc.gov/reactors/new-reactors/col.html>, viewed 29 May 2012.

lawsuit against the decision.²⁰² On 30 March 2012, South Carolina Electric & Gas received the second COL for units 2 and 3 at its Summer site. In an unprecedented move, Gregory B. Jaczko, Chairman of the NRC voted against the opinion of the four other Commissioners, stating that the decision was being taken “as if Fukushima never happened”.²⁰³ Jaczko subsequently resigned from his NRC position.

License applications cover five different reactor designs including GE-Hitachi’s Advanced Boiling Water Reactor (ABWR) and Economic Simplified Boiling Water Reactor (ESBWR), Mitsubishi’s Advanced Pressurized Water Reactor (APWR), AREVA NP’s Evolutionary Pressurized Water Reactor (EPR), and Westinghouse’s AP1000. Only two of these designs, the ABWR and the AP1000, have been certified by the NRC. Yet, the ABWR certification, which is referenced only in the application for South Texas units 3 and 4, is already 15 years old and ran out in June 2012. Major modifications are likely to be needed for it to be re-certified. The AP1000 was certified on 30 December 2011, after 19 revisions of a first certification issued in 2006. Certification of the EPR was delayed from June 2013 to end of 2014 at the earliest. (See section EPR – European Problem Reactor.)

Delays to the generic approval process have meant that the sequence of approval has been inverted. As a result, utilities are likely to be granted COLs before generic approval of the reactor design to be built has been granted. It is unclear whether a parallel process of assessing and implementing post-Fukushima safety improvements might later alter designs that are meanwhile licensed for construction and operation (as implied by former NRC Jaczko’s vote against the Vogtle and Summer COLs).

As of May 2012, the NRC had granted four Early Site Permits (ESP) and received two additional applications that are under review.²⁰⁴ This situation has not evolved over the past year. ESPs are independent of the construction/operating license.²⁰⁵ Only the Vogtle project has received an ESP, a COL and a certified design at this stage. However, as of the end of May 2012, the plant was still not officially under construction. The Summer reactors, which received the only other COL and were to start up in 2016 and 2017, have been experiencing repeated delays. The project is already seven-and-a-half-months late and could face “additional potential delays recently identified”, according to an independent construction monitor, hired by Georgia regulators. Both projects, Summer and Vogtle, “face significant challenges in maintaining the project forecast at or below” budget, the monitor stated.²⁰⁶

Policy support measures

The July 2005 U.S. Energy Policy Act was aimed at stimulating investment in new nuclear power plants. Measures include a tax credit on electricity generation, a loan guarantee of up to 80 percent of debt (not including equity) or \$18.5 billion for the first 6 GW (in exchange for a credit subsidy fee that the utility must pay to the federal government and that is calculated based on the borrower’s risk of default), additional support in case of significant construction delays for up to six reactors, and the extension of limited liability (the Price Anderson Act) until 2025.

By the end of 2008, nuclear utilities had applied for \$122 billion in loan guarantees, and in May 2009 the DOE short-listed four companies for the first group of loan guarantees: Southern Nuclear Operating Co. for two AP1000s at the Vogtle nuclear power plant site in Georgia; South Carolina

²⁰² Mindy Goldstein et al., “Petitioners’ motion to stay the effectiveness of the Combined License for the Vogtle electric generating plant units 3 and 4 pending judicial review”, Docket Nos. 52-025 & 52-026, 16 February 2012.

²⁰³ MSNBC, “U.S. licenses first nuclear reactors since 1978”, 9 February 2012.

²⁰⁴ ESP granted: Clinton (Exelon), Grand Gulf (SERI), North Anna (Dominion), Vogtle (Southern). ESP under review Victoria County Station (Exelon), PSEG Site (PSEG).

²⁰⁵ NRC, “Early Site Permit Applications for New Reactors,” www.nrc.gov/reactors/new-reactors/esp.html, viewed 29 May 2012.

²⁰⁶ Bloomberg, “Southern’s Nuclear Reactors May Be Delayed, Monitor Says”, 1 June 2012.

Electric & Gas for two AP1000s at the Summer site in South Carolina; NRG Energy for two ABWRs at the South Texas Project site in Texas; and Constellation for one EPR at the Calvert Cliffs site in Maryland. By then, the limit for coverage of loan guarantees had been increased from 80 percent of the debt to 80 percent of the total cost. Constellation Energy abandoned the application for a loan guarantee for the Calvert Cliffs-3 project after discovering a “shockingly high estimate of the credit subsidy cost” (11.6 percent or \$880 million).²⁰⁷ Constellation has since been absorbed by Exelon, and Calvert Cliffs project partner EDF is still looking for a new U.S.-based ally, since the U.S. legislation forbids foreign-controlled ownership of U.S. nuclear facilities. Nuclear utility NRG, the majority shareholder of the South Texas Project (STP), announced in April 2011 that it is withdrawing from the project, writing down \$481 million investment and excluding any further investment. NRG CEO David Crane said that the Fukushima aftermath was “dramatically reducing the probability that STP 3 and 4 can be successfully developed in a timely fashion.”²⁰⁸

In February 2010, Southern’s Vogtle project was the first to have been awarded a conditional loan guarantee (\$8.3 billion) for a nuclear power plant project worth an estimated \$14 billion. The reactors are supposed to start operating by 2016 and 2017. Carol Browner, then director of the Office of Energy and Climate Change Policy, stated in December 2010: “Ultimately, the government continuing to provide loan guarantees is probably not going to be a practical solution.”²⁰⁹

In early May 2012, Progress Energy announced that it was delaying its Levy project for two AP1000 by three years to start-up the first unit in 2024 and the second 18 months later. The “shift in schedule will increase escalation and carrying costs and raise the total estimated project to between \$19 and \$24 billion”, from a 2008 price tag of \$17 billion, the company announced.²¹⁰

While the industry continues to struggle with licensing and financing issues the electricity sector is rapidly changing. In particular, gas prices, due to the accelerated development on non-conventional gas are extremely low and increase the uncertainty over the economics of building new nuclear plants. “Let me state unequivocally that I’ve never met a nuclear plant I didn’t like,” said John Rowe, former chairman and CEO of Exelon Corporation, the largest nuclear operator in the U.S. with 22 nuclear power plants. “Having said that, let me also state unequivocally that new ones don’t make any sense right now.”²¹¹

Public opposition has also been growing over the past year, according to a March 2012 poll by ORC International. While supporters of new build stagnated at 46 percent, opponents increased their share from 44 to 49 percent. At the same time, people were split over lifetime extensions with 49 percent in favor and 47 percent opposed. On the other side, over three quarters of the respondents (77 percent) favor the shift of loan guarantees from nuclear to renewable energies.²¹²

In its provisional *Annual Energy Outlook 2012*, the DOE projects an increase in installed nuclear capacity of about 11 GW to 2035. About 10 GW of new capacity would come online, 7 GW would come from uprating while 6 GW would be shut down. The nuclear share would shrink from 20 percent to 18 percent.²¹³ In other words: while DOE does not seem to anticipate any significant “Fukushima effect” in the future on early plant closures, however, the “nuclear renaissance” will not take place either in the United States over the next 25 years.

²⁰⁷ Michael J. Wallace, Chairman of Constellation Energy Nuclear Group, letter to Dan Poneman, DOE, 8 October 2010.

²⁰⁸ WNN, “NRG Withdraws From Texan Project”, 20 April 2011.

²⁰⁹ WNN, “More Funds for Loan Guarantees,” 10 December 2010.

²¹⁰ WNN, “Levy nuclear project moved back by three years”, 2 May 2012.

²¹¹ Forbes, “Exelon’s ‘Nuclear Guy’: No New Nukes”, 29 March 2012.

²¹² ORC International, “One Year After Fukushima – American Attitudes About Nuclear Power”, commissioned by Civil Society Institute, March 2012.

²¹³ DOE, EIA, “AEO2012 Early Release Overview”, Washington, DC, January 2012.

Asia

China Focus

China came relatively late to the civil nuclear industry, starting construction of its first commercial reactor only in 1985. As of July 2012, China had 16 reactors in operation, which in 2011 provided a record 82.6 TWh, but still only 1.8 percent of the country's electricity, the lowest nuclear share of any country. This compares to a historical maximum of 2.2 percent, as despite increases in the production from nuclear power electricity, demand and supply by other sources are growing faster. Despite, or maybe because of, its late arrival to the nuclear field, China had, until Fukushima, an impressive recent history of construction starts. It has 26 reactors under construction representing 39 percent of global new build. However, during 2011, while it completed three reactors, it didn't start any new construction.

In the aftermath of Fukushima, on 14 March 2011, Xie Zhenhua, vice chairman of the National Development and Reform Commission, stated that "[e]valuation of nuclear safety and the monitoring of plants will be definitely strengthened."²¹⁴ Then an account of a mid-March 2011 State Council meeting chaired by Premier Wen Jiabao read: "We will temporarily suspend approval of nuclear power projects, including those in the preliminary stages of development.... We must fully grasp the importance and urgency of nuclear safety, and development of nuclear power must make safety the top priority."²¹⁵ As a result a new China National Plan for Nuclear Safety with short-, medium- and long-term actions was ordered and approval for new plants will remain suspended until it is approved.²¹⁶ The China Guangdong Nuclear Power Corporation's (CGN) Chairman He Yu was reported in October 2011 to say that two plants were to be completed by the end of 2012²¹⁷.

However, as of end of May, the safety plans had yet to be approved. It is suggested that the delay is in part due to uncertainty over the strategic direction for future reactor designs, whether future construction would be dominated by the domestic, standardized CPR 1000 design or move towards the greater deployment of the Generation III+ designs, both the international and the domestic designs (ACP-1000 and the ACPR 1000). The potential move towards much greater or even total dependence on the most modern—currently international—design is driven by conflicting concerns, the higher costs of the international design and greater confidence in the safety standard. Tange Zede, a member of the State Nuclear Power Technology Corp (SNPTC), was reported as saying that the domestically designed CPR-1000 did not even meet the national safety standards issued in 2004, let alone the most up-to-date international standards. Zede also said that "unless the constructed Gen-II reactors are renovated, they should not be allowed to load fuel and start operation".²¹⁸

Prior to Fukushima the 12th Five-Year Plan anticipated 43 GW of nuclear power in operation by the end of 2015.²¹⁹ Meeting this target would have required the completion of all the reactors under construction at the end of 2010, plus those that were planned to be started in 2011. This target therefore cannot be met. A report on implementation of the 12th Five-Year Plan published by the China Electricity Council on 14 March 2012 estimated that China's nuclear-generating capacity

²¹⁴ Archana Chaudhary, "Nuclear Accident Forces China Policy Review as India Sees Safety Backlash," Bloomberg.com, 14 March 2011.

²¹⁵ The Guardian "China Suspends Approval for Nuclear Power Plants" 16 March 2011.

²¹⁶ WNA, "Nuclear Power in China", May 2012, <http://www.world-nuclear.org/info/inf63.html>

²¹⁷ Dynabond, "China's nuclear safety plan might be completed by the end of this year", 27th October 2011. <http://www.dynabondpowertech.com/en/nuclear-power-news/national-news/6-national/5038-chinas-nuclear-safety-plan-might-be-completed-by-the-end-of-this-year>

²¹⁸ Nuclear Intelligence Weekly, "Despite Inspections, Post Fukushima Impact on Newbuild is Minimal", 30 January 2012.

²¹⁹ Dr. Shin Wei Ng and Nick Mabey, Chinese Challenge or Low Carbon Opportunities: The Implications of China's 12th Five-Year-Plan for Europe, E3G, February 2011.

would reach 80 GW by 2020²²⁰. Reportedly, a State Council meeting held on 31 May 2012 ended without an agreement on the future of the nuclear industry.²²¹ In fact, the suspension of the start of new construction, the uncertainty over the strategic direction for future designs, along with the problems outlined below, mean that achieving the 2020 target highly unlikely. Chinese nuclear industry officials were told at the 31 May 2012 meeting, the 80 GW target “was excessive, given the state of the political leadership’s concerns about the safety of nuclear energy at this time”.²²²

Concerns have been raised about the availability of qualified staff and about the impact of such rapid construction on supply chains, leading a research unit of the State Council (China’s Central Government) to suggest that the rate of growth be limited.²²³ Moreover, public acceptance of new reactors can no longer be taken for granted. Historically, nuclear protests had mainly occurred in Hong Kong against the Daya Bay facility (both before and after the transfer of sovereignty). However, following the Fukushima accident and with reactors being proposed in up to 16 provinces, greater public concern and wider public engagement is likely. A global IPSOS survey conducted in June 2011 found that 42 percent of those surveyed in China were supportive of nuclear power but 48 percent were opposed²²⁴. It is also reported that public opposition and environmental concerns have led to the delay in construction of three inland nuclear power sites. In March 2012 opposition to the proposed Pengze power plant in Jiangxi became visible on a previously unreported scale with local authority documents critical of the project posted on the internet. In addition to the posting, ten delegates of a ‘political consultative conference’ in a neighboring province appealed to their provincial governor to ask Beijing to abandon the project.²²⁵

China’s importance in the global nuclear sector is not just construction numbers but the types of reactors now being built. Currently, many of the world’s major reactor vendors, including AREVA and Westinghouse, are building their most advanced designs in China. In the case of Westinghouse, the AP1000 is the company’s flagship Generation III design, and China is its only sale. The contract is worth around \$5.3 billion, well below the commercial rate for four units.²²⁶ A key factor in the contract was that it contained technology transfer not only for the reactor but also for the so called back-end services, particularly nuclear waste management.²²⁷ Construction of these four units, two at Sanmen and two at Haiyang is underway, although delays of six to twelve months are reported. For the first unit at Sanmen, this is said to be due to design changes post Fukushima, while for the remaining three due to supply chain issues relating to the increasing local content. It is suggested that the domestic content across the series of the four reactors will increase from 30 percent to 70 percent, with any future reactors built with purely Chinese parts²²⁸. The estimated construction costs of the AP1000 are also quoted as rising. In 2009, it was said they would cost US\$1,940/kW, but the latest figures range from US\$2,300-2,600/kW²²⁹. While this is far below the estimated costs of any other Generation III+ project globally, it is significantly higher than the reported costs for the CPR-1000 at \$1800/kW.²³⁰

In November 2007 AREVA announced the signing of a €8 billion (\$11.6 billion) contract with the CGN for the construction of two European Pressurized Water Reactors (EPR) in Taishan in

²²⁰ China Dialogue, “New nuclear spring for China?”, Feng Jie, March 29, 2012.

²²¹ Gregory Kulacki, “Chinese Government Divided on Long-Term Future of Nuclear Power”, Union of Concerned Scientists, 4 June 2012.

²²² Ibidem.

²²³ Straits Times “China’s Nuclear Power Build-up Moving Too Fast” 11 January 2011.

²²⁴ IPSOS, op.cit.

²²⁵ Nuclear Intelligence Weekly, “Microblogging Spotlights Controversy Over Pengze NPP”, 2 March 2012.

²²⁶ Bloomberg, “Westinghouse Wins \$5.3 Billion China Nuclear Contract (Update5)”, Bloomberg.com, 16 December 2006.

²²⁷ Westinghouse, “Westinghouse, Shaw Group Sign Landmark Contracts to Provide Four AP1000 Nuclear Power Plants in China,” press release, July 2007.

²²⁸ Nuclear Intelligence Weekly, “AP-1000s Delayed by 6-12 Months SNPTC Says”, 17 January 2012.

²²⁹ Nuclear Intelligence Weekly, “Wang Declares AP1000 Back on Track”, 23 March 2012.

²³⁰ Nuclear Intelligence Weekly, “AP-1000s Delayed by 6-12 Months SNPTC Says”, 17 January 2012.

Guangdong Province and that it will provide “all the materials and services required to operate them.”²³¹ In November 2010, China and France signed an agreement opening the way to industrial cooperation on the back end of the nuclear fuel system, committing to undertake feasibility studies for the construction of an 800 ton-per-year spent fuel reprocessing plant in Jiayuguan, Gansu Province. Design, construction, and commissioning were expected to take a decade starting from 2010. In November 2010, an industrial agreement was signed that AREVA called “the final step towards a commercial contract”²³² for the project, though this view clearly seems overly optimistic. AREVA’s annual reference report merely states that in 2011 “discussions continued between AREVA and CNNC [China National Nuclear Corp] on cooperation between the two companies in the Chinese used fuel treatment and recycling field”.

India operates 20 nuclear power reactors with a total capacity of 4.4 GW; the majority of these have a capacity of 220 MW per unit. In 2011, nuclear power provided a record 29 TWh that covered just 3.7 percent of India’s electricity, a level already achieved in 2001/02.

India lists seven units as under construction with a total of 4.8 GW. Most currently operating reactors experienced construction delays, and operational targets have rarely been achieved. With a lifetime load factor of only 57.3 percent as of the end of 2011, the lowest in the world. The annual load factor slipped to less than 42 percent in 2009.²³³

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. International sanctions of different kinds 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 Non-Proliferation Treaty, has developed and maintains a nuclear weapons program, and refuses full-scope safeguards,²³⁴ it is still permitted to receive nuclear assistance and to carry out nuclear commerce with other nations. France has abstained from any criticism of the India’s nuclear weapons program and has strongly supported the NSG to grant India access to international cooperation. A French parliamentary report states:

Grateful for these diplomatic positions in its favour and conscious about the French technological excellence in this sector, India has logically chosen to make France one of its principal partners.²³⁵

²³¹ AREVA, “China: AREVA and CGNPC Sign the Biggest Contract Ever in the History of Nuclear Power and Enter into a Long-term Commitment. AREVA and CNNC Strengthen Their Links”, press release, 26 November 2007.

²³² World Nuclear Association (WNA), “China’s Nuclear Fuel Cycle,” www.world-nuclear.org/info/inf63b_china_nuclearfuelcycle.html, updated January 2011.

²³³ Caroline Peachey, “Power Plant Performance: Load Factors to End December 2009,” Nuclear Engineering International, May 2010 [updated June 2010].

²³⁴ Comprehensive inspection and verification that all nuclear materials and all nuclear facilities have been used for declared purposes only.

²³⁵ Eric Woerth, “Rapport fait au nom de la Commission des Affaires Etrangères sur le Projet de Loi n°4021, autorisant l’approbation de l’accord entre le Gouvernement de la République française et le Gouvernement de la République de l’Inde relatif à la répartition des droits de propriété intellectuelle dans les accords de développement des utilisations pacifiques de l’énergie nucléaire”, Assemblée Nationale, 18 January 2012.

However, the report also highlights “the problems generated by the law on civil responsibility” that the Indian Parliament voted in September 2011, in particular because the supplier could be held liable for potential accidents under some circumstances. Furthermore, a petition filed by prominent lawyer Prashant Bhushan has requested the Indian Supreme Court to declare the liability legislation “unconstitutional and void ab initio” [meaning to be treated as invalid from the outset]. The outcome could mean the application of “absolute liability” to nuclear plants. Vendors will then be faced with the question “whether they are confident enough in the safety of their reactors to risk potential bankruptcy”.²³⁶

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.²³⁷ The contract reportedly would be worth some €7 billion (\$10 billion) for *two* EPRs, a surprisingly low figure considering that the cost-estimate for the French and Finnish EPRs is over €6 billion *each*.²³⁸ (See EPR section.)

Even before the agreement was signed, as on other sites, opposition against the Jaitapur project was massive. The Fukushima events also triggered a significant 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”.²³⁹ Around 10,000 people have been blocking the site for weeks, and 15 opponents are on an indefinite hunger strike since 1 May 2012.²⁴⁰

Prime Minister Singh claimed the protesting NGOs “are often funded from the United States and the Scandinavian countries, which are not fully appreciative of the development challenges that our country faces”.²⁴¹ The project is immersed in controversy opposing the government, the nuclear industry and many civil society representatives. The Indian government, however, appears intent on starting up the reactors. Meanwhile the state of West Bengal has scrapped another project for up to six Russian reactors at the coastal site of Haripur.²⁴²

It remains to be seen whether the Indian nuclear sector will meet its own expectations of 20 GW installed by 2020. While the official target still remains the same, a retired chairman of the Atomic Energy Commission disclosed in November 2011 that the expected nuclear capacity in 2020 might be as low as 11 GW.²⁴³

AREVA is awaiting approval from the Japanese government for the purchase of Japan Steel Work’s EPR pressure vessels for the Jaitapur project. In principle, Japan does not export nuclear equipment to non-NPT signatory countries.²⁴⁴ In the meantime, AREVA Solar is building Asia’s largest concentrated solar plant in India with two 125 MW plants in Rajasthan, with the first one scheduled to start operating in May 2013.²⁴⁵ India is in fact represented in the Top 5 in the world of annual additions in 2011 in hydropower, PV, wind power and solar thermal capacity.²⁴⁶ India now has an

²³⁶ Suvrat Raju, M.V. Ramana, “A New Twist in the Saga of India’s Liability Law”, NIW, April 2012.

²³⁷ AREVA, “India: Agreements Between AREVA and NPCIL for the Supply of Two EPR Reactors and Fuel for 25 Years,” press release, 6 December 2010.

²³⁸ “India Signs \$9.3 Billion Deal for Areva to Build Two Nuclear Power Plants,” Bloomberg.com, 6 December 2010.

²³⁹ 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.

²⁴⁰ See <http://www.dianuke.org/latest-updates-from-koodankulam/>, accessed 30 May 2012.

²⁴¹ Asian Scientist, “PM Manmohan Singh Discusses R&D Roadmap For India”, 24 February 2012, see <http://www.asianscientist.com/topnews/indian-prime-minister-manmohan-singh-interview-with-science-magazine-february-2012/>, accessed 30 May 2012.

²⁴² Nucleonics Week, “West Bengal eliminates Haripur as second VVER site: reports”, 25 August 2011.

²⁴³ See <http://www.deccanherald.com/content/207192/india-scales-down-n-power.html>

²⁴⁴ “Le futur EPR en Inde est suspendu à un accord du Japon,” Les Echos, 31 January 2011.

²⁴⁵ PEI, “India set for Asia’s largest CSP plant”, April 2012.

²⁴⁶ REN21, “Renewables 2012 – Global Status Report”, June 2012.

installed capacity of wind of 16 GW, compared to 4.3 GW of nuclear capacity with the contribution of the wind sector to electricity supply is likely to overtake that of nuclear power in 2012.

Japan Focus

*The nuclear accident has transformed society,
which needs to be built on confidence,
into a caldron of distrust.*

Asahi Shimbun, Editorial
5 May 2012

In Japan nuclear power provided in 2011 about 18 percent of the electricity, compared to 29 percent in 2010 and the historic maximum of 36 percent in 1998.

The tragic events of 11 March 2011 have become known in Japan and overseas as 3/11. The triple disaster earthquake-tsunami-nuclear accident that hit Japan on 11 March 2011 had a profound impact on environment, economy and energy policy. One year later, the technical situation at the Fukushima Daiichi site seems anything but stable. The class 9 quake on 3/11 triggered hundreds of after shocks including six class 7, 96 class 6 and 588 class 5 quakes.²⁴⁷ Reactor buildings, rapidly repaired or new-built infrastructure and provisional facilities remain fragile. Large areas are severely contaminated. Over 100,000 people were asked to give up their homes in contaminated areas or have self-evacuated. Many people do not have confidence in food safety. High cesium concentrations have been identified in numerous food stuffs.²⁴⁸ Measuring devices have multiplied throughout society without a coherent, global system of laboratory qualification, certification and labeling. Many Tokyo citizens will not buy food items from Fukushima.

The number of evacuees exceeds by far those that had to leave contaminated land. A total of 344,000 people are awaiting to go back home or find a new place to live. But only 6 percent of an estimated 22 million tons of debris and rubble have been disposed of.²⁴⁹

On the other hand, some restoration efforts were more efficient and faster than anticipated. The Ministry of Economics, Trade and Industry (METI) estimates that industrial production had recovered to over 99 percent by August 2011. Production levels had resumed for 93 percent at directly and 83 percent at indirectly afflicted manufacturing bases but affected areas only account for 2.5 percent of the Japanese economy.²⁵⁰ The energy industry was also hard hit by 3/11 and its aftermath. However, one year after 3/11, all of the oil and gas supply infrastructure and all thermal power stations but a 2,000 MW coal fired plant have resumed operation.²⁵¹

In October 2011 the Cabinet office released an energy white paper calls that dropped a paragraph on the expansion of nuclear power and instead called for the reduction on the reliance on nuclear power. Furthermore, the paper stated that the government “regrets its past energy policy and will review it with no sacred cows”,²⁵²

According to Japanese legislation, every nuclear power plant has to be shut down at least every 13 months for inspection and maintenance. As of 26 March 2012, Japan’s main island Honshu was no longer using nuclear power, when unit 6 at Kashiwazaki-kariwa shut down for refueling, maintenance and inspection. Tomari-3 in Hokkaido was the last unit to go offline all over Japan and as of 5 May 2012, all of the 54 Japanese nuclear power reactors were closed.

²⁴⁷ As of 8 February 2012, according to METI, “Japan’s Challenges Towards Recovery”, March 2012.

²⁴⁸ for example, 18,700 Bq/kg of cesium in salmon called yamame in the Niida River in Iitate ; see Mainichi Daily News, “Highest level of radioactive cesium to date faound in freshwater fish in Fukushima village”, 30 March 2012.

²⁴⁹ IEEJ, “Japan Energy Brief”, n°18, March 2012.

²⁵⁰ As of 8 February 2012, according to METI, “Japan’s Challenges Towards Recovery”, March 2012.

²⁵¹ IEEJ, “Japan Energy Brief”, n°18, March 2012.

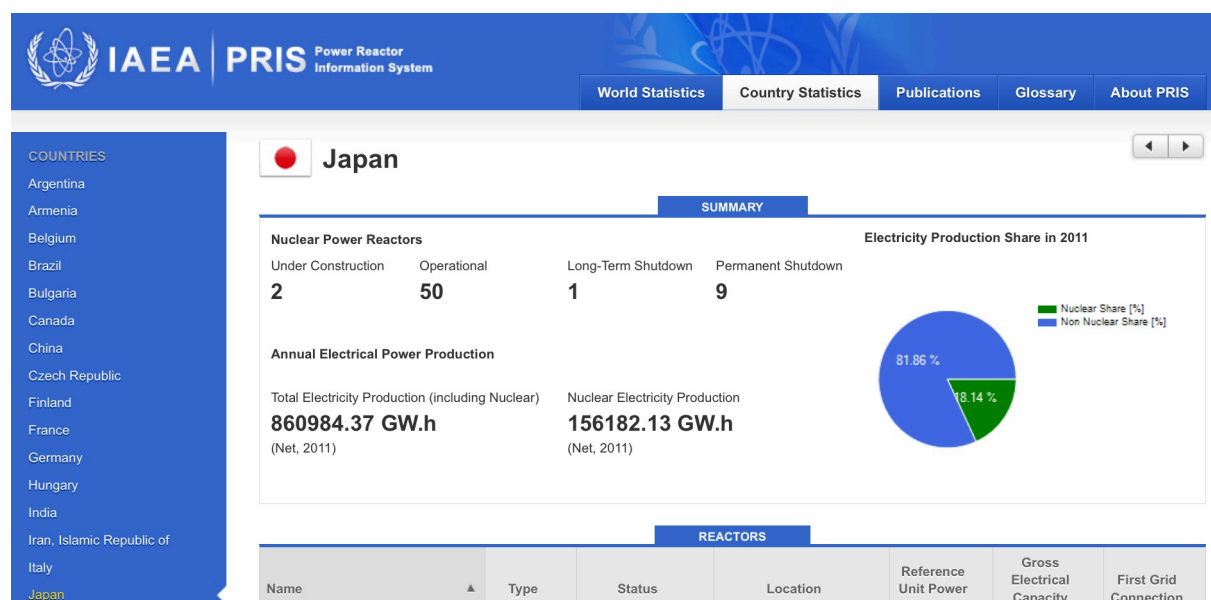
²⁵² Bloomberg, “Nuclear Promotion Dropped in Japan Energy Policy After Fukushima”, 27 October 2011.

Officially, the Japanese government declared only four of the Fukushima Daiichi units “permanently shut down”, the other 50 units remaining “operational” and two units “under construction” in the international statistics (see screenshot of the International Atomic Energy Agency’s PRIS database hereunder). It is virtually impossible to believe that all reactors will return to operation, and more likely that many of them will never generate power again.

Two reactors at the Ohi²⁵³ plant in Fukui Prefecture are the first to have received restart approval by the nuclear safety authorities based on Europe inspired stress tests and government support. Ohi mayor Shinobu Tokioka initially did not support restart unless adequate disaster response plans are in place. While Fukui Governor Issei Nishikawa originally told the government that he would not allow restart without consulting local residents. The governors of Kyoto, Osaka and Shiga Prefectures as well as the powerful mayors of Osaka City, Kyoto City and Kobe were opposed to any short-term restart.²⁵⁴ Shiga Governor Yukiko Kada declared: “We cannot say yes to restarts until we are certain that they are absolutely safe”.²⁵⁵ The Noda government, nevertheless, on 16 June 2012, authorized the restart of the two Ohi reactors and Fukui Governor Issei Nishikawa caved in. Only two days later, 73 mayors from 35 prefectures across Japan protested the decision in a letter to the Prime Minister.²⁵⁶

It is an unwritten law in Japan that no reactor can operate without the explicit approval of local communities. And the current Prime Minister Yoshihiko Noda had earlier explicitly stated that he would abide by the rule. A recent survey had 62 percent of the respondents opposing the restart of the Ohi reactors and 84 percent considering that the stress tests were insufficient as restart criteria.²⁵⁷

Figure 22: The International Atomic Energy Agency’s Japan Datasheet on 1 July 2012



Source: IAEA-PRIS, 2012

²⁵³ Also spelled Oi.

²⁵⁴ City Mayors, “Japanese governors and mayors oppose restart of nuclear reactors”, 17 April 2012; http://www.citymayors.com/news/metronews_asia.html, viewed on 20 April 2012.

²⁵⁵ Reuters, “Japan Shiga threatens to rain on nuclear restarts”, 6 April 2012.

²⁵⁶ Asahi Shimbun, “Local leaders blast Noda’s handling of Oi restart”, 18 June 2012; see <http://ajw.asahi.com/article/0311disaster/fukushima/AJ201206180056>, accessed 19 June 2012.

²⁵⁷ Mainichi Daily News, “84 percent say government stress tests for nuclear plant restarts inadequate: survey”, 2 April 2012.

While Noda believes that “the reactors which can be restarted need to be restarted”, he envisages a “society that doesn’t rely on nuclear power”.²⁵⁸ The Prime Minister’s statements have been echoed by METI Minister Yukio Edano who stated in a stunning interview with the *Wall Street Journal* that by 2030 the nuclear share should be “as close to zero as possible”. Rather than wondering “how do we increase supply”, Edano stated, the question should be “how do we use energy resources we have more effectively”.²⁵⁹

The Japanese government is facing unprecedented opposition to nuclear power in the country. Opinion polls indicate large majorities in favor of a nuclear phase out. A national petition asking for the immediate abandoning of nuclear power has collected more than seven and a half million signatures (as of July 2012). At a “Mega Event” on 14-15 January 2012 in Yokohama, nuclear critics demonstrated that they can now mobilize support from all sectors of society. Over a period of two days a total of 11,500 experts, artists, environmentalists, farmers, representatives of city, prefecture, country and European Parliament (including delegations from 30 countries) and ordinary citizens gathered in the largest international nuclear phase-out conference in history, while 100,000 people followed the events via live-streaming over the internet.²⁶⁰

Japanese media have turned increasingly critical not only on the way the aftermath of the Fukushima disaster is managed, but also on the political pressure to restart reactors. The daily Mainichi sees “no choice but to decommission the Hamaoka nuclear plant”²⁶¹. The prestigious Asahi Shimbun stated: “There is an enormous gap between the public sentiment toward nuclear power generation created by the Fukushima meltdowns and the government’s attempt to ride out the crisis without changing the old ideas and assumptions concerning atomic energy.”²⁶²

Many observers wonder how the Japanese society succeeded to go from close to one third nuclear share in their power supply to zero in one year. How did they manage the summer peak in 2011, how will they manage in 2012?

Numerous measures were taken between March and September 2011 to reduce demand. Their estimated costs ranged from a few yen to a few hundred yen per kWh, in other words from very cheap to ridiculously high. Now, “METI is studying a ‘Nega-Watt Trade’ and other innovative programs” and an in-depth revision of the Energy Conservation Law is under preparation.²⁶³

In the meantime, fossil fuel imports were boosted. Natural gas purchases increased by 37.5 percent or 1.3 trillion yen (US\$15.8 billion) in 2011 compared to the previous year. Although national consumption increased by only 11.6 percent and therefore the higher overall importation cost is a result of higher regional gas prices—which are five times that of North America. According to estimates by the Institute for Energy and Economics of Japan (IEEJ), imports might increase by another 38 percent to 6.5 trillion yen (US\$79 billion) in 2012.²⁶⁴

TEPCO was able to maintain a reasonable reserve capacity (>10 percent) throughout the summer peak period, but, with more nuclear plants going off-line, the situation has gradually deteriorated over the past months to reach a 6 percent level on 5 March 2012 (see Figure 23).

²⁵⁸ Press conference, Tokyo, 2 September 2011.

²⁵⁹ Wall Street Journal, “Unlikely Hand Flips Japan’s Power Switch”, 29 March 2012.

²⁶⁰ See <http://npfree.jp/english.html>

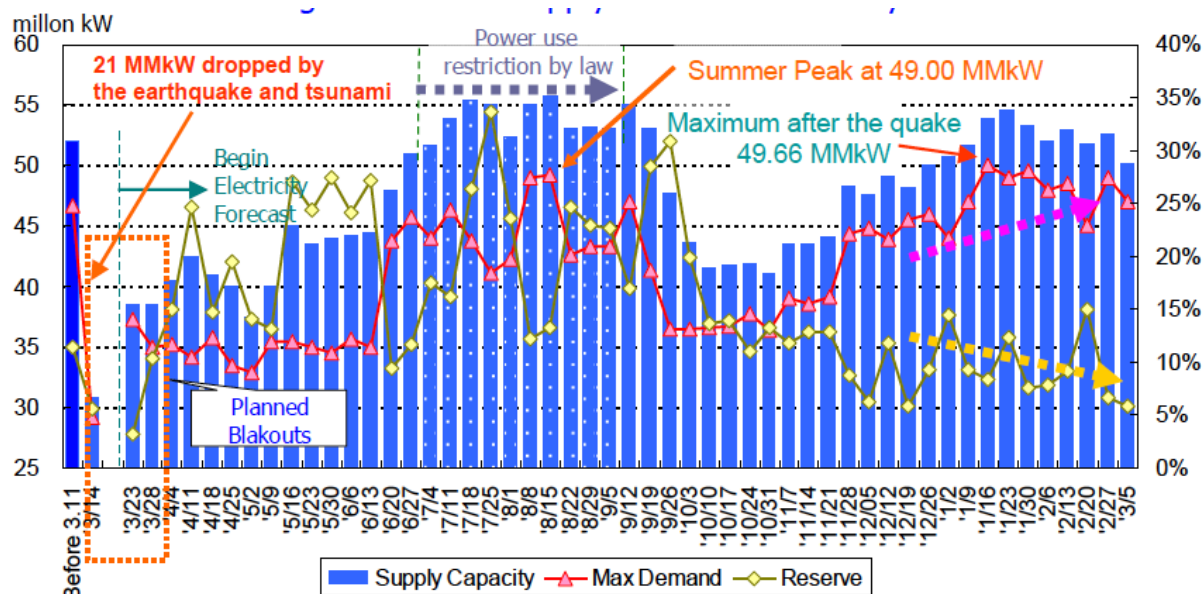
²⁶¹ The Mainichi, “Editorial: No choice but to decommission the Hamaoka nuclear plant”, 17 April 2012

²⁶² The Asahi Shimbun, “Editorial: Policymakers must make serious responses to people’s deep distrust of nuclear power”, 5 May 2012.

²⁶³ IEEJ, “Japan Energy Brief”, n°18, March 2012.

²⁶⁴ IEEJ, “Japan Energy Brief”, n°18, March 2012.

Figure 23: TEPCO's Supply Capacity, Maximum Demand and Reserve Post-3/11



Source: Tokyo Electric, "Electricity forecast" and other information

In fact, for the time being, the situation is much less dramatic than it appears. Since TEPCO's last reactor (Kashiwasaki-5) was shut down on 26 March 2012, the reserve capacity remained comfortable between 10 and 20 percent, with the exception of one day when it dropped to 8 percent on 7 April 2012.²⁶⁵ TEPCO also has a very large pumped storage capacity (ca. 10,000 MW), which provides the utility with excellent load management flexibility. However, the real test will be the summer peak. Apparently, TEPCO does not count on any restart within the current fiscal year and has based its steep tariff increases of 17 percent for industrial and 10 percent for residential customers on the assumption of no nuclear restart.

Several official committees, involving stakeholders from various organisations, are looking into the origins, management and consequences of the 3/11 disaster and into future energy and nuclear policy for Japan. Major strategic reorientation is to be expected. However, while the reduction of the reliance on nuclear power is an explicit goal, little can be said about an alternative strategy in scope and timescale of implementation. In the meantime, the government introduced feed-in tariffs for renewable energy that are significantly higher than those practiced in Germany. The tariffs became effective on 1 July 2012 and are expected to boost the rapid build-up of renewable energies in Japan.

Pakistan operates three reactors that provided 3.8 TWh and 3.8 percent of the country's electricity in 2011. The third unit, 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 MW reactors in the country.²⁶⁶ The Pakistan Atomic Energy Commission (PAEC) indicated a target capacity of 8.8 GW with 10 installed units by 2030.²⁶⁷ Construction of two 315 MW 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.

In the 1980s, Pakistan developed a complex system to illegally access components for its weapons program on the international black market, including from various European sources.²⁶⁸ Immediately following India's nuclear weapons tests in 1998, Pakistan also exploded several nuclear devices.

²⁶⁵ Data from <http://www.tepco.co.jp/en/forecast/html/calendar-e.html>, viewed on 30 May 2012.

²⁶⁶ "Nuclear Energy on Agenda as Chinese Premier Visits Pakistan," *Spero News*, 17 December 2010.

²⁶⁷ "Ten Nuclear Power Plants Planned," *Dawn.com*, 12 January 2011.

²⁶⁸ See Mycle Schneider, "Nucléaire: Paris, plaque tournante du trafic pakistanais," *Politix* (Paris), 1989.

International nuclear assistance has been practically impossible, given that Pakistan, like India, has not signed the Non-Proliferation Treaty (NPT) and does not accept full-scope safeguards, and is currently unlikely to be granted the same exception as India to the Nuclear Suppliers Group's export rules. The Pakistani nuclear program will therefore most likely maintain its predominantly military character.

On the Korean Peninsula, the **Republic of Korea** (South Korea) operates 23 reactors, of which two were connected to the grid in January 2012, several months later than planned. Nuclear plants provided a record 147.8 TWh or 34.6 percent of the country's electricity in 2011 (down from a maximum of 53.3 percent in 1987). In addition, three reactors are listed as under construction and a groundbreaking ceremony took place at the Uljin site on 6 May 2012 for two more units to be started up in 2017 and 2018.²⁶⁹ South Korea's reactors have shown excellent performance in the past and held the fourth position of lifetime load factors with 86.8 percent by the end of 2011.

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.²⁷⁰ However, observers see a "dramatic political shift against nuclear power in the year since Fukushima".²⁷¹ According to polls, less than one third of the South Korean population favors new build and believes that nuclear power is a long-term option. Two thirds of those opposing nuclear power changed their mind after the Fukushima tragedy was triggered, the highest level of any of the 24 countries studied by IPSOS.²⁷² Many anti-nuclear initiatives were launched. Seven months after 3/11, a group of university professors founded the Korean Professors' Organization for a Post-Nuclear Energy Society (K-POPONS), with the aim of "ultimately eliminating nuclear energy".²⁷³ The Mayor of Seoul initiated a program to "save away" the equivalent amount of energy generated by one nuclear reactor and sent a video taped greeting to the Global Conference for a Nuclear Power Free World in Yokohama in January 2012.

The Korean government reacted nervously to the mounting criticism and banned three Greenpeace representatives from entering the country in early April 2012. However, two weeks later, the CEO of Korea Hydro & Nuclear Power (KHNP) was forced to resign over the cover-up of two significant incidents, a 12-minute station blackout at Kori-1 with two emergency diesels failing to start up on 9 February 2012 and another diesel failure at Yonggwang-2 on 28 March 2012. Both events had not been disclosed for several weeks.²⁷⁴ It is now likely that nuclear power will be one of the issues in the December 2012 presidential election, with the opposition arguing for a reduction in the dependency on nuclear power.

In December 2009, South Korea succeeded in securing its first major overseas nuclear deal, "snatching" a multi-billion dollar contract with the United Arab Emirates (UAE) from the world's largest builder AREVA, backed by French state utility EDF, for the building of four 1.4 GW reactors. In the meantime, however, cost estimates have soared and financing negotiations have been delayed into the second half of 2012 (see section on UAE in chapter Potential Newcomer).

Taiwan operates six reactors that provided a record 40.4 TWh or 19 percent of the country's electricity in 2011 (down from a maximum of 41 percent in 1988). Two 1.3 GW Advanced Boiling Water Reactors (ABWR) have been listed as under construction at Lungmen, near Taipei, since 1998 and 1999 respectively. Their startup has been delayed many times and are many years behind schedule. As of end of January 2012, according to Taipower, they were 93 percent complete. In

²⁶⁹ NIW, "South Korea", 11 May 2012.

²⁷⁰ Ki Hak Kim, "Fueling the Sustainable Future", 6 April 2011.

²⁷¹ NIW, "South Korea: Growing Nuclear Skepticism"

²⁷² IPSOS, op.cit.

²⁷³ See <http://cafe.daum.net/inter-nonuke>, accessed 31 May 2012.

²⁷⁴ NIW, "Kim Out at KHNP Over Reporting Lapses", 20 April 2012.

March 2012, the Atomic Energy Minister raised doubt over the safety of the plant.²⁷⁵ In May 2012, media reports gave 2014-15 as the current planned start-up date. According to the Minister of Economic Affairs, the project costs Taipower an estimated NT\$400–600 million (\$10–15 million) for each month of delay.²⁷⁶

Taiwan's nuclear program has a certain number of very specific problems. The nuclear plants are located in areas with high population density, high seismicity and at risk from tsunamis. In addition, with the absence of a long-term waste strategy, the spent fuel pools are filling up and, in spite of re-racking and dense-packing, the first pools are expected to be full by 2014.²⁷⁷ “The confidence of residents are feeble on nuclear safety issue”, admitted Taipower Vice-President Hsu Hwai-Chiung in July 2011. “The license renewal of NPPs will be suspended until National Energy Policies are clear in near future.”²⁷⁸ In November 2011, the government 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”.²⁷⁹ The document released by the Ministry of Economic Affairs' Bureau of Energy also announced the shutdown of its oldest reactors at Chinshan (grid connection 1977 and 1978) as soon as the Lungmen reactors come online and the non-renewal of operating licenses beyond 40-year lifetime. In parallel, Taiwan plans to accelerate its already aggressive energy efficiency and renewable energy policy (see chapter on Renewable Energy vs. Nuclear Power).

European Union (EU27) and Switzerland

The European Union 27 member states (EU27) have gone through three nuclear construction waves, two small ones in the 1960s and the 1970s plus a large one in the 1980s (mainly in France). The region has not had any significant building activity since the 1990s. (See Figure 24.)

In May 2012, 14 of the 27 countries in the enlarged EU operated 132 reactors—about one-third of the world total—11 less than before the Fukushima events and one quarter down from the historic maximum of 177 units in 1989. (See Figure 25.) The vast majority of the facilities, 113 or 86 percent, are located in eight of the western countries, and only 19 are in the six newer member states with nuclear power.

In 2011, nuclear power produced 27.4 percent of the commercial electricity in the EU, down from 31 percent in 2003. Nearly half (49 percent) of the nuclear electricity in the EU27 was generated by one country, France.

With the lack of new reactor construction, the average age of the EU's reactors now stands at 28 years (see Figure 26).

²⁷⁵ Asia Pulse, “Minister Casts Doubt on Viability of 4th Taiwan Nuclear Plant”, PennEnergy, 15 March 2012.

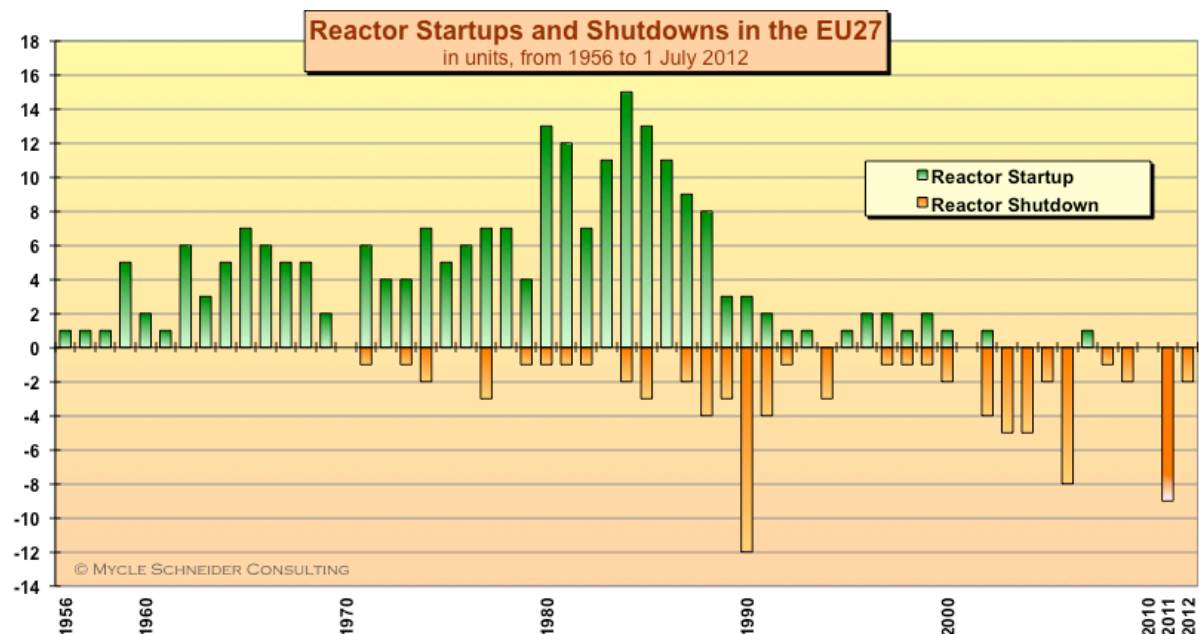
²⁷⁶ Focus Taiwan News Channel, “Start Date for Commercial Operation of Nuclear Power Plant Postponed,” 6 January 2011, at http://focustaiwan.tw/ShowNews/WebNews_Detail.aspx?ID=201101060017&Type=aECO.

²⁷⁷ Le Monde, “Taïwan, l'apprenti sorcier du nucléaire”, 8 February 2012.

²⁷⁸ Hsu Hwai-Chiung, “The Impacts on Taipower Nuclear Power Plants after Fukushima Accident”, Taipower, 27 July 2011.

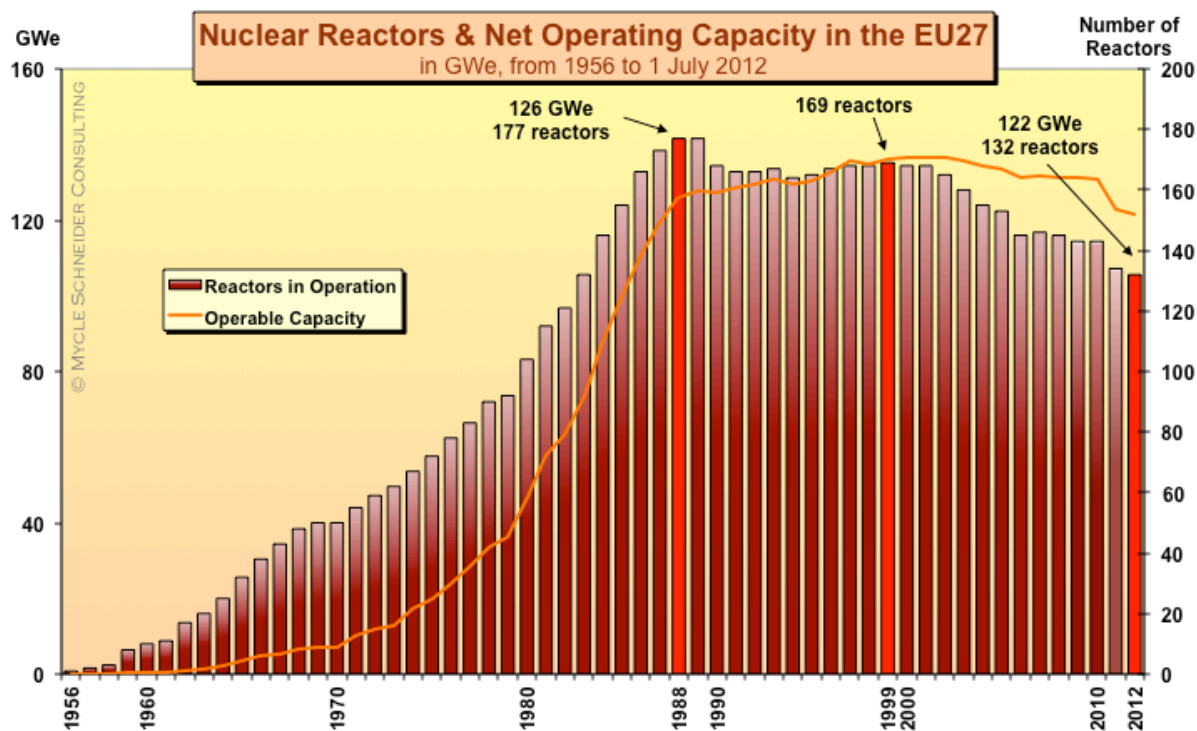
²⁷⁹ Bureau of Energy, “Ensure Nuclear Security—Steadily Reduce Nuclear Dependency—Create a Low-carbon Green Energy Environment & Gradually Move Towards a Nuclear-free Homeland”, Ministry of Economic Affairs, 3 November 2011.

Figure 24. Nuclear Reactors Startups and Shutdowns in the EU27, 1956–2012



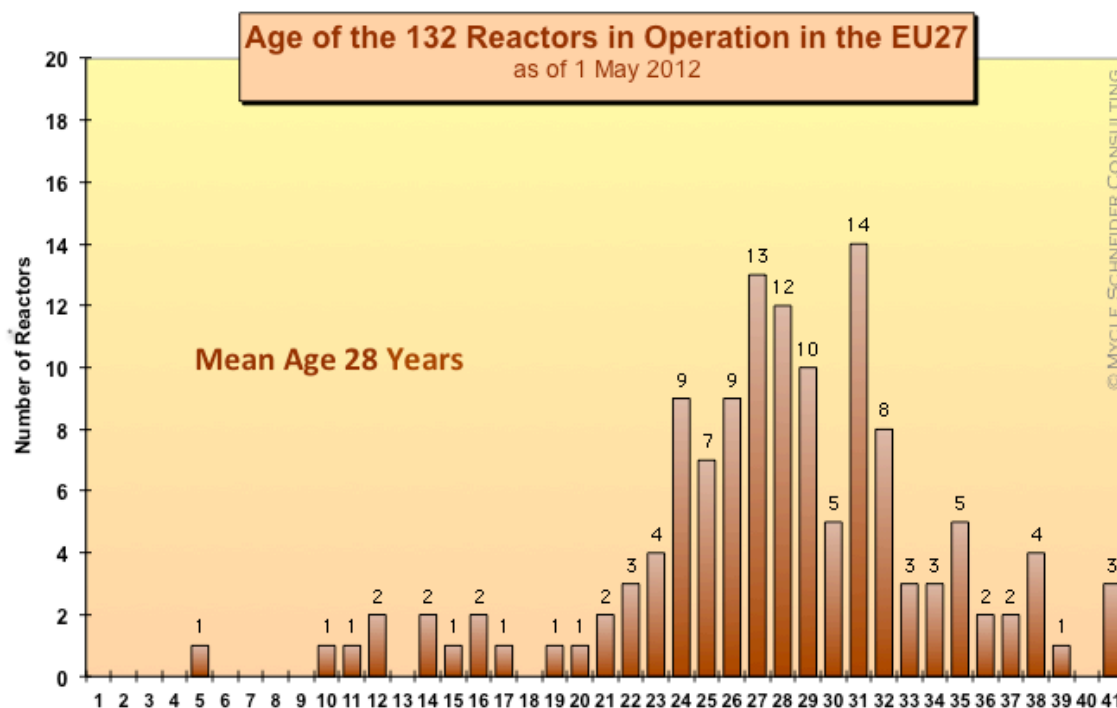
Source: IAEA-PRIS, MSC, May 2012

Figure 25. Nuclear Reactors and Net Operating Capacity in the EU27, 1956–2012



Source: IAEA-PRIS, MSC, May 2012

Figure 26. Age Pyramid of the 132 Nuclear Reactors Operated in the EU



Sources: IAEA-PRIS, MSC, 2012

Western Europe

In Western Europe (EU15), as elsewhere, the public generally overestimates the significance of electricity in the overall energy picture, as well as the role of nuclear power. Electricity currently accounts for only about one-fifth of the EU15's commercial primary energy consumption.

As of July 2012, the EU15 was home to 113 operating nuclear power reactors, or 44 units less than in the peak years of 1988/89. In 2008, nuclear energy provided roughly 29 percent of gross commercial electricity production, 14 percent of commercial primary energy consumption, and 6 percent of final energy consumption.²⁸⁰

Two reactors are currently under construction in the older member states EU15, one in Finland and one in France. These are the first building sites in the region since construction began on the French Civaux-2 unit in 1991. Apart from the French exception, until the reactor project in Finland, no new reactor order had been placed in Western Europe since 1980.

The following provides a short overview by country (in alphabetical order).

Belgium operates seven reactors and has the world's second highest share of nuclear in its power mix, at 54 percent in 2011 (down from a maximum of 67.2 percent in 1986). It is interesting to note that the nuclear plants had their best productivity level in 1999 and have not produced as much power since then (46.7 TWh). In 2002, the country passed nuclear phase-out legislation that required the shutdown of nuclear plants after 40 years of operation, meaning that (based on their start-up dates) plants would be shut down between 2015 and 2025. On 13 October 2009, the 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

²⁸⁰ European Commission, Eurostat, online database,

<http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database>, accessed 19 February 2011.

power.”²⁸¹ However, that government was voted out in June 2010 before being about to vote according legislation. Following Fukushima and the establishment of a new Government the still existing phase-out legislation was left in place and no legislative initiative has been taken to overturn it, even if the operator GDF-Suez is lobbying hard to postpone for an extension of “at least 10 years”.²⁸²

Finland currently operates four units that supplied 22.3 TWh or 31.6 percent of its electricity in 2011 (down from a maximum of 38.4 percent in 1986). 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 Siemens²⁸³, 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”. Construction started in August 2005 at Olkiluoto on the Finnish west coast. Six and a half years later, the project is about five years behind schedule and over 100 percent over budget (for details see EPR – European Problem Reactor section). It remains unclear who will cover the additional cost.

From the beginning, the Olkiluoto-3 (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 latest issue was revealed in late April 2012, when a non-conformity issue was identified in a batch of small pipes.²⁸⁴

The Finnish regulator STUK has still not yet validated the EPR’s Instrumentation and Control (I&C) system. TVO stated in October 2011 that AREVA “has informed about further delay in the development of the I&C system, which has become critical for the time schedule”.²⁸⁵

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 for the Finnish government. OL3 was 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 will force Finland to use emissions trading to compensate for the GHG’s produced in the country.

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 1–1.8 GW reactor to start construction in 2012 and enter operation “in the late 2010s”.²⁸⁶ The decision was ratified by the Finnish Parliament on 1 July 2010. But already 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 are expected in early 2013. A license application is planned for mid-2015 “at the latest” and start-up “around 2020”.²⁸⁷

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

²⁸¹ Prime Minister of Belgium, “Déclaration du gouvernement relative à sa politique générale,” 13 October 2009, at <http://archive.vanrompuy.belgium.be/files/Statepremier.pdf>.

²⁸² Gérard Mestrallet, et al., “Nuclear in Belgium: recent developments”, GDF Suez, 4 November 2011.

²⁸³ Siemens quit the consortium in March 2011 and announced in September 2011 to abandon the nuclear sector entirely.

²⁸⁴ TVO, “TVO investigates a quality finding in small pipes at OL3 plant unit”, press release, 24 April 2012.

²⁸⁵ TVO, “Regular operation of Olkiluoto nuclear power plant unit may be postponed further”, 12 October 2011.

²⁸⁶ TVO, “Construction of a Nuclear Power Plant Unit at Olkiluoto – General Description – OL4,” www.tvo.fi/www/page/2840/, August 2008.

²⁸⁷ WNN, “Bidding starts for Olkiluoto-4”, 26 March 2012, see http://www.world-nuclear-news.org/NN-Bidding_starts_for_Olkiluoto_4-2603124.html, accessed 2 June 2012.

Pyhäjoki, —which has since been narrowed down to the latter site and to being either an EPR or ABWR. Startup is planned for 2020. Bids were received on 31 January 2012 from AREVA and Toshiba. The plant supplier should be selected in 2012 or 2013.²⁸⁸

Finland is planning a final spent fuel repository at the Olkiluoto site as well. Drilling of the access tunnel of the ONKALO “rock characterization facility,” slated to become a final repository, started in 2004. The project, based heavily on the Swedish approach of disposing of spent fuel in copper canisters, is often presented as exemplary; however, geological aspects in particular have received severe criticism. Matti Saarnisto, a professor of geology, former research director of the Geological Survey of Finland, and former secretary general of the Finnish Academy of Science and Letters, has commented of the location: “It is insane to believe you can store nuclear waste for 100,000 years... You can see traces in the landscape of major earthquakes that have occurred about every 2,500 years.”²⁸⁹ In 2010, the operator Posiva Oy, held jointly by TVO and Fortum, received a decision-in-principle to license an increase in the final disposal capacity from 6,000 tons to 12,000 tons to accommodate not only fuel from OL4 but also from Loviisa-3.²⁹⁰ Cost estimates are standing at €6 billion with €1.9 billion currently funded. All of the costs have to be carried by the nuclear power plant operators. Posiva Oy plans to apply for a construction license in 2012 with construction starting in 2015, a schedule that raised the regulator’s concerns.²⁹¹

France Focus

France is the worldwide exception in the nuclear sector. In 1974, the government launched the world’s largest public nuclear power program as a response to the oil crisis in 1973. However, less than 12 percent of France’s oil consumption that year was used for power generation. More than three decades later, per capita oil consumption in France is as high or higher than in Germany, Italy, the United Kingdom, or the EU27 on average.²⁹² The incoming government under President François Hollande will likely lead to a significant shift in energy policy for the first time in almost four decades.

In 2011, France’s 58 reactors²⁹³ produced 423.5 TWh or 77.7 percent of the country’s electricity, even though only about half of the country’s installed electricity-generating capacity is nuclear. Nuclear’s share in France’s power mix reached its maximum in 2005, at 78.5 percent.

France has a significant base load overcapacity that has led to the “dumping” of electricity on neighboring countries and stimulated the development of highly inefficient thermal-applications electricity. A historical winter peak-load of 102 GW in February 2012, (up from 97 GW in December 2010) is to be compared with an installed capacity of 126.5 GW²⁹⁴. However, during the coldest days in February 2012, France imported up to 13 GW of power, of which Germany contributed about 3 GW. This is quite contrary to the expectation of French decision-makers and the nuclear lobby, who anticipated Germany to be dependent on imports of French nuclear electricity after having shut down nearly half of its nuclear reactors in the aftermath of 3/11.

France’s seasonal peak electricity load has increased rapidly since the mid-1980s, due mainly to the widespread introduction of electric space and water heating. Over 30 percent of French households

²⁸⁸ Fennovoima, “Fennovoima received bids for nuclear power plant”, press release, 31 January 2012.

²⁸⁹ Oker-Blom, op. cit. note 133.

²⁹⁰ Ministry of Employment and the Economy, “Application to the MEE for a Decision-in-principle on Expanding the Spent Nuclear Fuel Final Disposal Facility,” press release, 13 March 2009.

²⁹¹ NIW, “Room for More at the Planned Waste Facility?”, 16 March 2012.

²⁹² For a detailed analysis of the French nuclear and energy sector, see Mycle Schneider, “Nuclear Power Made in France – A Model?” in Henry D. Sokolski, ed., *Nuclear Power’s Global Expansion: Weighing Its Costs and Risks* (Carlisle, PA: Strategic Studies Institute, U.S. Army War College, December 2010), pp. 189–277.

²⁹³ All pressurized water reactors, 34 x 900 MW, 20 x 1300 MW. and 4 x 1400 MW.

²⁹⁴ Capacity increased by 2,660 MW in 2011, mainly from solar (+1,350 MW) and wind (+875 MW) additions. Source: RTE, “Bilan électrique 2011”, January 2012.

heat with electricity, the most wasteful form of heat generation because it results in the loss of most of the primary energy during transformation, transport, and distribution. The difference between the lowest load day in summer and the highest load day in winter is now over 70 GW. A drop of 1°C in outside temperature is equivalent to an increase in capacity of 2.6 GW. Short-term peak load cannot be met with nuclear power but by either fossil fuel plants or expensive peak-load power imports.

Considering its existing nuclear overcapacities and the average age of its reactors (roughly 27 years), France should not need to build any new units for a long time. In addition, the nuclear share in the power mix is too high; lifetimes of operating units are planned to be extended; the shutdown of the gaseous diffusion uranium enrichment plant will save huge amounts of electricity²⁹⁵, and several nuclear plants should be made redundant through efficiency.

It therefore will be years, if not decades, before capacity constraints require new baseload power plants in France. If the French government and EDF opt to proceed with construction of a new unit, then this is because the nuclear industry faces a serious problem of maintaining competence in the field.

In December 2007, EDF started construction of Flamanville-3. The FL3 site encountered quality-control problems with basic concrete and welding similar to those at the Olkiluoto-3 (OL3) project in Finland, which started two-and-a-half years earlier. As in Finland, the extensive employment of foreign workers exacerbates communication and social problems.²⁹⁶ It took until April 2012 for the French safety authority to judge satisfactory the instrumentation and control (I&C) system solution proposed by EDF for FL3. The project is now at least four years late, around 100 percent over budget, and not expected to start commercial operation before 2016. (For further details see EPR – European Problem Reactor section).

Beyond the EPR building problems, the two state-owned companies EDF and AREVA are fighting over several strategic issues: follow-up agreements on reprocessed uranium conversion, uranium enrichment, reprocessing and plutonium fuel fabrication, as well as the overall industrial strategy.²⁹⁷

Even before the Fukushima accident, but especially after 3/11, there have been major difficulties with large investment projects—in Italy, the United Kingdom, and the United States—and all are taking a toll on the balance sheet and credit rating of France’s major nuclear companies. While EDF accumulated a huge debt burden of €33.3 billion (end of 2011), AREVA lost €2.4 billion in 2011, a staggering figure considering its turnover of €8.9 billion. In December 2011, Standard & Poor’s downgraded AREVA to ‘BBB-’ rating as well as its stand-alone credit profile of ‘bb-’.²⁹⁸ As of

²⁹⁵ The EURODIF plant at Tricastin consumed the production of up to three reactors and is scheduled for shut-down by the end of 2012.

²⁹⁶ The French Nuclear Safety Authority (ASN) notes in an inspection report that a translator, one of only two French speaking individuals in a team of steel workers, “had difficulties to understand the questions” the inspectors asked, per ASN, “Letter to the Director of the FL3 Construction Project,” 29 December 2010. A worker’s lethal fall on 24 January 2011 was only the latest signal of the working and living conditions that trade unions claim have been criticized for the past three years; see CGT, “Chantier EPR de Flamanville – Les conditions de vie et de travail des salariés doivent s’améliorer!” press release, 3 February 2011. The Human Rights League got involved considering that “its intervention became indispensable since questions of freedom and dignity were firmly raised”; see “LDH: Grand chantier EPR de Flamanville: le point”, L’Humanité, 6 February 2011. Even the Bulgarian media have picked up the issue; see “Bulgarians, Romanians Building Nuclear Reactor in France Face Ruthless Exploitation,” novinite.com, 12 January 2011.

²⁹⁷ François Roussely, “Avenir de la filière française du nucléaire civil,” Synthèse du Rapport, 16 June 2010.

²⁹⁸ 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”.

May 2011, AREVA's share price had plunged by 88 percent of its 2007 value, and EDF shares had lost over 82 percent of their value over the same time period.²⁹⁹

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. France's two La Hague facilities are licensed to process 1,700 tons of fuel per year; however, all significant foreign clients have finished their contracts and have stopped plutonium separation. The La Hague operator AREVA NC therefore depends entirely on the domestic client EDF for future business.

The incoming government under President Hollande constitutes without any doubt a major rupture not only with previous President Nicolas Sarkozy, but also with previous administrations. For the first time since 1974, a French government announced plans for the closure of the oldest operating reactors (Fessenheim-1 and -2, connected to the grid in 1977 and 1978), the abandoning of a new build project (Penly-3) and the systematic reduction of the share of nuclear generated electricity (from about 75 to 50 percent by 2025). While the incoming minister in charge of energy, Delphine Batho, was the security expert of the French Socialist Party and has no prominent public position on nuclear power, Géraud Guibert, her chief of staff, which is the most influential and powerful position in the Minister's office that has now oversight of nuclear policy, is clearly in favor of a nuclear phase-out, no lifetime extensions and strong energy efficiency policy.³⁰⁰ Other key ministers of the new government include Pierre Moscovici, Minister of Economy, Finances and Foreign Trade, who is a partisan of Hollande's line, and Arnaud Montebourg, Minister of Industrial Renewal, is a strong supporter of an "energy transition" that will allow for the "overcoming nuclear".³⁰¹

Germany Focus

Four days after 3/11, **Germany's** government decided to shut down 8 of its fleet of 17 reactors. Originally for a three-month period, however, the closure of almost half of the German reactors turned out to be permanent. Nuclear power plants generated 102 TWh net in 2011—a drop of 23 percent compared to the previous year—and provided 17.6 percent of the electricity (gross) in the country (down from the historic maximum of 30.8 percent in 1997)³⁰².

In 2001 the German Parliament had adopted a nuclear phase-out law that stipulated the shutdown of the country's nuclear power plants after an average lifetime of about 32 years. The last unit would have been shut down around 2022. The current coalition government (Christian Democrats and Liberal Democrats) significantly amended the phase-out legislation and on 28 October 2010, the government majority in the German Parliament voted in favor of a lifetime extension for the nuclear plants of 12 years on average (based on an electricity generating credit per reactor). Under the modified legislation, nuclear units that started operating in 1980 or before could have been operated eight years longer than planned and more recent units up to 14 years longer. However, new build remained explicitly prohibited. Nuclear power was labeled as "bridging technology" on the way to a renewable energy based power system. As under the previous legislation, a generation credit would be permitted to be transferred from an older to a newer plant.

On 14 March 2011, Chancellor Angela Merkel abruptly announced putting the 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, including a revision (the 13th) of the

²⁹⁹ This performance is to be compared with a value reduction of about one half of the national indicator CAC40 since 2007; see Boursorama, www.boursorama.com, viewed 1 June 2011.

³⁰⁰ On 8 April 2011, Guibert co-authored an Oped in *Le Monde* entitled "Sortons du nucléaire" (Lets phase-out nuclear power).

³⁰¹ See "Dépasser le nucléaire", <http://www.arnaudmontebourg2012.fr/content/depasser-le-nucleaire>, accessed 1 June 2012.

³⁰² These figures are from AGEb, "Bruttostromerzeugung in Deutschland von 1990 bis 2011 nach Energieträgern", February 2012.

Nuclear Law (Atomgesetz). The legislation passed the Bundestag on 31 July 2011 and came into force on 6 August 2011. The main characteristics are the following:

- The 40 percent increase in electricity production credit that was decided in 2010 was dropped.
- The operating licenses will expire once the production credit is used up and at the latest according to the Table 5. This meant that the eight units that had been shut down just after 3/11 lost their operating license with the coming into force of the legislation.
- A specific clause potentially allowed for an exception with one of the eight units being maintained as “reserve capacity” until 31 March 2013. However, the Federal Network Agency eventually decided that there was no need to keep such a reserve reactor.
- The production credit can be transferred from older to newer plants.

The legislative package included seven other laws stretching from energy efficiency (€3 billion per year for buildings) and increase in the use of renewable energy (with a new target of 35 percent share of electricity by 2020) and natural gas as well as the large scale extension of the grid system.

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’. Further claims that ‘the decision would lead to unprecedented costs and result in vastly increased greenhouse gas emissions’ also turned out to be untrue or exaggerated.

Table 5: Closure Dates for German Nuclear Reactors 2011-2022

Reactor Name (type, net capacity)	Owner/Operator	End of license (latest closure date)	First Grid Connection
Biblis-A (PWR, 1167 MW)	RWE	6 August 2011	1974
Biblis-B (PWR, 1240 MW)	RWE		1976
Brunsbüttel (BWR, 771 MW)	KKW Brunsbüttel ³⁰³		1976
Isar-1 (BWR, 878 MW)	E.ON		1977
Krümmel (BWR, 1346 MW)	KKW Krümmel ³⁰⁴		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	31 December 2015	1981
Gundremmingen-B (BWR, 1284 MW)	KKW Gundremmingen ³⁰⁵	31 December 2017	1984
Philippsburg-2 (PWR, 1402 MW)	EnBW	31 December 2019	1984
Brokdorf (PWR, 1410 MW)	E.ON/Vattenfall ³⁰⁶	31 December 2021	1986
Grohnde (PWR, 1360 MW)	E.ON		1984
Gundremmingen-C (BWR, 1288 MW)	KKW Gundremmingen		1984
Isar-2 (PWR, 1410 MW)	E.ON	31 December 2022	1988
Emsland (PWR, 1329 MW)	KKW Lippe-Ems ³⁰⁷		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

In fact, the news from Germany includes the significant progress in energy efficiency. According to preliminary results, energy consumption decreased by around 5 percent in 2011 and by around 1 percent once the figure is climate corrected.³⁰⁸ This result was achieved in spite of an economic

³⁰³ Vattenfall 66,67%, E.ON 33,33%

³⁰⁴ Vattenfall 50%, E.ON 50%

³⁰⁵ RWE 75%, E.ON 25%

³⁰⁶ E.ON 80%, Vattenfall 20%

³⁰⁷ RWE 87,5%, E.ON 12,5%

³⁰⁸ All figures in this paragraph, if not otherwise noted, from AGEB, “Energieverbrauch in Deutschland – Daten für das 1.-4. Quartal 2011”, January 2012

growth of 3 percent³⁰⁹, which indicates that overall energy intensity—the amount of energy needed to generate one unit of Gross Domestic Product (GDP)—decreased by about 3 percent. While the consumption of lignite increased by 4 percent, oil consumption decreased by 3 percent to the lowest level since 1990, gas consumption plunged by 10 percent and the use of hard coal in power plants decreased by 2 percent.

So how was the reduction of 32.5 TWh of nuclear electricity compensated for? While a detailed analysis is not yet available, provisional figures³¹⁰ indicate that consumption decreased by 1.9 TWh, net power exports decreased by 11.7 TWh—still leaving a net export of about 6 TWh—and renewables increased generation by 19.2 TWh. No need for additional fossil fuel burning. No need for net imports.³¹¹ Interestingly enough, in January and February 2012, during an unusually cold period in France, Germany exported power to France up to the maximum capacity of 3,000 MW (see section on France for more information).

Germany's political landscape has been profoundly marked by the Fukushima events. In a historic election in Baden-Württemberg, the Green Party doubled its votes to reach 24.2 percent and trailed only the formerly governing CDU. For the first time, a Green Prime Minister of the third largest German State, with a population of over 10 million, leads a coalition with the Social Democrats. The State bought back EDF's participation in the utility EnBW, and co-owns four nuclear reactors, two of which are among the eight that were closed post-3/11. In Germany, State governments have primary administrative responsibility for nuclear licensing and safety.

The Fukushima events and the political reaction accelerated industrial strategic shifts. Electronics giant Siemens, which built all of Germany's nuclear plants and exported more, announced in September 2011 that, after having left AREVA NP, the joint consortium with AREVA, it would quit the nuclear sector entirely. Siemens Chairman Peter Löscher declared that “we will not enter into the overall responsibility or the financing of the construction of nuclear power plants anymore. This chapter is closed for us. (...) Siemens will be a motor for the German energy transition (Energiewende)”.³¹²

The **Netherlands** operates a single, 38-year-old 480 MW plant that provided 3.9 TWh or 3.6 percent of the country's power in 2011 (down from a maximum of 6.2 percent in 1986). In June 2006, the operator and the government reached an agreement to allow operation of the reactor until 2033.³¹³ In 2009, the German utility RWE bought up Essent, which owns half of the reactor, but in January 2011 the Dutch Supreme Court blocked the planned ownership transfer after the other co-owner, DELTA, argued that the unit should remain in public ownership.³¹⁴

In February 2011 the Dutch government presented the parliament with a 17-page document outlining the conditions for new nuclear construction, including safety requirements and financial guarantees. The government wished to accelerate the decision making process to provide a construction license before the end of its term in 2015, and to see plant commissioning by 2019.³¹⁵

³⁰⁹ Statistisches Bundesamt, “Wirtschaftswachstum 2011”, see <https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/GesamtwirtschaftUmwelt.html>, accessed on 3 April 2012.

³¹⁰ AGEb, “Bruttostromerzeugung in Deutschland von 1990 bis 2011 nach Energieträgern”, 15 February 2012

³¹¹ Lower consumption + less exports + more renewables = 32.8 TWh. These are obviously only rough, provisional figures and they do not take into account climate factor or sectorial changes.

³¹² Der Spiegel, “Kapitel abgeschlossen”, 17 September 2011. One month earlier, Siemens had announced that it had entered a “strategic alliance” with the U.S. company Boeing to develop micro-grids to boost efficiency and the use of renewable energies. Source: Siemens, Press Release, 8 August 2011.

³¹³ WNA, “Nuclear Power in the Netherlands,” www.world-nuclear.org/info/inf107.html, updated January 2011.

³¹⁴ “Court Halts Transfer of Stake in Dutch Nuclear Plant,” Expatica.com, 21 January 2011.

³¹⁵ “Conditions Laid Out for Netherlands Nuclear,” WNN, 18 February 2011.

On 23 January 2012, DELTA announced it was putting off decision “for a few years” and that there would be “no second nuclear power 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 (...).”³¹⁶

In early 2004, Borssele operator EPZ extended a reprocessing contract with AREVA NC. This is a curious decision considering that there are no possibilities in the Netherlands of using separated plutonium. Therefore, EPZ pays the French utility EDF to get rid of the plutonium.

Spain operates eight reactors that provided 55.1 TWh or 19.5 percent of the country’s electricity in 2012 (half of the maximum of 38.4 percent in 1989). Beyond the de-facto moratorium that has been in place for many years, the previous Premier Jose Luis Zapatero announced at his swearing-in ceremony 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, “there will be no new nuclear plants.”³¹⁷

Spain is, however, implementing both uprating and lifetime extensions for existing facilities. Licenses for the operating units would have run out between 2010 and 2018; however, in 2009 the government extended the operating license of the 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 7 percent. The 28-year old Almaraz-2 plant also will be updated.³¹⁸

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.³¹⁹ In early May 2012, the Ministry of Industry of the conservative government elected in November 2011 reportedly agreed to initiate a formal procedure to extend the lifetime of Garoña beyond the current closure date of 6 July 2013.³²⁰ The operator has until September 2012 to transmit the supporting documents to the nuclear safety authority CSN (Consejo de Seguridad Nuclear). Lifetime extension “will almost certainly prove more costly than plant operator Nuclenor originally envisioned, since it will now have to implement post-Fukushima safety requirements”, notes trade journal Nuclear Intelligence Weekly.³²¹

The added capacity from Spain’s nuclear uprating (64 MW at Almaraz so far) remains negligible compared to the country’s surge in renewables. With an installed renewable electricity capacity of 32 GW (end of 2011), four times larger than its nuclear capacity, Spain is number four in the world. In spite of difficult economic conditions, the sector attracted US\$8.6 billion in 2011, an increase of 25 percent compared to the previous year.³²²

Sweden operates 10 reactors that provided 58.1 TWh or 39.6 percent of the country’s electricity in 2011 (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 very inefficient thermal use of electricity. Electric space heating and domestic hot water represent up to a quarter of the country’s power consumption.

³¹⁶ DELTA, “DELTA puts off decision for a few years, no second nuclear plant at Borssele for the time being”, press release, 23 January 2012

³¹⁷ “Spain Insists on Energy Saving, Not Nuclear Plants,” *Reuters*, 21 January 2009.

³¹⁸ “Spain Approves Increase in Nuclear Power Output, *Expansion* Says,” Bloomberg.com, 4 January 2011.

³¹⁹ “No Limits for Spanish Reactors,” WNN, 17 February 2011.

³²⁰ WNN, “Spanish government starts turnaround”, 11 May 2012.

³²¹ NIW, “Spain – New Government to Overturn Garona Closure”, 9 January 2012.

³²² PEW, “Who is Winning the Clean Energy Race?”, PEW Charitable Trust, April 2012.

Sweden decided in a 1980 referendum to phase out nuclear power by 2010. Oddly, 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 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 defines ambitious renewable energy and energy efficiency targets and calls 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.³²³ 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. It is remarkable that while Swedish public opinion is split over general nuclear power acceptance, polls have indicated a majority of 57 percent against new build and a stunning 91 percent (the largest share in anyone of the 24 countries studied) that consider nuclear power as “not a viable long term option” and “soon obsolete”.³²⁴

In the meantime, operators have pushed uprating projects to over 30 percent: at Oskarshamn-2 a 38 percent capacity increase is under way while a 33 percent uprate has already been implemented at Oskarshamn-3.

U.K. Focus

The **United Kingdom** operates 16 reactors as of 1 July 2012, one unit was shut down in 2011 (Oldbury-A2) and two in early 2012 (Oldbury-A1, Wylfa-2). Nuclear plants provided 62.7 TWh or 17.8 percent of the country’s electricity in 2011 (down from a maximum of 26.9 percent in 1997). The first-generation Magnox reactors, with 11 stations, have all been retired, except for the last one at Wylfa, which is to close by the end of 2012.³²⁵ The seven second-generation stations, the Advanced Gas-cooled Reactors (AGR), are also at or near the end of their design life, although the owners now hope to extend their life to 40 years, with retirement only in 2016–29. It remains to be seen whether this plan is feasible. The AGRs have always had reliability problems, and their operating costs are now so high that it may be uneconomic to keep them in service even if a safety case can be made. The newest plant, Sizewell-B, is the United Kingdom’s only PWR and was completed in 1995.

The U.K. nuclear industry has gone through many troublesome decades. In 2004 the government prevented privately owned nuclear generator British Energy from going into liquidation. The state-owned nuclear fuel and technology company BNFL was also effectively bankrupt because it could not meet its liabilities. The government split the company up, passing the physical assets to a new agency, the Nuclear Decommissioning Authority (NDA), while the capabilities were privatized. The reactor design and fuel manufacture division of BNFL (based mainly on the Westinghouse nuclear division acquired in 1998) was re-privatized as Westinghouse and sold to Toshiba.

The NDA is now responsible for decommissioning all Britain’s civil nuclear facilities except those owned by British Energy, a discounted liability³²⁶ estimated in 2011 to be in excess of £50 billion (US\$77 billion), up from less than £34 billion (US\$52 billion) in 2007. The NDA inherited negligible funds for this task, relying partly (and increasingly) on grants from the Treasury and partly

³²³ “Swedish Government Overturns Nuclear Ban,” www.neimagazine.com, 21 June 2010.

³²⁴ IPSOS, op.cit.

³²⁵ Magnox, “Fact and figures”, see <http://www.magnoxsites.co.uk/our-sites/wylfa/facts-and-figures>, viewed 3 June 2012

³²⁶ The recent NDA Annual Reports only give discounted figures. In the 2007/08 report the discounted £40.7 billion turn into an undiscounted £63 billion.

on income from the facilities still in operation, including one remaining Magnox reactor, the THORP reprocessing plant, and the SMP 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.³²⁷

In 2008, the government of Gordon Brown started to organize the framework of a new-build program. In April 2009, the NDA auctioned off the first pieces of land earmarked for the construction of new reactors. EDF Energy, the French utility's U.K. branch,³²⁸ and German companies E.ON and RWE were among the buyers. By May 2009, EDF Energy had issued pre-qualification questionnaires to a number of firms for preparatory and civil works contracts.³²⁹ While EDF Energy would propose the EPR model, RWE was in negotiations with Westinghouse over the construction of up to three AP1000 in North Wales starting in 2013.³³⁰ Ten days after 3/11, the CEO of EDF's U.K. subsidiary, Vincent de Rivaz, stated that the U.K.'s plans for nuclear power plants "have to go ahead."³³¹

In July 2011, the government released the National Policy Statement (NPS) for Nuclear Power Generation, which states:

The Government believes that energy companies should have the option of investing in new nuclear power stations. Any new nuclear power stations (...) will play a vitally important role in providing reliable electricity supplies and a secure and diverse energy mix as the UK makes the transition to a low carbon economy.³³²

The eight "potentially suitable" sites considered in the document for deployment "before the end of 2025" are exclusively current or past nuclear power plant sites in England or Wales.³³³ Northern Ireland and Scotland³³⁴ are not included.

In early 2012, doubts were raised over the likelihood of the delivery of the governments nuclear objectives with the withdrawal of several key players. On 29 March the German utilities announced that they intended to withdraw from their plans to build up to 6 GW of nuclear power in the U.K. and that they are looking for an investor that would take over their joint 50/50 consortium Horizon Nuclear Power. E.ON stated in a press release that it will "focus on other strategic projects that will deliver earlier benefit for customers and the company". Accordingly, "UK investments [will be] focused on Renewables, Distributed Energy and Energy Efficiency", E.ON adds.³³⁵ Two weeks later, Gérard Mestrallet, Chairman and CEO of GDF-Suez, declared in an interview that his company needed more financial incentives if it was to proceed with a new build project at Sellafield. In the meantime an investment decision is delayed until 2015.³³⁶ GDF-Suez had started up a joint venture

³²⁷ Cumbrians Opposed to a Radioactive Environment (CORE), Sellafield – Breaching International Treaty Targets on Radioactive Marine Pollution (Broughton-in-Furness, Cumbria: February 2011).

³²⁸ As early as 2006, EDF hired a powerful ally, Andrew Brown, the then-Prime Minister's younger brother, who, as of May 2009, acted as press officer for EDF Energy. By February 2011, someone else was responding to his extension number.

³²⁹ Platts' David Stellfox, in a February 2009 presentation in Washington, D.C., put it this way: "How to resurrect a flagging nuclear industry quickly – give it to the French!"; "Ten Firms in Race for £700m Nuclear Civils Packages," Contract Journal, 20 May 2009.

³³⁰ "Westinghouse Gets Set for UK Construction," WNN, 5 September 2008.

³³¹ Bloomberg, "EDF's De Rivaz Says U.K. Nuclear Power Plans Will Proceed," 20 March 2011.

³³² DECC, "National Policy Statement for Nuclear Power Generation", July 2011.

³³³ Bradwell, Hartlepool, Heysham, Hinkley Point, Oldbury, Sizewell, Sellafield, and Wylfa.

³³⁴ 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.

³³⁵ E.ON, "E.ON looks to find new owner for Horizon Nuclear Power", press release, 29 March 2012.

³³⁶ The Guardian, "GDF-Suez's nuclear reservations hit government energy policy", 16 April 2012.

called NuGen with Spanish utility Iberdrola to build up to 3.6 GW of nuclear capacity under the project name of Moorside.³³⁷

Finally, on 7 May 2012, the day after the election of President Hollande, the London *Times* stated: “Energy policy is hanging by a thread after the only credible company left to build nuclear reactors in Britain increased the price by 40 per cent to £7 billion each”.³³⁸ (See also EPR – European Problem Reactor section). EDF Energy’s new price tag of £14 billion for two EPRs planned for the Hinkley Point site would make it difficult indeed to achieve a “correct market framework that will allow an appropriate return on the massive investment required” as requested by the utility. On 11 May 2012, EDF’s partner in the project, the domestic energy utility Centrica’s CEO Sam Laidlaw stated in front of the shareholder meeting: “The investment case for nuclear has yet to be proven.”³³⁹ Three days later, it was reported that EDF Energy has delayed ground work at Hinkley Point: “Work to move millions of cubic meters of soil and rock at the Hinkley site was due to begin in August, according to West Somerset council’s planning department. But EDF staff have been told the work will now start in 2013.”³⁴⁰ Reportedly, project investment has already cost EDF and its partner around £1 billion.³⁴¹ In August 2011, EDF had ordered forgings from AREVA for its UK plans. These plans now look even more remote as credit rating agency Moody’s has warned over the negative impact the implementation of new build would have on the ratings of companies involved³⁴² and as plant life extension of the existing fleet is becoming an increasingly attractive option.³⁴³

The only non-EU Western European country that operates nuclear power plants is **Switzerland**. It operates five reactors that generated 25.7 TWh that covered 40.8 percent of the country’s electricity consumption in 2010 (down from a maximum of 44.4 percent in 1996). 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. At the time of Fukushima the nuclear operators had just initiated a debate over the potential replacement of the country’s aging nuclear plants. The utilities Axpo, BKW, and Alpiq jointly planned the rebuild of two replacement units for the aging Beznau (oldest operating unit in Europe) and Mühleberg reactors. A local referendum on 13 February 2011 saw a slim 51/49 percent majority for future replacement of the 40-year old Mühleberg reactor that is expected to shut down by 2022. That same day, a cantonal referendum on a proposed geological repository in Nidwalden turned into a fiasco for its proponents, with 80 percent of voters refusing the nuclear waste disposal project.³⁴⁴

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.³⁴⁵ 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.

³³⁷ Another partner, SSE announced it was withdrawing from its partnership with Suez and Iberdrola and planned to invest in renewables rather than nuclear power - Scottish and Southern Energy abandons nuclear plans for wind, 23 September 2011, see, <http://www.telegraph.co.uk/finance/newsbysector/energy/8785655/Scottish-and-Southern-Energy-abandons-nuclear-plans-for-wind.html#>

³³⁸ The Times, “Soaring costs threaten to blow nuclear plans apart”, 7 May 2012.

³³⁹ The Telegraph, “Centrica shareholders revolt against the executive pay”, 11 May 2012.

³⁴⁰ The Guardian, “Hinkley nuclear power station delay deals blow to government hopes”, 14 May 2012.

³⁴¹ The Times, “Soaring costs threaten to blow nuclear plans apart”, 7 May 2012.

³⁴² This is Money, “UK nuclear programme is at risk in Moody’s credit alert”, 7 April 2012, see <http://www.thisismoney.co.uk/money/markets/article-2126499/UK-nuclear-programme-risk-Moody-s-credit-alert.html>, accessed, 5 June 2012.

³⁴³ The Guardian, “Nuclear reactor reprieve puts UK energy plans in doubt”, 22 May 2012.

³⁴⁴ “Bern Says Yes to Nuclear Power Plant,” swissinfo.ch, 13 February 2011.

³⁴⁵ AREVA, “Impact of Fukushima event on nuclear power sector – Preliminary assessment”, 25 March 2011.

Court cases in Switzerland might accelerate further the shutdown of units. The Federal Administrative Court ruled in March 2012 that, because of its deteriorated state, incomplete assessment of earthquake resistance and lack of alternative cooling options, the 41-year old Mühleberg reactor could only operate until 28 June 2013. In order to extend operation beyond this date—the original scheduled shutdown was around 2022—the operator would have to implement a significant refurbishment program.³⁴⁶ The government has appealed against the judgement, while the Region Vorarlberg lodged a new complaint against the further operation of Mühleberg. On 29 May 2012, the Federal Court rejected the operator's request for a suspensive effect.³⁴⁷

Central and Eastern Europe

In **Bulgaria**, nuclear power provided 15.3 TWh or 32.6 percent of the country's electricity in 2011 (down from a maximum of 47.3 percent in 2002), with generation occurring at the remaining two units of the Kozloduy plant. As part of the deal to join the EU, the Bulgarian government agreed to close the four VVER 440-230 designed units at Kozloduy, two of which were closed in 2002 and two in 2006. Bulgaria has received €550 million (US\$800 million) from the EU as compensation for the closure, with up to €300 million (US\$437 million) more possible in the coming years.³⁴⁸ A report released in February 2012 from the European Court of Auditors was highly critical of the decommissioning process to date in Bulgaria, Lithuania and Slovakia (which all closed reactors as part of the accession process to the EU), the report concluded: "There is no comprehensive assessment concerning the progress of the decommissioning and mitigation process. Delays and cost over runs were noted for key infrastructure projects". The report also concluded that there was likely to be a budgetary shortfall of around €2.5 (US\$3.2) billion for all three projects³⁴⁹.

Construction of a reactor at the Belene site began in 1985 but was suspended following the political changes in 1989 and formally stopped in 1992, due in part to concerns about the geological stability of the site. In 2004, a call for tender for completion of the 2 GW of nuclear capacity was made and seven firms initially expressed an interest. In November 2010, NEK signed a memorandum of understanding (MoU) with the Russian state energy company Rosatom to re-establish the Belene Power Company—again with 51 percent initially being held by NEK. For its part, Rosatom is endeavoring to arrange financing for the project, to attract other investors, and to facilitate ASE's commissioning of the reactors by 2016 and 2017 at a fixed price of €6.3 billion (\$9.2 billion). The ownership structure is shared between NEK (51 percent stake), Rosatom (47 percent), and Fortum and Altran (1 percent each).

After Fukushima, the EU Energy Commissioner, Günther Oettinger, stated that the Belene project would have to be re-examined.³⁵⁰ Subsequently, Energy and Economy Minister Traicho Traikov stated that Bulgaria would 'request additional information and guarantees from the manufacturer'.³⁵¹ The most recent consortium proposed to start construction by October 2011. But in September 2011 the Russian company responsible for the export of reactors (AtomStroyExport) and the state utility (NEK) extended their pre-construction agreement until March 2012.

³⁴⁶ WNN, "Court ruling threatens extended Mühleberg operation", 8 March 2012.

³⁴⁷ Land Vorarlberg, "AKW Mühleberg: Schweizer Bundesgericht verweigert Zeitaufschub", press release, 29 May 2012.

³⁴⁸ SofiaEcho.com, "Bulgaria Might Get More Compensation for Shutting Down Reactors at Kozloduy NPP Media Reports Say," 27 October 2009.

³⁴⁹ *European Court of Auditors*, "EU Financial Assistance For The Decommissioning Of Nuclear Plants In Bulgaria, Lithuania And Slovakia: Achievements And Future Challenges", Special report No 16, 2011 <http://bookshop.europa.eu/en/eu-financial-assistance-for-the-decommissioning-of-nuclear-plants-in-bulgaria-lithuania-and-slovakia-pbQJAB11014/>

³⁵⁰ Sofia News Agency, "'EC Reexamines Bulgaria's Belene Nuclear Project'", 15 March 2011

³⁵¹ Bloomberg, "Bulgaria to Seek Nuclear Safety Guarantees on Russian Reactors" 14 March 2011

However, in March 2012, the project was officially cancelled by the Prime Minister who stated: “We just can't afford to pay the total cost of the project, which will reach some 10 billion euros. And there is no way we can make future generations pay”³⁵².

The **Czech Republic** has six Russian-designed reactors in operation at two sites, Dukovany and Temelín. The former houses four VVER 440-213 reactors, and the latter two VVER 1000-320 units. Between them, they produced a record 26.7 TWh or 33 percent (down from the historic maximum in 2009 of 33.8 percent of the country's electricity in 2011). Temelín was the focus of considerable controversy since a decision was taken to restart construction in the mid-1990s after being halted in 1989. The two reactors were eventually started in 2000 and 2002, with financial assistance from the U.S. Export-Import Bank and I&C technology supplied by Westinghouse.

In July 2008, CEZ announced a plan to build two more reactors at Temelín, with construction to start in 2013 and commissioning of the first unit in 2020. In March 2010, CEZ announced that discussions had begun with three vendor groups prior to the bid submission: a consortium led by Westinghouse; a consortium of Škoda JS, Atomstroyexport, and OKB Gidropress; and France's AREVA.³⁵³ In February 2011, the final delivery date was shifted to 2025.³⁵⁴ In October 2011 CEZ asked for tenders from three companies (AREVA, Westinghouse and Atomstroyexport with Skoda) for a turnkey contract for the construction of two units plus nine years' worth of fuel. The bids are due in July 2012, with contracts to be signed in late 2013. CEZ is reported to be considering seeking an outside investor, for \$10 billion, for the project³⁵⁵. CEZ stated in May 2012, that “the partnership will probably be formed after the contract with the selected supplier is signed, which is expected to happen in 2013”.³⁵⁶

However, in order to attract outside investors additional government financial support is likely to be required, though different government departments have so far rejected proposed funding mechanisms. The Finance Minister Miroslav Kalousek told the business daily *Hospodářské noviny* that state guarantees for any loans to the power firm's nuclear expansion were out of the question, while the chairwoman of the Czech Energy Regulatory Office (ERÚ) Alena Vitásková said she has taken a hard line against subsidized power production in the renewable sector and stated “I cannot imagine guaranteed prices. I do not know how that could be explained to consumers that after solar they would have to fund other power plants”.³⁵⁷

The Dukovany plants have operated since the first half of the 1980s and have been the subject of engineering changes to extend the life of the reactors while simultaneously expanding their output by about 15 percent. The operators envisage that the units will continue operating until 2025.

Hungary has only one nuclear power plant at Paks, which houses four VVER 440-213 reactors that provided a record 14.7 TWh or 43.2 percent of the country's electricity in 2011 (down from a maximum of 51.4 percent in 1990). 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 accompanied by a 20 percent increase in capacity. In April 2003, the site's second reactor experienced the country's worst ever nuclear accident, rated on the international scale as a “serious incident” (INES Level 3). It resulted in evacuation of the main reactor hall and the venting of radioactivity to the

³⁵² Reuters, “UPDATE 2-Bulgaria abandons Belene nuclear plant plans”, 28 March 2012, <http://www.reuters.com/article/2012/03/28/bulgaria-nuclear-idUSL6E8ES7A420120328>

³⁵³ World Nuclear Association, “Nuclear Power in Czech Republic,” January 2012. www.world-nuclear.org/info/inf90.html,

³⁵⁴ Reuters, “Czech CEZ Puts off Temelin Expansion Deadline to 2025,” 18 February 2011.

³⁵⁵ Bloomberg, “CEZ May Seek Investor for \$10 billion Temelin Reactor Project”, 26 January 2012.

³⁵⁶ CEZ, “CEZ to consider the inclusion of a strategic partner in the completion of Temelin”, 9 May 2012.

³⁵⁷ Czechposition.com, “Czech Fin Min gives mixed message on Temelín support”, 29th March 2012 <http://www.ceskapozice.cz/en/business/companies/czech-fin-min-gives-mixed-message-temelin-support>

outside environment. It later transpired that the accident was caused by inadequate cooling of the fuel rods during maintenance and cleaning, leading to their overheating and to their damage. The reactor was out of operation for 18 months.

In March 2009, the Hungarian parliament approved a government decision-in-principle to build additional reactors at Paks.³⁵⁸ In January 2011, national media reported that the operation of existing units, after plant life extension, would cease between 2030 and 2040. The proposed additional units (5 and 6) “will not generate extra power but make up for the output of the phased-out blocks.”³⁵⁹ Russian assistance seems to be the preferred option, and Hungary’s foreign minister has indicated that expansion of the Paks plant would be part of a “package deal” on outstanding economic issues with Russia.³⁶⁰ Prime Minister Viktor Orban said in December 2011 that the goal is to have nuclear power provide 60 percent of the country’s electricity needs, compared with around 40 percent now.³⁶¹ In May 2012, the government announced it plans a “two block” extension to the Paks plant.³⁶² Meanwhile, according to a post-Fukushima survey, a 62 percent majority of Hungarians opposes new build and a surprising 80 percent consider nuclear’s viability “limited and soon obsolete”.³⁶³

Lithuania’s Ignalina nuclear power plant, which was shut down in 2009, was an RBMK design similar to that used at Ukraine’s Chernobyl site. Given the impact of the Chernobyl accident across Western Europe, it is remarkable that a similar design of reactor was allowed to operate within the EU for so long. As part of the accession agreement, the sole remaining Ignalina unit was closed on 31 December 2009, several years after the first unit was shut down in 2004. The justification for the long phase-out was the country’s high dependency on the stations.

Before the 2009 shutdown, Lithuania’s remaining unit generated 76.2 percent of the country’s electricity, the largest percentage share worldwide. Lithuania also holds the absolute world record of providing 88 percent of the country’s electricity in 1993 from nuclear power. Although the country has more-than-sufficient other installed generation capacity to make up for the loss of Ignalina, it now imports a considerable amount of (cheaper) electricity from Russia following the 2009 closure.

In February 2007, the governments of the three Baltic States and Poland agreed to build a new nuclear power plant at Ignalina.³⁶⁴ Lithuania passed a parliamentary bill that July calling for construction and completion by 2015. During the following two years, various permutations of ownership structures and sizes of the proposed reactor(s) were put forward. In April 2010 formal proposals from five selected strategic investors were submitted to the government, with bids subsequently sought. The Lithuanian government then announced that it would instead conduct direct negotiations with potential investors and that it hoped to begin operation of the new plant in 2020.³⁶⁵ This led to exclusive negotiations with Korean utility KEPCO, which turned down cooperation in early December 2010, two weeks after submitting a bid. In reaction, the prime ministers of Lithuania, Latvia, Estonia, and Poland confirmed their support for the Baltic power plant project during a meeting in Warsaw, though none of them made any concrete commitments.³⁶⁶ In 2011 Poland withdrew from the project and two nuclear projects are now being developed.

³⁵⁸ John Shepherd, “Hungary’s Parliament Paves Way to Build New Reactor Unit,” NucNet, 31 March 2009.

³⁵⁹ Caboodle.hu “Hungary Mulls Plans to Build New Nuclear Blocks.”, 14 January 2011.

³⁶⁰ Realdeal.hu “Hungary, Russia Seek to Resolve All Outstanding Issues in One Package, Says FM,” 21 January 2011.

³⁶¹ Bloomberg “Hungary Targets Expansion of Nuclear Energy Use”, 15 December 2011

<http://www.businessweek.com/ap/financialnews/D9RL100O1.htm>

³⁶² NIW, “Hungary: More Reactors at Paks”, 1 June 2012.

³⁶³ IPSOS, op.cit.

³⁶⁴ Foratom, “New Member States Take the Nuclear Lead,” May 2007, at www.foratom.org/e-bulletin-tout-1378/new-member-states-tout-1387/419-new-member-states-take-the-nuclear-lead.html.

³⁶⁵ WNA, “Nuclear Power in Lithuania,” www.world-nuclear.org/info/inf109.html, December 2011.

³⁶⁶ WNN, “Tender for New Lithuanian Plant Investor Stalls,” 6 December 2010.

The Lithuanian government, along with its partners in Estonia and Latvia, are in talks with Hitachi Ltd. to build a nuclear power plant. Lithuania has picked Hitachi together with its Hitachi-GE Nuclear Energy Ltd. unit as a strategic investor and technology supplier to construct a nuclear plant in the Baltic country by the end of 2020.³⁶⁷ In May 2012, the government adopted a concession agreement aiming for a 20 percent share for reactor vendor Hitachi in a \$6.5 billion 1,350 MW Hitachi Advanced Boiling Water Reactor, with Lithuania taking up 38 percent, Estonia 22 percent and Latvia 20 percent. First concrete is apparently planned for in mid-2016.³⁶⁸

Romania's Cernavoda nuclear power plant hosts Europe's only CANDU (Canadian-designed) reactors. The plant project was initiated under the regime of Nicolae Ceausescu in the 1970s and was initially proposed to house five units. Construction began in 1980 on all the reactors, in part using funding from the Canadian Export Development Corporation, but this was scaled back in the early 1990s to focus on unit 1. The first unit was completed in 1996 at an estimated cost of around US\$2.2 billion, nearly a decade late. The second unit, also completed with foreign financial assistance (a C\$140 million [US\$146 million] Canadian loan and a €223 million [US\$324 million] Euratom loan) was connected to the grid in August 2007. The two reactors generated 10.8 TWh or 19 percent of Romania's electricity in 2011 (down from 20.6 percent in 2009).

Plans are being actively developed to complete at least one additional unit at the power plant.

In November 2008, an investment agreement was signed between SNN and ENEL of Italy, CEZ of the Czech Republic, GDF Suez of France, and RWE Power of Germany (with each having 9.15 percent) as well as Iberdrola of Spain and Arcelor Mittal Galati of Romania (with both having 6.2 percent). Commissioning of unit 3 was due initially in October 2014 and unit 4 in mid 2015; however, this has since been revised, with the first unit not expected to be completed until 2016 at the earliest. In January 2011, CEZ sold its shares to Nuclearelectrica, and GDF Suez, RWE, and Iberdrola also withdrew from the project, explaining that "economic and market uncertainties surrounding this project, related for the most part to the present financial crisis, are not reconcilable now with the capital requirements of a new nuclear power project."³⁶⁹

In January 2011, Nuclearelectrica announced nevertheless that its tender for construction of Cernavoda 3 and 4 had received three bids: from U.S./Canadian engineering giant Bechtel, from a consortium led by Canada's SNC Lavalin and including Italy's Ansaldo and Romania's Elcomex, and from a full Russian consortium led by Atomtechnoprom.³⁷⁰

In April 2012, the head of the energy department in the Economy Ministry indicated that potential investors were awaiting a price evaluation that would be "closer to reality", while the government is considering the option of "going solo" on the Cernavoda extension and downsize the project to only one additional unit.³⁷¹ On 17 May 2012, Prime Minister Victor Ponta stated that "the 15 September [2012] is a realistic term to take a decision".³⁷²

³⁶⁷ 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>

³⁶⁸ NIW, "Lithuania", 11 May 2012.

³⁶⁹ GDF-Suez, RWE, and Iberdrola, "GDF-Suez, RWE and Iberdrola Have Decided Not to Continue to Participate in the Cernavoda Nuclear Project in Romania," press release, 20 January 2011.

³⁷⁰ NEI Magazine "Foreign Investors Ditch Cernavoda 3&4 Project," www.neimagazine.com, 24 January 2011.

³⁷¹ Morning News Brief, "Investors in the expansion of the Cernavoda nuclear power plant are awaiting price evaluation", 5 April 2012, see <http://www.morningnewsbrief.ro/business-commerce/investors-in-the-expansion-of-the-cernavoda-nuclear-power-plant-are-awaiting-price-evaluation/>, accessed 5 June 2012.

³⁷² Victor Ponta, "Victor Ponta: Pour le Gouvernement actuel c'est une priorité et mon intention de mettre en fonction les projets relatifs aux groupes 3 et 4 de la Centrale de Cernavoda", Gouvernement de la Roumanie, 17 May 2012, <http://www.gov.ro/victor-ponta-pour-le-gouvernement-actuel-c-est-une-priorite-et-mon->

In **Slovakia**, the state utility Slovak Electric (SE) operates all nuclear power plants at two sites: Bohunice, which houses two VVER 440 units, and Mochovce, with two similar reactors. In 2011, these generated 14.3 TWh and provided 54 percent of the country's electricity production (down from a maximum of 57.4 percent in 2003). Of the three other reactors that once existed at Bohunice, the first, A1, was closed after two meltdown accidents in the late 1970s. Two older VVER 440-230 reactors were closed in 2006 and 2008 as part of the EU-accession partnership agreement. The two remaining operational units were the subject of both uprating (from 440 MW to 505 MW each) and upgrading (extending their operating lives to 40 years), which would enable the station to operate until 2025.³⁷³

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 (\$2.9 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 the lower amount of €1.8 billion (US\$2.6 billion). In July 2008, the European Commission gave a conditioned opinion on the Mochovce 3 and 4 project, noting that the reactor did not have the "full containment" structure used in the most recent nuclear power plants planned or under way in Europe and requesting that the investor and national authorities implement additional features to withstand a potential impact from a small aircraft.³⁷⁴

Construction at Mochovce restarted on 3 December 2008. In 2009, an Environmental Impact Assessment (EIA) was carried out, and three permits were given for major changes in the safety setup of the project. This led to formal complaints by a group of NGOs to the Aarhus Convention Compliance Committee, which resulted in December 2010 in a verdict that the three permits had been issued in breach of the convention over access to information, public participation, and access to justice in environmental matters.³⁷⁵ The startup of the units has been delayed, officially due to stress tests, and they are now expected to commence operation at the end of 2013 and mid 2014. €2.8 billion has been allocated to the completion project³⁷⁶.

In **Slovenia**, the Krsko nuclear power plant was the world's first reactor to be owned jointly by two countries, **Croatia** and Slovenia. The reactor, a 696 MW Westinghouse PWR, was connected to the grid in 1981 and is due to operate until 2021. The output is shared between the two countries. The generation of 5.9 TWh corresponds to 41.7 percent of Slovenia's power consumption in 2011 (down from a maximum of 42.4 percent in 2003). Discussions remain ongoing for the construction of a second reactor at the site; a decision has been delayed several times in Slovenia and has been pushed back to 2012 in Croatia.³⁷⁷ The French Foreign Service writes on its website: "The call for tenders should be launched between 2011/2013 to start construction in 2015 and activation between 2020/2025."³⁷⁸ However, the webpage has not been updated since June 2010.

intention-de-mettre-en-fonction-les-projets-relatifs-aux-groupes-3-et-4-de-la_13a117181.html, accessed 5 June 2012.

³⁷³ TheDaily.sk, "SE Switches on Two Upgraded Nuclear Power Units," 11 October 2010.

³⁷⁴ European Commission, "Commission Issues Its Opinion on Units 3 and 4 of the Slovak Nuclear Power Plant of Mochovce," IP/08/1143 (Brussels: 5 July 2008).

³⁷⁵ Nuclear Monitor, "Mochovce Public Participation Insufficient," Nuclear Information Resource Service, World Information Service on Energy, 21 January 2011.

³⁷⁶ WNA, "Nuclear Power in Slovakia", May 2012, <http://world-nuclear.org/info/inf91.html>, accessed 5 June 2012.

³⁷⁷ Novinite.com "East Europe Nuclear Plants Struggle to Find Investors," 27 January 2011.

³⁷⁸ The French Ministry of Foreign Affairs states: "Three manufacturers have been shortlisted: AREVA (1600W EPR), Westinghouse (ATMEA) and Mitsubishi (APWR and AP-1000)." See <http://www.diplomatie.gouv.fr/en/country-files/slovenia/france-and-slovenia/economic-relations-7252/article/economic-relations-14294>, accessed 5 June 2012.

Former Soviet Union

Armenia has one remaining reactor at the Medzamor (Armenia-2) nuclear power plant, which is situated within 30 kilometers of the capital Yerevan and provides 33 percent of the country's electricity. The reactor is of early Soviet design, a VVER 440-230, and has raised considerable concerns. 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."³⁷⁹ Due to this proximity, a 1998 referendum resulted in an agreement to close the then-two operating VVER 440-230 reactors. In October 2011, a third of the 450 employees at the plant went on strike requesting 50 percent higher salaries (average salaries are around US\$740 per month). They went back to work a few days later after having obtained a 10 percent increase.³⁸⁰

In December 1988, Armenia suffered a major earthquake that killed some 25,000 people and led to the rapid closure of the 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, the younger of the two units.

The reactor provided 2.4 TWh or 33.2 percent of the country's electricity in 2011 (down from a maximum of 45 percent in 2009). It was due to close in 2016 or 2017, but Armenia's Minister of Energy stated in February 2011 that it will be closed only when a new plant is operational, "probably" in 2017 or 2018.³⁸¹ On 19 April 2012, the Armenian Cabinet decided to authorize the extension of the operation of Medzamor until 2020.³⁸²

In September 2007, the Minister of Energy called for a new reactor with an anticipated construction cost of US\$2 billion and a construction time of four-and-a-half years. In December 2009, the government approved setting up JV Metzamorenenergoatom, a 50-50 Russian-Armenian joint stock company set up by the Ministry of Energy and Natural Resources with Atomstroyexport, with shares offered to other investors.³⁸³ In August 2010, an intergovernmental agreement determined that the Russian party will build at least one VVER-1000 reactor, supply nuclear fuel for it, and decommission it. Construction should commence in 2012 and was expected to cost \$5 billion.³⁸⁴ However, in February 2012, the Prime Minister of Armenia announced that construction would not start until 2014.³⁸⁵

Kazakhstan had just one fast breeder reactor in operation at Aktau, the BN 350, which went on line in 1973 as the world's first commercial fast breeder reactor. Used to generate power (never more than 0.6 percent of national consumption) and heat, and for desalination, it was closed down in 1999. A wide range of proposals for new nuclear power exist, ranging from further FBRs, to larger light

The number of errors in this statement is stunning. It should probably say: "AREVA (1600MW EPR), Westinghouse (AP1000) and Mitsubishi (APWR)". ATMEA is a joint venture between AREVA and Mitsubishi. However, apparently, no other information has been published about this "shortlist".

³⁷⁹ DOE, Office on Energy Intelligence, "Most Dangerous Reactors: A Worldwide Compendium of Reactor Risk", Washington, DC, May 1995.

³⁸⁰ armenews.com, "Les employés de la central nucléaire arménienne reprennent le travail après une augmentation de salaire", 31 October 2011, see http://www.armenews.com/article.php3?id_article=74110*, accessed 5 June 2012.

³⁸¹ NEWS.am, "Armenian NPP to Operate Until 2016," 15 February 2011.

³⁸² French Embassy, "L'Arménie prolonge la durée d'exploitation de son réacteur nucléaire", armenews.com, 27 April 2012, see http://www.armenews.com/article.php3?id_article=78928, accessed 5 June 2012.

³⁸³ Nuclear.ru, "New Company Being Established to Build New Reactor in Armenia," 25 December 2009.

³⁸⁴ WNA, "Nuclear Power in Armenia," www.world-nuclear.org/info/inf113.html, November 2011.

³⁸⁵ Armenpress, "Construction of New Unit of Armenian Nuclear Power Plant to Start in 2014", 8 February 2012, <http://armenpress.am/eng/news/679085/construction-of-new-unit-of-armenian-nuclear-power-plant-to-start-in-2014.html>, accessed 5 June 2012.

water reactors, to as many as 20 smaller reactors deployed in towns across the country. The plans mainly involve Russian or Japanese technology. In September 2010, Japan Atomic Power Co, Toshiba and Marubeni signed a technical cooperation agreement with the National Nuclear Centre (NNC) to study the feasibility of building nuclear power capacity in the country.³⁸⁶ Sergey Yashin, deputy head of the national nuclear company Kazatomprom, reportedly stated in October 2011 that a nuclear power plant could “become a reality in the next 10 years”.³⁸⁷ First Deputy Prime Minister Serik Akhmetov stated in March 2012 that the country would target 4.5 percent share of nuclear power by 2030 and decisions should be taken “this year”.³⁸⁸ Interesting to note that Kazakhstan owns 10 percent of reactor builder Westinghouse, majority owned by the Japanese group Toshiba.

In 2009, Kazakhstan became the largest producer of uranium in the world and by 2011, it had increased its share to 33 percent of total global production.³⁸⁹

Russia is home to 33 operating reactors with a total installed capacity of 23.6 GW. In 2011, this nuclear fleet generated a record 162 TWh, or 17.6 percent of the country’s electricity, practically identical to the historical maximum of 17.8 percent in 2009. Of the reactors in operation, 15 reflect early designs (four first-generation VVER 440-230s and 11 RBMKs), four are small (11 MW) BWRs used for cogeneration in Siberia, one is a fast breeder (BN-600), and 13 are second-generation light water reactors (two VVER 440-213s and 11 VVER 1000s). Three have been completed in the last 10 years: one in 2004 after nearly 20 years of construction, one in 2010 at Rostov after 27 years of construction and one in 2011 after twenty five years of construction.

Lifetime extension is an issue in Russia as elsewhere. The three Smolensk Chernobyl-type RBMK reactors—no other country operates RBMKs—shall undergo “large-scale modernization” programs in order to achieve a 15-year extension of their operational life. In addition, all RBMK reactors, with the exception of the oldest unit Leningrad-1 that started operating in 1973, shall undergo 5 percent power uprating.³⁹⁰

Ten reactors are listed as under construction. The most recent construction starts were in February 2012 as RosEnergoAtom announced that concrete was poured on the one VVER 1200 MW units at Kaliningrad³⁹¹ with construction on the second expected to start later this year. In February 2012, Rosatom were reported as saying that the Kursk-5 RBMK reactor, would no longer be completed.

In May 2010, Russia announced that over the period 2010–16, it would commission a total of 10 GW of new nuclear capacity, including starting up partially built reactors of older light water and fast breeder designs as well as building new units of the most recent design, the VVER 1150 MW.³⁹² As of early 2012, the country’s longer-term target for 2020 anticipated that an additional 16 GW of capacity will come on line between 2016 and 2020.³⁹³

Russia is also constructing reactors for export, with sales of the latest design of the VVER 1000, the AES 91 and AES 92, underway or proposed to a number of countries including China, and India.

³⁸⁶ Marubeni, “Memorandum of Understanding with National Nuclear Center of the Republic of Kazakhstan,” press release Tokyo: 29 September 2010

³⁸⁷ NEI, “Kazakhstan ‘may build a nuclear plant in the next 10 years’”, 17 October 2011, see <http://www.neimagazine.com/story.asp?storyCode=2060904>, accessed 5 June 2012.

³⁸⁸ WNN, “Kazakhstan reaffirms nuclear power commitment”, 15 March 2012, see http://www.world-nuclear-news.org/NP-Kazakhstan_reaffirms_nuclear_power_commitment-1503127.html, accessed 5 June 2012.

³⁸⁹ WNA, “Uranium and Nuclear Power in Kazakhstan”, May 2012, see <http://www.world-nuclear.org/info/inf89.html>, accessed 5 June 2012.

³⁹⁰ WNN, “New lease of life for Smolensk”, 9 February 2012, see http://www.world-nuclear-news.org/C-New_lease_of_life_for_Smolensk-0902127.html, accessed, 5 June 2012.

³⁹¹ WNN, “Construction starts at Baltic plant”, 27 February 2012, see http://www.world-nuclear-news.org/NN-Construction_starts_at_Baltic_plant-2702125.html

³⁹² NEI magazine “Russia Releases Near-term Nuclear Plans,” www.neimagazine.com, May 2010.

³⁹³ WNA, “Nuclear Power in Russia,” www.world-nuclear.org/info/inf45.html, February 2012

Other reactor designs also are being developed, including smaller 300 MW BWRs. In November 2010, Russian nuclear manufacturer Atomenergomash stunned analysts with its ambition to become “a global player in wind energy” by 2020.³⁹⁴

Russia has developed the whole nuclear fuel chain. According to the OECD’s Nuclear Energy Agency, the country is home to around 10 percent of the world’s reasonably assured uranium resources and also has inferred resources, with the largest mines close to the Chinese/Mongolian border.³⁹⁵ For many decades, Russia was involved in the supply of fresh fuel to Central and Eastern Europe, and the take-back of spent fuel, practices that have now largely ceased. Despite intending to expand its reprocessing efforts, Russia currently reprocesses only VVER 440 fuel, with the VVER 1000 and RBMK fuel stored. Construction of the RT-2 plant at Krasnoyarsk, proposed for reprocessing of VVER 1000 fuel, has been stopped.

In February 2012, Rosatom hit a real “coup” in announcing the appointment of the former Finnish chief Nuclear Safety regulator Jukka Laaksonen, just days after leaving office, as Vice-President of the Overseas Department. Vladimir Ponomarev, Deputy Director for Strategic Development and Planning of the Institute for Safe Development of the Nuclear Power Industry of the Russian Academy of Sciences said Laaksonen’s appointment was “timely and useful”.³⁹⁶

Ukraine has 15 reactors in operation, which provided 84.9 TWh or 47.2 percent of the country’s electricity in 2011 (down from a maximum of 51.1 percent in 2004). The Ukraine has one of lowest lifetime load factors in the world for their nuclear plants.

The accident at Chernobyl in 1986 not only did huge damage to the country’s economy, environment, and public health, but also stopped the domestic development of nuclear power. A subsequent accident at Chernobyl’s unit 2 in 1991 further exacerbated the situation. The two remaining units at Chernobyl have since been closed and the station is undergoing decommissioning. Recently, there have been reports that the Ukrainian government is seriously considering significantly reducing the dimension of the exclusion zone and preparing resettlement of the area.³⁹⁷

Since 1986, three reactors have been completed: Zaporozhe 6, Khmelnytsky 2, and Rovno 4. In December 2010, the operating license of Rovno-1, Ukraine’s oldest operating reactor at 30 years, was extended for another 20 years. After an accident at the turbine in January 2011, reactor power had to be reduced by 50 percent, even though the reactor had recently undergone major upgrading work. Ukrainian environmental organizations have severely criticized the 20-year lifetime extension.³⁹⁸

In 2006, the government approved a strategy that would lead to a doubling of nuclear installed capacity by 2030, requiring the replacement of 9 to 11 existing reactors and the addition of 11 new reactors. In February 2011, Russia and Ukraine signed an intergovernmental agreement to resume work on the third and fourth units at Khmelnytsky. Russia is to finance the design, construction, and commissioning of the two reactors, as well as any services and goods the country supplies.³⁹⁹ The project’s estimated cost has increased by a factor of 2.5 within half a year and stood at some

³⁹⁴ “Russian Nuclear Manufacturer Moves into Wind,” WNN, 12 November 2010.

³⁹⁵ NEA, Uranium 2009... op. cit.

³⁹⁶ ITAR-TASS, “Experts welcome Laaksonen’s appointment to Rusatom Overseas”, 9 February 2012.

³⁹⁷ WNN, “Most Chernobyl towns fit for habitation”, 25 April 2012, see http://www.world-nuclear-news.org/RS_Most_Chernobyl_towns_fit_for_habitation_2504121.html, accessed 5 June 2012.

³⁹⁸ National Ecological Center of Ukraine, “The Operation of the Old Reactor, Lifetime of Which Was Extended for 20 Years, Is Unstable,” press release, 18 January 2011.

³⁹⁹ WNN, “Contract Agreement for Khmelnytsky 3 and 4,” 10 February 2011.

UAH40 billion (US\$5 billion) in early 2011.⁴⁰⁰ The mid 2011 energy policy revision proposes 2,300 MWe of new capacity with decision on technology to be made only after 2015⁴⁰¹.

⁴⁰⁰ National Ecological Center of Ukraine, "Construction of Unit-3 and Unit-4 at Khmelnytska NPP Has Not Yet Started But the Cost Has Already Increased 2.5 Times," press release, 15 February 2011.

⁴⁰¹ WNA, "Nuclear Power in Ukraine", February 2012, <http://www.world-nuclear.org/info/inf46.html>

Annex 2: Reactor Construction Times 1992-2012

Construction Times <i>Startups between 1992 and 2012</i>				
Country	Units	Mean Time	Min	Max
Brazil	1	24,5	24,5	24,5
Canada	2	8,0	7,8	8,3
China	15	5,8	4,3	11,2
Czech Rep.	2	14,5	13,8	15,2
France	6	9,7	7,5	12,6
India	13	8,7	5,1	14,2
Iran	1	36,3	36,3	36,3
Japan	17	4,4	3,2	8,3
Korea, South	14	4,6	4,0	5,3
Mexico	1	17,4	17,4	17,4
Pakistan	2	6,0	5,3	6,8
Romania	2	19,0	14,0	24,1
Russia	5	20,0	9,0	26,8
Slovakia	2	15,5	14,8	16,2
UK	1	6,6	6,6	6,6
Ukraine	3	15,7	9,3	19,5
USA	2	20,8	18,5	23,2
Total	89	8,9	3,2	36,3

Sources: IAEA-PRIS, MSC, 2012

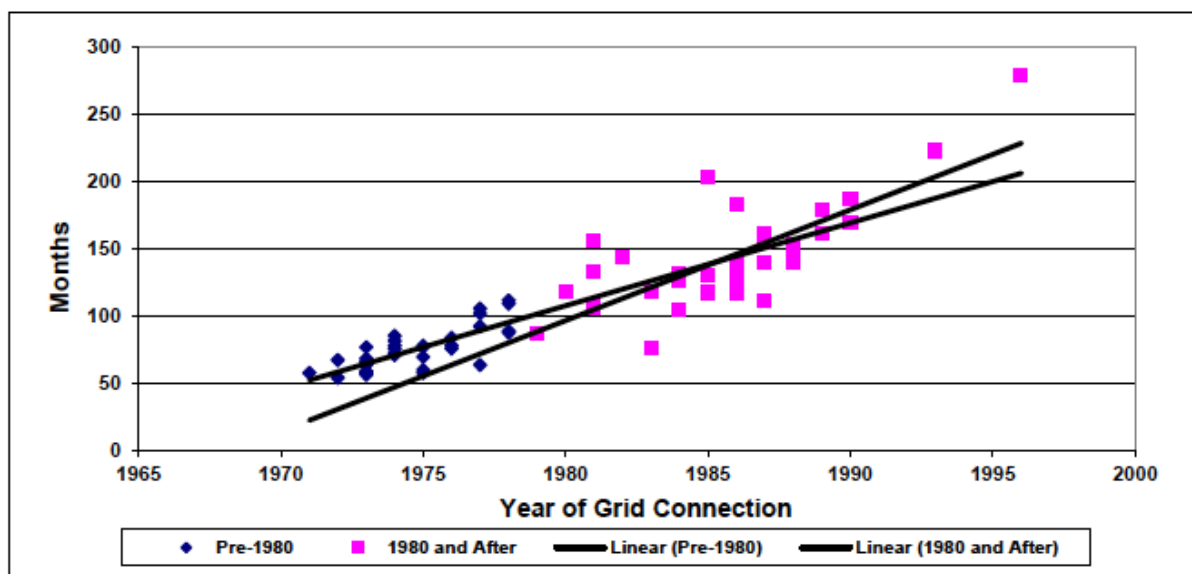
Annex 3: Construction and Operating License (COL) Applications in the U.S.
(as of May 2012)

Plant	Type	COL Application	Last Activity	NRC Decision
Bell Bend	EPR	October 10, 2008	07/22/09	?
Bellefonte, Units 3 & 4	AP1000	October 30, 2007	08/15/08	suspended
Callaway, Unit 2	EPR	July 24, 2008	12/12/08	suspended
Calvert Cliffs, Unit 3	EPR	July 13, 2007	05/13/11	?
Comanche Peak Units, 3 & 4	APWR	September 19, 2008	05/13/11	12/14
Fermi, Unit 3	ESBWR	September 2008	10/11	?
Grand Gulf, Unit 3	ESBWR	February 27, 2008	11/26/08	closed
Levy County, Units 1 & 2	AP1000	July 30, 2008	04/27/12	?
Nine Mile Point, Unit 3	EPR	September 30, 2008	12/12/08	suspended
North Anna, Unit 3	APWR	November 27, 2007	03/02/11	?
River Bend Station, Unit 3	ESBWR	September 25, 2008	12/04/08	suspended
Shearon Harris, Units 2 & 3	AP1000	February 18, 2008	11/18/08	?
South Texas Project, Units 3 & 4	ABWR	September 20, 2007	10/31/11	?
Turkey Point, Units 6 & 7	AP1000	June 30, 2009	12/10	?
Victoria County Station, Units 1 & 2	ESBWR	September 3, 2008	10/30/08	suspended
Virgil C. Summer, Units 2 & 3	AP1000	March 27, 2008	04/11	granted 3/12
Vogtle, Units 3 & 4	AP1000	March 28, 2008	04/01/11	granted 2/12
William States Lee III, Units 1 & 2	AP1000	December 12, 2007	09/11/08	?

Sources: USNRC, “Combined License Applications for New Reactors”, see <http://www.nrc.gov/reactors/new-reactors/col.html>, viewed 29 May 2012; USDOE, “Nuclear Power Deployment Scorecard”, updated April 2012, see <http://www.nuclear.energy.gov/np2010/neScorecard/neScorecard.html>, viewed 29 May 2012.

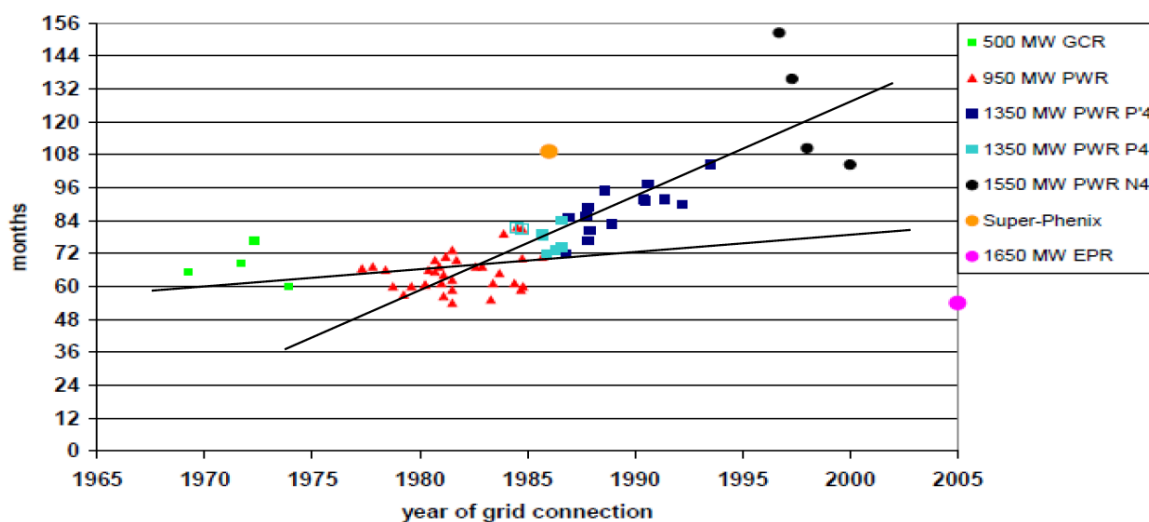
Annex 4: Construction Times in the U.S. and France

Figure 27a: Construction Times PWRs in the United States



Source : Cooper, 2012

Figure 27b: Construction Times Reactors in France



Source : Cooper, 2012

Annex 5: 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	P-2	A		A		
A3		A-		A-		
Baa1		BBB+	A-2	BBB+	F2	Lower medium grade
Baa2	P-3	BBB		BBB		
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 6: Abbreviations

ABWR – Advanced Boiling Water Reactor
AECL – Atomic Energy Canada Limited
AGR – Advanced Gas Reactor
APWR – Advanced Pressurized Water Reactor
ASN – French Nuclear Safety Authority
BOOT – Build-Own-Operate-Transfer
CANDU – Canadian Deuterium Uranium
CEA – French Atomic Energy Commission
CfD – Contracts for Difference
CGN - Chinese Guangdong Nuclear Power Company
CHP – Combined Heat and Power
COL – Construction and Operation Licence
CNSC – Canadian Nuclear Safety Commission
CSN - Consejo de Seguridad Nuclear – Spain Safety Authority
EIA – Environmental Impact Assessment
EPR – European Pressurized Water Reactor or Evolutionary Pressurized Water Reactor#
ERÚ - Czech Energy Regulatory Office
ESBWR – Economic Simplified Boiling Water Reactor
ESP – Early Site Permit
EVN – Electricity of Vietnam
EU – European Union
EWEA – European Wind Energy Association
FL3 – Flamanville-3
I&C – Instrument and Control
INIG - Integrated Nuclear Infrastructure Group
IAEA – International Atomic Energy Agency
IEEJ – Institute for Energy and Economics of Japan
IZES - Institut für Zukunfts Energie Systeme
JAEC – Jordon Atomic Energy Commission
KA-CARE - King Abdullah City for Atomic and Renewable Energy
KEPCO – Korea Electric Power Corporation
KHNP – Korea Hydro and Nuclear Power
K-POPONS - The Korean Professors’ Organization for a Post-Nuclear Energy Society
METI – Ministry of Economics, Trade and Industry
MoU – Memorandum of Understanding
NPS – National Policy Statement (UK)

NDA – Nuclear Decommissioning Authority
 NPCIL – Nuclear Power Corporation of India Ltd
 NPI – Nuclear Power International
 NPT – Non-Proliferation Treaty
 NNC – National Nuclear Centre –(Kazakhstan)
 NSG – Nuclear Suppliers Group
 NRC – Nuclear Regulatory Commission – US
 OL3 - Olkiluoto-3
 OPG – Ontario Power Generation
 PAEC – Pakistan Atomic Energy Commission
 PLEX – Plant Life Extension
 PBMR – Pebble Bed Modular Reactor
 PRIS – Power Reactor Information System
 PV – Photovoltaic
 PWR – Pressurized Water Reactor
 RBMK – Light water cooled, graphite moderated
 S&P – Standard and Poor's
 SE – Slovak Electric
 STP – South Texas Project
 TVO - Teollisuuden Voima Tyj
 TVA – Tennessee Valley Authority
 UAE – United Arab Emirates
 VEB - Vnesheconombank
 VVER – Light Water Reactor – Russian design
 WANO – World Association of Nuclear Operators
 WNN – World Nuclear News

Electrical Units

kW – kilowatt (unit of installed electric power)
 kWh – kilowatt hour (unit of electricity)
 MW – megawatt (10^6)
 GW – gigawatt (10^9)
 GWe – gigawatt electric
 TWh – terawatt hour (10^{12})

Annex 7. Status of Nuclear Power in the World (1 July 2012)

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	2	935	33	1	5%(=)	2%
Armenia	1	376	32		33%(-)	?%
Belgium	7	5 927	32		54%(+)	17%
Brazil	2	1 884	21	1	3%(=)	1%
Bulgaria	2	1 906	23		33%(-)	19%
Canada	18	12 604	28		15%(=)	6%
China	16	11 816	8	26	2%(=)	<1%
Czech Republic	6	3 766	21		33%(+)	15%
Finland	4	2 736	33	1	32%(+)	19%
France	58	63 130	27	1	78%(+)	41%
Germany	9	12 068	27		18%(-)	8%
Hungary	4	1 889	14		43%(=)	16%
India	20	4 388	18	7	4%(=)	1%
Iran	1	915	1		?% (+)	?%
Japan	44	38 120	25		18%(-)	8%
Mexico	2	1 300	20		4%(=)	1%
Netherlands	1	482	39		4%(=)	1%
Pakistan	3	725	18	2	4%(=)	1%
Romania	2	1 300	10		19%(=)	8%
Russia	33	23 643	29	10	18%(=)	6%
Slovakia	4	1 816	20	2	54%(+)	20%
Slovenia	1	668	31		42%(+)	?%
South Africa	2	1 830	27		5%(=)	2%
South Korea	21	18 657	17	3	35%(+)	13%
Spain	8	7 567	29		20%(=)	9%
Sweden	10	9 325	33		40%(+)	28%
Switzerland	5	3 263	37		41%(+)	21%
Taiwan	6	4 949	31	2	19%(=)	9%
Ukraine	15	13 107	24	2	47%(=)	16%
United Kingdom	16	9 246	29		18%(+)	8%
USA	104	101 465	33	1	19%(=)	8%
EU27	132	121 846		4	27%(=) ⁶	
World Total	429	363 908	28	59	11%(-) ³	5%

© MYCLE SCHNEIDER CONSULTING

Notes

¹ According to IAEA, PRIS database, www.iaea.org/programmes/a2/index.html, July 2012, unless noted otherwise.

² In 2011, based on IAEA, PRIS database, July 2012.

³ BP, "Statistical Review of World Energy", June 2012)

⁴ As of 1 July 2012.

⁵ A +/-/= in brackets refer to change in 2011 versus the level in 2010; a change of less than 1% is considered =.

⁶ Eurostat, "Electricity Statistics", 2011,

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

Annex 8. Nuclear Reactors in the World Listed as “Under Construction” (1 July 2012)

Country	Units	MWe (net)	Construction Start	Planned Grid Connection
Argentina	1	692	1981/07/14	2013 ¹
Brazil	1	1 245	2010/06/01	2016 ²
China ³	26	27 400		
...Changjiang-1		1000	2010/04/25	2014
...Changjiang-2		1000	2010/11/21	2015
...Fangchenggang-1		1000	2010/07/30	2015
...Fangchenggang-2		1000	2010/12/23 ⁴	2016
...Fangjiashan-1		1000	2008/12/26	2013/12
...Fangjiashan-2		1000	2009/07/17	2014/10
...Fuqing-1		1000	2008/11/21	2013/11
...Fuqing-2		1000	2009/06/17	2014/09
...Fuqing-3		1000	2010/12/31	2015/07
...Haiyang-1		1000	2009/09/24	2014/05
...Haiyang-2		1000	2010/06/21	2015/03
...Hongyanhe-1		1000	2007/08/18	2012/10
...Hongyanhe-2		1000	2008/03/28	2013
...Hongyanhe-3		1000	2009/03/07	2014
...Hongyanhe-4		1000	2009/08/15	2014
...Ningde-1		1000	2008/02/18	2012/12
...Ningde-2		1000	2008/11/12	2013
...Ningde-3		1000	2010/01/08	2014
...Ningde-4		1000	2010/09/29	2015
...Sanmen-1		1000	2009/04/19	2013/11
...Sanmen-2		1000	2009/12/17	2014/09
...Taishan-1		1700	2009/10/28	2013/10
...Taishan-2		1700	2010/04/15	2014/11
...Yangjiang-1		1000	2008/12/16	2013/08
...Yangjiang-2		1000	2009/06/04	2014
...Yangjiang-3		1000	2010/11/15	2015
Finland	1	1 600	2005/08/12	2014 ⁵
France	1	1 600	2007/12/03	2016 ⁶
India	7	4 824		
...Kakrapar-3		630	2010/11/22	2015/03/31
...Kakrapar-4		630	2010/11/22	2015/09/30
...Kudankulam-1		917	2002/03/31	? ⁸
...Kudankulam-2		917	2002/07/04	2012/07/31 ⁹
...PFBR		470	2004/10/23	2013 ¹⁰
...Rajasthan-7		630	2011/07/18	2016/03/31
...Rajasthan-8		630	2011/09/30 ⁷	2016/09/30
Pakistan	2	630		
...Chasnupp-3		315	2011/05/28	2016/09/01
...Chasnupp-4		315	2011/12/18	2017/07/01
Russia ¹¹	10	8 258		
...Baltiisk		1082	2012/02/22	2017/01/01
...BN-800		750	1985 ¹²	2014 ¹⁵
...Leningrad-2-1		1085	2008/10/25	2013/10 (commercial operation) ¹⁶
...Leningrad-2-2		1085	2010/04/15	2016 (commercial operation) ¹⁷
...Novovoronezh-2-1		1085	2008/06/24	2014 (commercial operation) ¹⁸
...Novovoronezh-2-2		1085	2008/07/12	2016 (commercial operation) ¹⁹
...Lomonosov-1		32	2007/04/15	2014 (commercial operation) ²⁰
...Lomonosov-2		32	2007/04/15	2014 (commercial operation) ²¹
...Rostov-3		1011	1983 ¹³	2014 (commercial operation) ²²
...Rostov-4		1011	1983 ¹⁴	2017/06 (commercial operation) ²³
Slovakia	2	782		
...Mochovce-3		391	1985/01/01 ²⁴	2013/12 ²⁶
...Mochovce-4		391	1985/01/01 ²⁵	2014/06 ²⁷
South Korea	3	3 640		
...Shin-Kori-3		1340	2008/10/31	2013/09 (commercial operation) ²⁸

...Shin-Kori-4		1340	2009/09/15	2014/09 (commercial operation) ²⁹
...Shin-Wolsong-2		960	2008/09/23	2013/01 (commercial operation) ³⁰
Taiwan	2	2 600		
...Lungmen-1		1300	1999/03/31	2014-15 (commercial operation) ³¹
...Lungmen-2		1300	1999/08/30	2015 (commercial operation) ³²
Ukraine	2	1 900		
...Khmelnitski-3		950	1986/03/01	2015/01/01 ³³
...Khmelnitski-4		950	1987/02/01	2016/01/01 ³⁴
USA	1	1 165	1972/12/01	2015/09-12 ³⁵
Total	59	56,336	1972-2012	2012-2018

© MYCLE SCHNEIDER CONSULTING

Sources: IAEA-PRIS, July 2012, unless otherwise noted.

Notes

¹ Delayed multiple times. This date from Nucleoeléctrica Argentina S.A., “La Central Atucha II Entrará En Operación a Medios De 2013”, 3 June 2012, <http://www.na-sa.com.ar/news/detail/199>, accessed June 6, 2012.

² Delayed multiple times. IAEA startup date for 2018 withdrawn, not replaced. This estimate from <http://world-nuclear.org/info/inf95.html>, accessed 4 May 2012.

³ No IAEA startup date for any Chinese reactor. The estimate for all reactors are drawn or derived from www.world-nuclear.org/info/inf63.html, accessed 3 May 2012.

⁴ This date was introduced by IAEA-PRIS at a much later date. The WNA gives 2011 as construction start, see <http://www.world-nuclear.org/info/inf63.html>, accessed on 3 May 2012.

⁵ After numerous revisions of the original planned commissioning in 2009, the date refers to “commercial operation”, according to TVO (see <http://www.tvo.fi/www/page/2305/>, accessed 4 May 2012).

⁶ Delay of at least four years from original planning. EDF maintains this target date for first “commercialization of electricity” in spite of persisting major building issues (concreting, maintenance bridge...), see EDF, “Remplacement des consoles du pont de manutention du bâtiment réacteur”, Note d’information, 16 mars 2012.

⁷ Announced only in February 2012.

⁸ Delayed numerous times. No IAEA or WNA startup date. The latest IAEA date (2011/02/28) was simply dropped without being replaced. Construction at least 5 years behind schedule.

⁹ Delayed numerous times. Current IAEA date replaced last year’s date (2011/08/31). Construction at least 5 years behind schedule.

¹⁰ Delayed numerous times. No IAEA start-up date. This estimate for commercial operation from www.world-nuclear.org/info/inf53.html, delayed from 2012 a year ago. According to update from 1 May 2012, reactor was 86 percent complete, (M.V. Ramana, personal communication, 14 June 2012).

¹¹ Note on the Kursk-5 project: We decided to pull it from the list. No IAEA startup date is given and it was deleted from the WNA construction list. WNA states on its website: “In February 2012 Rosatom confirmed that the project was terminated.” Kursk-5 is based on an upgraded RBMK design.

¹² The IAEA Power Reactor Information System (PRIS) database curiously provides a construction start date as 2006/07/18. Until 2003, the French Atomic Energy Commission (CEA) listed the BN-800 as “under construction” with a construction startup date of “1985.” In subsequent editions of the CEA’s annual publication ELECNUC, Nuclear Power Plants in the World, the BN-800 had disappeared.

¹³ Originally construction started in 1983 and it resumed after interruptions in September 2009, from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

¹⁴ Originally construction started in 1983 and, after interruptions, “first new concrete” was poured in June 2010, from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

¹⁵ Delayed numerous times; no IAEA startup date. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

¹⁶ No IAEA startup date. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

¹⁷ No IAEA startup date. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

¹⁸ No IAEA startup date. Delayed from 2012/12/31. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

¹⁹ No IAEA startup date. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

²⁰ No IAEA startup date. Commercial operation originally planned for 2010 at Severod. Since moved to Lomonosov and delayed by two years. Then delayed by another two years to 2014. Estimate according to <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

²¹ No IAEA startup date. Commercial operation originally planned for 2010 at Severod. Since moved to Lomonosov and delayed by two years. Then delayed by another two years to 2014. Estimate according to <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

²² No IAEA startup date. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

²³ Delayed from 2016. No IAEA startup date. This estimate from <http://www.world-nuclear.org/info/inf45.html>, accessed 4 May 2012.

²⁴ On 11 June 2009 construction officially resumed.

²⁵ On 11 June 2009 construction officially resumed.

²⁶ Delayed numerous times. This date from <http://www.world-nuclear.org/info/inf91.html>, accessed 5 June 2012.

²⁷ Delayed numerous times. This date from <http://www.world-nuclear.org/info/inf91.html>, accessed 5 June 2012.

-
- ²⁸ No IAEA startup date. Delayed. This date from www.world-nuclear.org/info/inf81.html, accessed 4 May 2012.
- ²⁹ No IAEA startup date. Delayed. This date from www.world-nuclear.org/info/inf81.html, accessed 4 May 2012.
- ³⁰ No IAEA startup date. Delayed. Startup date of 2012/05/28 withdrawn from IAEA-PRIS. This date from www.world-nuclear.org/info/inf81.html, accessed 4 May 2012.
- ³¹ No IAEA startup date. Delayed many times from original start-up date of mid-2006. This date according to media reports, including <http://mobile.globalpost.com/dispatch/news/regions/asia-pacific/120305/taiwan-nuclear-power-plant-longmen-lungmen>, accessed 5 May 2012.
- ³² No IAEA startup date. Delayed many times from original start-up date of mid-2006. This date according to media reports, including <http://mobile.globalpost.com/dispatch/news/regions/asia-pacific/120305/taiwan-nuclear-power-plant-longmen-lungmen>, accessed 5 May 2012.
- ³³ Delayed numerous times.
- ³⁴ Delayed numerous times.
- ³⁵ The IAEA still carries the planned startup date as 2012/08/01. However, in April 2012, TVA has considerably delayed the planned completion date to “between September and December 2015”; see http://www.tva.com/news/releases/aprjun12/watts_bar.html, accessed 4 May 2012.