The World Nuclear Industry Status Report 2009
With Particular Emphasis on Economic Issues

By

Mycle Schneider
Independent Consultant, Mycle Schneider Consulting, Paris (France)
Project Coordinator

Steve Thomas
Professor for Energy Policy, Greenwich University (UK)

Antony Froggatt
Independent Consultant, London (UK)

Doug Koplow
Director of Earth Track, Cambridge (USA)

Modeling and Additional Graphic Design
Julie Hazemann
Director of EnerWebWatch, Paris (France)

Paris, August 2009

Commissioned by
German Federal Ministry of Environment, Nature Conservation and Reactor Safety
(Contract n° UM0901290)

About the Authors

Mycle Schneider is an independent international consultant on energy and nuclear policy based in Paris. He founded the Energy Information Agency WISE-Paris in 1983 and directed it until 2003. Since 1997 he has provided information and consulting services to the Belgian Energy Minister, the French and German Environment Ministries, 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. Since 2004 he has been in charge of the Environment and Energy Strategies lecture series for the International MSc in Project Management for Environmental and Energy Engineering Program at the French Ecole des Mines in Nantes. 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 Antony 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.
Mr. Froggatt works intensively with environmental groups across Europe, particularly on energy markets and policy and helped to establish a network on energy efficiency. He is a regular speaker at conferences, universities and training programs across the region.
Prior to working freelance Antony worked for nine years as a nuclear campaigner and co-coordinator for Greenpeace International.

Steve Thomas is Professor for energy policy at the Public Services International Research Unit (PSIRU), University of Greenwich, where he has been senior researcher since 2001.
Mr. Thomas holds a BSc (honors) degree in Chemistry from Bristol University and has been working in energy policy analysis since 1976. His main research interests are reforms of energy industries, economics and policy towards nuclear power, and corporate policies of energy industry companies. Recent clients include Public Services International, the European Federation of Public Service Unions, the Nonproliferation Policy Education Center (USA), Energywatch (UK) and Greenpeace International.

Doug Koplow founded Earth Track in 1999 to more effectively integrate information on energy subsidies. For the past 20 years, Mr. Koplow has written extensively on natural resource subsidies for organizations such as the Global Subsidies Initiative, the National Commission on Energy Policy, the Organisation for Economic Cooperation and Development, the United Nations Environment Programme (UNEP), Greenpeace, the Alliance to Save Energy, and the US Environmental Protection Agency. He has analyzed numerous government programs and made important developments in subsidy valuation techniques.
Mr. Koplow holds an MBA from the Harvard Graduate School of Business Administration and a BA in economics from Wesleyan University.

Contacts

Mycle Schneider	Antony Froggatt	Steve Thomas	Doug Koplow
Phone: +33-1-69 83 23 79	Ph: +44-20-79 23 04 12	Ph: +44-208 331 9056	Ph: +1-617-661 4700
Email: mycle@orange.fr	E: a.froggatt@btinternet.com	E: stephen.thomas@greenwich.ac.uk	E: dkoplow@earthtrack.net

Contents

Note

The authors wish to thank Amory B. Lovins, *Chairman of the Rocky Mountain Institute, USA, for his extremely useful comments on a draft version of the report. Thanks also to Mary B. Davis for her careful proofreading. However, the responsibility for any remaining errors remains with the authors.*
The project coordinator wishes to express his sincere gratitude to his co-authors for their invaluable contributions and creative thinking.

The report represents the perspective and opinion of the contractor and does not necessarily reflect the opinion of the orderer (German Federal Ministry for Environment, Nature Conservation and Reactor Safety).

Executive Summary and Conclusions

The future of the nuclear energy industry is subject to a large number of media reports, study projects, expert meetings and political debates. Much of the published data is based on speculation rather than on an in-depth analysis of nuclear energy's industrial history, current operating status and trends.

The *World Nuclear Industry Status Report 2009* provides the reader with the basic quantitative and qualitative facts on the nuclear power plants in operation, under construction and in planning phases throughout the world. A detailed overview assesses the economic performance of past and current nuclear projects.

As of 1st August 2009 there are 435 nuclear reactors operating in the world, nine less than in 2002. There are 52 units listed by the International Atomic Energy Agency (IAEA) as "under construction". At the peak of the nuclear industry's growth phase in 1979 there were 233 reactors being built concurrently. Even at the end of 1987, there were still 120 reactors in process. Much has changed. For the first time since commercial use of nuclear energy began in the middle of the 1950s no new nuclear plant was connected to the grid in 2008. In fact, no start-up has been reported for the past two years, since Cernavoda-2 was connected to the grid on 7 August 2007, after 24 years of construction.

In 1989 a total of 177 nuclear reactors had been operated in what are now the 27 EU Member States, but as of 1st August 2009 only 144 units were in operation. Today the worldwide operating reactors total 370,000 megawatts (370 GW), about 1,600 MW[1] less than one year ago.

In 2007 nuclear power plants generated about 2,600 TWh[2] and provided 14% of the world's electricity. After an unprecedented drop in electricity generation of 2% in 2007, nuclear power plants' output lost another half percentage point in 2008. Nuclear power provided 5.5% of the commercial primary energy production and about 2% of the final energy in the world, and has trended downwards for several years.

Twenty-seven of the 31 countries operating nuclear power plants maintained (23) or decreased (4) their share of nuclear power within the electricity mix in 2008 relative to 2007. Four countries (Czech Republic, Lithuania, Romania, Slovakia) increased their share.

The average age of the operating nuclear power plants in the world is 25 years. Some nuclear utilities envisage reactor lifetimes of 40 years or more. Considering the fact that the average age of all 123 units that have already been closed is about 22 years, the doubling of the operational lifetime seems rather optimistic. However, we have assumed an average lifetime of 40 years for all operating and in-construction reactors in our calculations of how many plants would be shut down year by year. The exercise makes possible an evaluation of the minimum number of plants that would have to come on-line over the next decades in order to maintain the same number of operating plants.

In addition to the 52 units currently under construction[3], 42 reactors (16,000 MW)[4] would have to be planned, built and started up by 2015 – one every month and a half – and an additional 192 units (170,000 MW) over the following 10-year period – one every 19 days.

---

[1] The equivalent of an EPR (European Pressurized Water Reactor), as under construction in Finland and France.

[2] Terawatthours or billion kWh.

[3] In contrast to earlier scenarios, we have considered that *all* units currently listed by the IAEA as "under construction" will be connected to the grid by 2016.

In a new "PLEX[5] Scenario" we have modeled the situation taking into account not only the start-up of all units currently under construction, but also the license renewal as of August 2009 of 54 US and some other nuclear reactors[6]. Even with license renewals, the number of units in operation would never again reach the historical peak of 444 in 2002. By 2015, the number of operating units in the world would be 10 short of the current level, though the installed capacity would increase by 9,600 MW. In the following decade an additional 174 reactors or about 152,000 MW would still have to be replaced to break even with the current nuclear fleet in the world.

Even if Finland and France each builds a reactor or two, China goes for an additional 20 plants and Japan, Korea or Eastern Europe add a few units, the overall worldwide trend will most likely be downwards over the next two decades. With extremely long lead times of 10 years and more, it will be practically impossible to maintain, let alone increase the number of operating nuclear power plants over the next 20 years. The one exception to this outcome would be if operating lifetimes could be substantially increased beyond 40 years *on average*; there is currently no basis for such an assumption.

For practically all of the potential nuclear newcomers, it remains unlikely that fission power programs can be implemented any time soon within the required technical, political, economic framework. None of the potential new nuclear countries has proper nuclear regulations, an independent regulator, domestic maintenance capacity, and the skilled workforce in place to run a nuclear plant. It might take at least 15 years to build up the necessary regulatory framework in countries that are starting from scratch.

Furthermore, few countries have sufficient grid capacity to absorb the output of a large nuclear plant, an often-overlooked constraint. This means that the economic challenge to financing a nuclear plant would be exacerbated by the very large ancillary investments required in the distribution network.

Countries with a grid size and quality that could apparently cope with a large nuclear plant in the short and medium term encounter an array of other significant barriers. These include a hostile or passive government (Australia, Norway, Malaysia, Thailand); generally hostile public opinion (Italy, Turkey); international non-proliferation concerns (Egypt, Israel); major economic concerns (Poland); a hostile environment due to earthquake and volcanic risks (Indonesia); and a lack of all necessary infrastructure (Venezuela). Many countries face several of these barriers at the same time.

Lack of a trained workforce and massive loss of competence are probably the most difficult challenges for proponents of nuclear expansion to overcome. Even France, the country with perhaps the strongest base of civilian nuclear competence, is threatened by a severe shortage of skilled workers. Demographics are a big cause: a large number of "baby-boomers" are approaching retirement — about 40% of the nuclear staff of the world's largest nuclear utility EDF by 2015. Currently, a maximum of 300 nuclear graduates are available for some 1,200 to 1,500 open positions. An additional difficulty stems from the fact that the number of nuclear graduates does not correspond at all to the availability of new recruits for the nuclear industry. In the USA for example only about one quarter of the 2008 nuclear graduates planned to actually work in the industry or a

[4] Units currently under construction range from 32 MW to 1600 MW, with an average of 880 MW, roughly the same as the average capacity of operating units with 855 MW. While it seems impossible to maintain the operating *number* of nuclear reactors under these conditions until 2015, an additional sixteen 1,000 MW units would be sufficient to maintain the installed nominal *capacity*. All of these units would have to start construction over the coming year and all be completed in optimal construction times. This seems unlikely considering the past experience but not impossible.

[5] Plant Life Extension

[6] Plus authorized lifetime extensions in the Netherlands, Spain and the UK.

nuclear utility. Many prefer either to continue their studies or to join the military or other government and business sectors.

The situation is similar or worse in most of the other nuclear countries.

At least in the short term, severe manufacturing bottlenecks (only one facility in the world, Japan Steel Works, can cast large forgings for certain reactor pressure vessels) further hamper any practical nuclear revival.

This report covers, in addition to the subjects in earlier editions, an economic analysis of past, present and likely future nuclear projects. While many industries experience declining costs as they move out their technological learning curve, the nuclear industry continues to face steadily increasing costs on existing construction and future cost estimates. The May 2009 nuclear investment cost estimate update by the Massachusetts Institute of Technology (MIT) simply doubled an earlier estimate from $2,000 to $4,000 overnight cost (excluding financing) per installed kilowatt.

In fact reality has already bypassed projections. The flagship EPR project at Olkiluoto in Finland, managed by the largest nuclear builder in the world, AREVA NP, has turned into a financial fiasco. The project is more than three years behind schedule and at least 55% over budget, reaching a total cost estimate of €5 billion ($7 billion) or close to €3,100 ($4,400) per kilowatt.

There are numerous ways by which governments have organized or tolerated subsidies to nuclear power. They range from direct or guaranteed government loans to publicly funded research and development (R&D). Direct ownership of subsidized nuclear fuel chain facilities, government funded nuclear decommissioning and waste management, generous limited liability for accidents and the transfer of capital costs to ratepayers via stranded cost rules or special rate-basing allowances are all common in many countries.

The current international economic crisis is exacerbating many of the problems that the proponents of the nuclear energy option are facing. At this point, there is as yet no obvious sign that the international nuclear industry could eventually turn the empirically evident decline into a promising future.

I. Introduction

The future of the global nuclear industry is subject to extensive media speculation, industrial announcements and political debate. However, there seems to be a widening gap between the industrial reality with its current trends and the widespread perception of some sort of "nuclear renaissance". In September 2008, the International Atomic Energy Agency (IAEA) issued a press release that perfectly illustrates the point: "The IAEA has revised upwards its nuclear power generation projections to 2030, while at the same time it reported that nuclear's share of global electricity generation dropped another percentage point in 2007 to 14%." While the IAEA figure for 2008 is not available yet, it is obvious that the relative significance of nuclear power in the global energy balance has continued to decline.

Are these just short-term tendencies rather than structural developments? What are the projections for the role of nuclear power in world energy and how realistic are they? New units are being built, but will they be delivered in time and on budget? Will there be enough of them to replace the aging reactor fleet? These are questions that the *World Nuclear Industry Status Report* has analyzed in previous years[7] and analyzes in the present version.

In addition, the German Federal Ministry of Environment, Nature Conservation and Reactor Safety (BMU) has requested that the 2009 analysis include as well a special focus on economic issues. With roots of the current international economic crisis linked to inadequate transparency and poor incentive structures in credit markets, it is imperative to properly understand the competitiveness of a technology such as nuclear that requires high capital input and generates equally high financial risksII. General Overview Worldwide

A nuclear power renaissance? Maybe not.

Fortune Magazine, 22 April 2009[8]

In June 2008 the IAEA announced that world nuclear electricity generation had plunged by 2% in 2007 – more than in any other year since the first fission reactor was connected to the Soviet grid in 1954. The EU region saw an even sharper decline of 6%. The drop by about 60 TWh corresponds to the average annual generation of ten reactors; or to more than what two thirds of the countries that operate atomic plants generate individually. The major influencing factors included: the seven units at Kashiwasaki in Japan that have remained shut down ever since a severe earthquake shook the region in July 2007; up to six German reactors that were off grid simultaneously for major repairs; and numerous French reactors that had to undergo inspections and maintenance after a generic problem was identified in the steam generators. The latter issue is expected to cost the French nuclear fleet another 2-3% on its average load factor in 2008 and 2009. Global nuclear generation did not recover in 2008 and lost another half percentage point over the 2007 level.

Though the "big six" nuclear generators, the USA, France, Japan, Germany, Russia and South-Korea, still generated about two thirds of the world's nuclear electricity in 2007 and 2008, the figure was down from three fourths in previous years.

II.1. Overview of Operation, Power Generation, Age Distribution

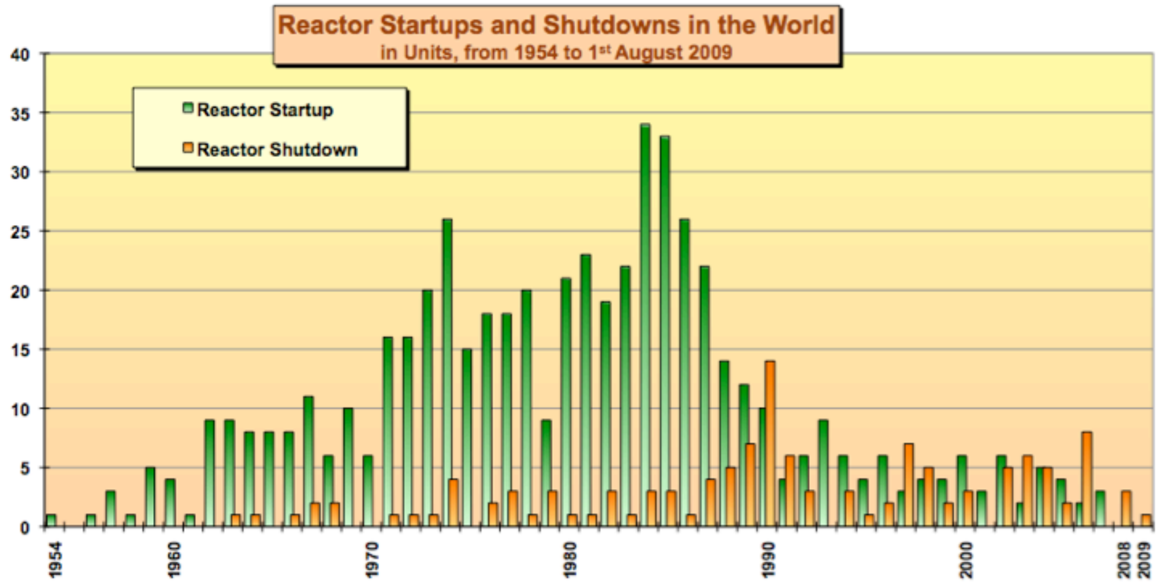
There have been two major waves of grid connections since the beginning of the commercial nuclear age in the middle of the 1950s (see Graph 1). A first wave peaked in 1974 with 26 reactor

---

7 Mycle Schneider, "The World Nuclear Industry Status Report 2008", The Bulletin of the Atomic Scientists, November-December 2008, http://www.thebulletin.org/web-edition/reports/2008-world-nuclear-industry-status-report.
Mycle Schneider with Antony Froggatt, "The World Nuclear Industry Status Report 2007", commissioned by the Greens-EFA in the European Parliament, Brussels-Paris-London, January 2008; French Version February 2008; Italian, Spanish Versions April 2008, http://www.greens-efa.org/cms/topics/rubrik/6/6659.energy@en.htm .
Earlier versions were released in 2004 by the Greens-EFA Group in the European Parliament and in 1992 jointly by World Watch Institute, Washington, Greenpeace International and WISE-Paris.
8 See http://money.cnn.com/2009/04/22/technology/nuclear.fortune/index.htm .

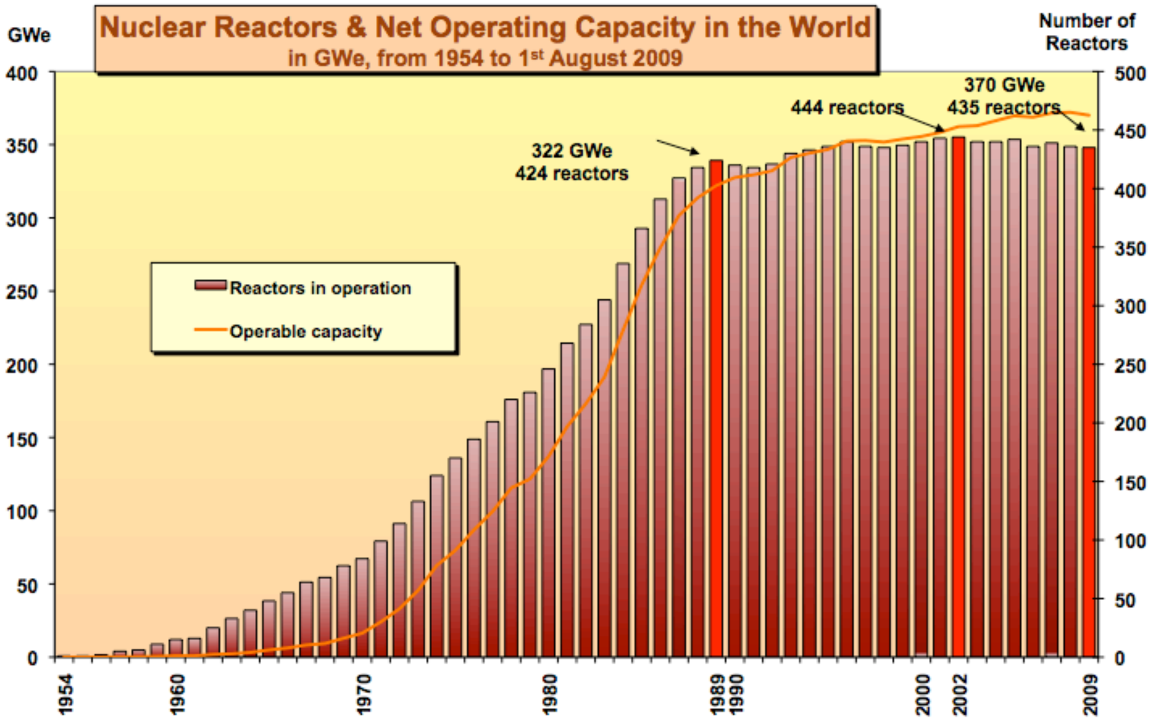
startups. The second one reached the historical record in 1984 and 1985, the years preceding the Chernobyl accident in 1986, with 33 grid connections each year. By the end of the 1980s the uninterrupted net increase of operating units had ceased, and in 1990 for the first time the number of reactor shutdowns outweighed the number of startups.

Graph 1: Nuclear Power Reactor Grid Connections and Shutdowns



© Mycle Schneider Consulting Source: IAEA-PRIS[9], MSC, 2009

Graph 2: The World Nuclear Reactor Fleet



© Mycle Schneider Consulting Source: IAEA-PRIS, MSC, 2009

9 The IAEA Database PRIS (Power Reactor Information System): http://www.iaea.org/programmes/a2/index.html.

As of 1st August 2009, a total of 435 nuclear reactors were operating (nine fewer than 2002) in 31 countries, with a total capacity of 370 gigawatts (thousand megawatts) (see Graph 3 and Annex 1 for details). 2008 was the first year in the history of commercial nuclear power that no new nuclear plant came online.[10] The historical peak of 294 operating reactors in Western Europe and North America was reached as early as 1989. In fact, the decline of the 'established' nuclear industry, unnoticed by the public, started many years ago.

The IAEA is required to publish data that is provided by member states, and this can sometimes generate data anomalies. A few years back, the Agency created a new reactor category of "long term shutdown" to add to its existing characterizations of "in operation" and "under construction". However, a reactor that is listed in the category as operating does not necessarily generate electricity and long term shutdown can be very long. This results in a number of serious statistical problems that can be illustrated for the year 2008:

- Five units are officially in "long term shutdown" mode, including four in Canada and one in Japan. The Canadian units have not generated power since 1995 (Bruce-1) and 1997 (Bruce-2, Pickering-2 and -3) respectively. Likewise the Japanese Monju fast breeder reactor has been shut down ever since sodium leak and fire in 1995.
- At least 17 units that were listed by the IAEA as "in operation" did not generate any power in 2008. Of these, ten are in Japan, four in India, two in Germany and one in the UK. Thirteen reactors have been out of service for over one year, one for over two years, two for over four years and one has not generated any power since 2001 (see Table 1). In fact, Chubu Electric, operator of two reactors at Hamaoka in Japan, on 22 December 2008, officially announced its decision to terminate operations "since it would not be economical to restart them".[11]

The installed capacity increased slightly in previous years. This has primarily occurred through technical alterations at existing plants, a process known as "uprating". According to the World Nuclear Association (WNA), in the USA the Nuclear Regulatory Commission (NRC) has approved 124 uprates since 1977, a few of them "extended uprates" of up to 20%. As a result an additional 5.6 gigawatts were added to the nuclear capacity in the USA alone.[12]

Table 1: Reactors "in operation" that did *not* generate any power in 2008

Country	Station Name	Production
Germany	Brunsbüttel (KKB)	no production in 2008
	Krümmel (KKK)	no production in 2008
	2	
India	Narora-2	no production in 2008
	Rajasthan-1	no production after 2004
	Rajasthan-2	no production in 2008
	Rajasthan-3	no production in 2008
	4	
Japan	Hamaoka-1	no production after 2001
	Hamaoka-2	no production after 2004
	Kashiwazaki Kariwa-1	no production after earthquake in July 2007
	Kashiwazaki Kariwa -2	no production after earthquake in July 2007
	Kashiwazaki Kariwa -3	no production after earthquake in July 2007
	Kashiwazaki Kariwa -4	no production after earthquake in July 2007
	Kashiwazaki Kariwa -5	no production after earthquake in July 2007
	Kashiwazaki Kariwa -6	no production after earthquake in July 2007
	Kashiwazaki Kariwa -7	no production after earthquake in July 2007
	Shika-1	no production in 2008
	10	
UK	Oldbury-A	no production after 2006
	1	
Total	**17**	

 Source: Nucleonics Week, 12 Feb 2009, IAEA-PRIS 2009

[10] With the exception of the year 1955, when no unit started up, after in 1954 the first small reactor (5 MW) had been connected to the grid in the USSR. Until 2005 the IAEA started its data series with the year 1956.

[11] Chubu Electric, Press Release, 22 December 2008. However, the IAEA statistics take into account the decision only as of the end of January 2009.

[12] WNA, "Plans for new reactors worldwide", March 2009, http://www.world-nuclear.org/info/inf17.html.

A similar trend of uprates and lifetime extensions of existing reactors can be seen in Europe. A number of countries including Belgium, Germany and Switzerland have applied extensive uprating. France plans a major uprating program between 2008 and 2015 that should add between 3% (at five 900 MW units) and 7% (at the twenty 1300 MW units) capacity. Similar programs are underway in Finland, Spain and Sweden. The nominal capacity of Oskarshamn-3 in Sweden, for example, will be boosted by 21% to 1450 MWe.

The capacity of the global fleet increased annually between the years 2000 and 2004 by about three gigawatts, much of it through uprating. Capacity increases dropped to two gigawatts per year in net additions between 2004 and 2007; and uprates were offset by plant closures in 2008, resulting in a net world nuclear capacity decline of about 1.6 gigawatts[13] in 2008.

These figures should be compared to the global power market place. The total electricity generating capacity under construction in 2007 has been estimated at over 600 gigawatts.[14] Of this, the vast majority was from coal, hydro and natural gas plants; the nuclear share was roughly 4.4%.

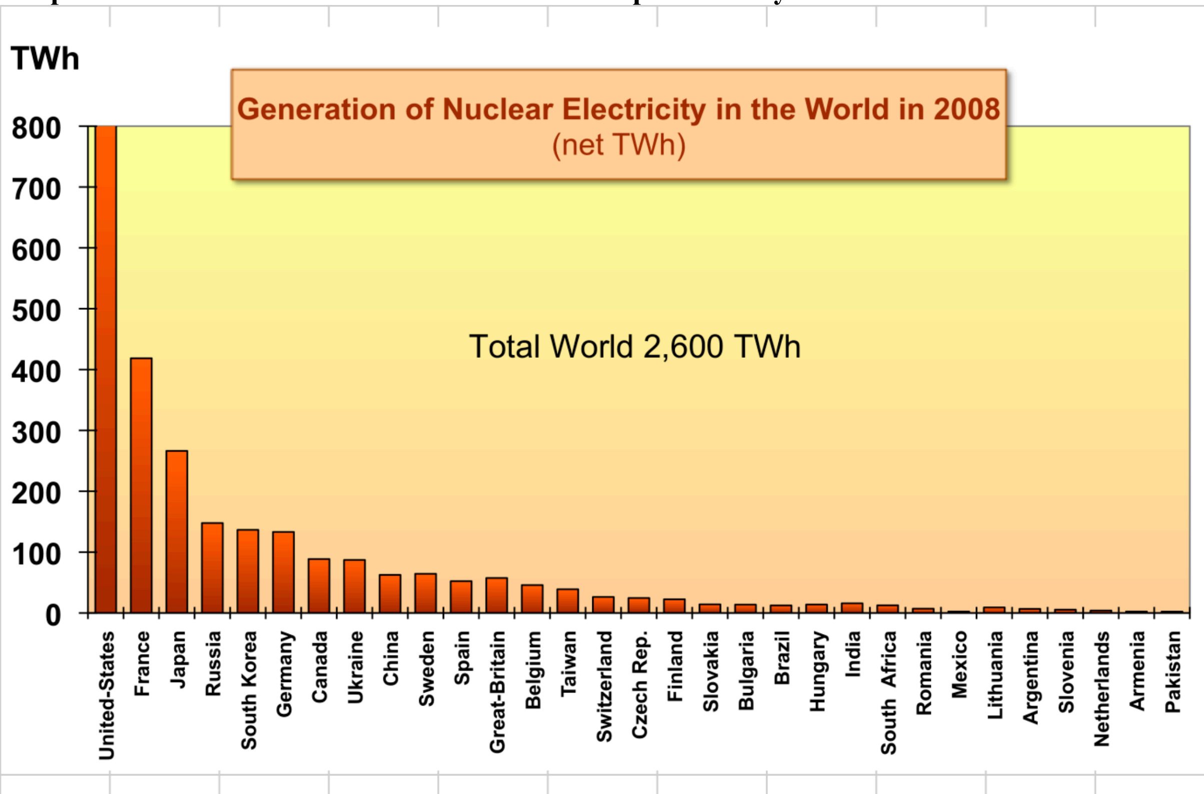
The use of nuclear energy has been limited to a small number of countries in the world. Only 31 countries, or 16% of the 192 United Nations Member States, operate nuclear power plants (see Graph 3). Half of the world's nuclear countries are located in the EU and account for almost half of the world's nuclear production.

There was no growth in the nuclear electricity generation in 2008, at 2,600 TWh[15], corresponding in 2007 to about 14% of the world's commercial electricity. This represents a decline from 15% in 2006 and 16% in 2005. 2008 generation comprised 5.5% of total commercial primary energy and only about 2% of final energy[16]. Only four countries (Czech Republic, Lithuania, Romania, Slovakia), operating together 13 units, increased their nuclear share in the power mix in 2008 over the previous year. Twenty-three countries remained stable (less than one percent change) and in four countries the role of nuclear power declined (Armenia, Japan, Sweden, UK). For details by country, see Annex 1.

The increasing operational problems nuclear operators have encountered over the last two years, in particular in France, Germany and Japan, do not seem to have dampened the widespread official enthusiasm in favor of nuclear power. As the statement of the last G8 meeting in Hokkaido in July 2008 points out: "In the last few years we have witnessed that a growing number of countries worldwide have expressed their interest in nuclear energy as a means for addressing climate change and energy security concerns. It is acknowledged that while the appropriate energy mix depends upon each country's situation and policy, there is clearly a rising interest in nuclear energy." The IAEA has reported that over 50 countries have demonstrated interest in nuclear energy.

[13] The equivalent of an EPR reactor (see hereunder).
[14] Platts, "World Electric Power Plants Database", January 2008, quoted in OECD-IEA, "World Energy Outlook 2008", August 2008, p. 144.
[15] Terawatt hours = billion kilowatt hours. Output dropped another 0.4% net (0.7% gross) in 2008. Sources: IAEA, "Nuclear Power Reactors in the World", July 2009; BP, "Statistical Review of World Energy", June 2009
[16] Final energy is the amount of remaining energy that arrives at the consumer after transformation and distribution losses.

Graph 3: Nuclear Power Generation in the World per Country



© Mycle Schneider Consulting *Source: IAEA, PRIS, 2009*[17]

II.2. International Nuclear Expansion Scenarios

We were here to discuss the promised 'Nuclear Renaissance' -
within the US, this Renaissance has yet to come about…
Robert Rosner
Director, Argonne National Laboratory
April 2009

The international nuclear community remains generally confident in a positive future. "Increasing energy demand, concerns over climate change and dependence on overseas supplies of fossil fuels are coinciding to make the case for nuclear build stronger. Rising gas prices and greenhouse constraints on coal have combined to put nuclear power back on the agenda for projected new capacity in both Europe and North America," says the WNA.[18]

The nuclear industry is not alone to proclaim its "renaissance". Over the last years, several international assessments of the possible future of nuclear power in the world have been adjusted to more optimistic prospects for 2030.

The **OECD International Energy Agency**'s World Energy Outlook (WEO) provides an annual analysis of world energy markets and trends. Recent WEO reports have had very optimistic assumptions on nuclear energy in all presented scenarios. The 2007 WEO version[19] presented a "reference scenario", an "alternative policy scenario" and a "450 stabilisation case" that include respectively 415 GW[20], 525 GW and 833 GW of nuclear power. Electricity generation from nuclear plants under the high scenario would more than double from current levels to reach 6,560 TWh in 2030.

[17] Source for Taiwan:
http://www.etaiwannews.com/etn/news_content.php?id=908024&lang=eng_news&cate_img=35.jpg&cate_rss=news_Business
[18] http://www.world-nuclear.org/info/inf104.html.
[19] OECD-IEA, "World Energy Outlook 2007", 7 November 2007.
[20] GW=gigawatts=thousand megawatts.

In the 2008 WEO version[21], the reference scenario projects 433 GW of nuclear power to be installed by 2030 and that generation would increase by one third to reach 3,460 TWh. But the share of nuclear power in world electricity generation would drop from some 14% in 2007 to 13% in 2015 and to 10% in 2030, while nuclear share in commercial primary energy supply would drop from 6% to 5% over the same period. WEO estimated that the growth in nuclear capacity would take place outside the EU. Inside the EU, nuclear capacity was projected to decline from 131 GW today to 89 GW in 2030 and generation from 795 TWh to 667 TWh. This scenario would effectively cut the nuclear share in the EU in half, from 30% in 2006 to 16% in 2030.

The World Energy Outlook 2008 introduces an intermediate "550 Policy Scenario". Nuclear power would represent 540 GW installed that generate 4,166 TWh[22] in 2030, 20% more than in the reference scenario. The new "450 Policy Scenario" envisages 680 GW of installed nuclear capacity, more than doubling the rate of build-up in the "550 Policy Scenario", generating over 5,200 TWh by 2030, twice as much as in 2008 but covering still only 18% of the total consumption. Both of these scenarios are much more optimistic for nuclear power than only a few years earlier.

Consider that the 2006 version of the World Energy Outlook had noted that "nuclear power will only become more important if the governments of countries where nuclear power is acceptable play a stronger role in facilitating private investment, especially in liberalised markets" and "if concerns about plant safety, nuclear waste disposal and the risk of proliferation can be solved to the satisfaction of the public."[23]

Similarly, a 2007 report commissioned by the **InterAcademy Council**, a research body that coordinates among national academies of science, stated: "As a low-carbon resource, nuclear power can continue to make a significant contribution to the world's energy portfolio in the future, but only if major concerns related to capital cost, safety, and weapons proliferation are addressed." The Council concluded that… "no certain conclusion regarding the future role of nuclear energy emerges, except that a global renaissance of commercial nuclear power is unlikely to materialize over the next few decades without substantial support from governments".[24]

The **US Department of Energy (DOE)**, in its 2007 edition of the *International Energy Outlook* (IEO), forecasts 438 GW of nuclear capacity by 2030, "in contrast to projections of declines in nuclear power capacity in past IEOs".[25] The 2008 IEO envisages that 498 GW of nuclear capacity generate 3,800 TWh by 2030, about 10% more than in the OECD-IEA reference case projection[26]. However, the 2008 IEO also notes:

> "Still, there is considerable uncertainty associated with nuclear power. Issues that could slow the expansion of nuclear power in the future include plant safety, radioactive waste disposal, and the proliferation of nuclear weapons, which continue to raise public concerns in many countries and may hinder the development of new nuclear power reactors. Moreover, high capital and maintenance costs may keep some nations from expanding their nuclear power programs."[27]

The **International Atomic Energy Agency (IAEA)** has revised its forecasts several times over the last years and in its most recent projections anticipates 473 GW of nuclear capacity in its "low" scenario and, with admirable precision, 747.5 GW in its "high" scenario by 2030.[28] The rate of

---

[21] OECD-IEA, "World Energy Outlook 2008", 22 October 2008.
[22] TWh = terawatthours or billion kWh.
[23] OECD-IEA, "World Energy Outlook 2006", 7 November 2006.
[24] InterAcademy Council, "Lighting the Way", October 2007.
[25] US Department of Energy, Energy Information Administration, "International Energy Outlook 2006", June 2006.
[26] The report also notes that the projection for nuclear electricity generation by 2025 in the IEO 2008 is 31% higher than in the IEO 2003. It would represent a stunning increase in just five years.
[27] US Department of Energy, Energy Information Administration, "International Energy Outlook 2008 - Highlights", June 2008. See www.eia.doe.gov/oiaf/ieo/index.html .
[28] IAEA, "Energy, Electricity and Nuclear Power Estimates for the Period up to 2030", Reference Data Series No. 1, Vienna, 2008.

increase projected by the IAEA for the period between 2020 and 2030 has doubled compared to the 2001 projections, "reflecting an increase in optimism about nuclear power in some regions".[29]

The secretariat of the **United Nations Framework Convention on Climate Change (UNFCCC)** published a "background paper" on investments relative to the "development of effective and appropriate international response to climate change" that presented a "reference scenario" and a "mitigation scenario" with respectively 546 GW[30] and 729 GW[31] of nuclear power plants by 2030.[32]

The above mentioned scenarios "forecast" an installed nuclear capacity by 2030 of anything between 415 GW and 833 GW, an increase of less than 13% to 125% respectively over the current installed 370 GW. In fact, even the lower figure corresponds to a significant challenge considering the current age structure of operating units – see Graph 5. None of the scenarios provide appropriate analysis of necessary and very substantial increases in nuclear related education, workforce development, manufacturing capacity and public opinion shifts.

II.3. Overview of Current New-build

Nuclear power is unlikely to play a critical role in limiting CO_2 equivalent
concentrations in the atmosphere until mid-century at the earliest …
No realistic plan foresees a reactor build rate that allows nuclear power to help stay below 550 ppme CO_2 within the next ~30-40 years[33].

Robert Rosner
Director, Argonne National Laboratory
April 2009[34]

The construction sites in the 15 countries that currently build nuclear power plants are accumulating substantial and costly delays. As of 1st August 2009, the IAEA lists 52 reactors as "under construction", 18 more than at the end of 2007. As a matter of comparison, the IAEA listed 120 units as under construction at the end of 1987 and a peak of 233 units with over 200 GW under construction in 1979 (see Graph 4). The year 2004, with 26 units under construction, represented the smallest figure for in-construction units since the beginning of the nuclear age in the 1950s.

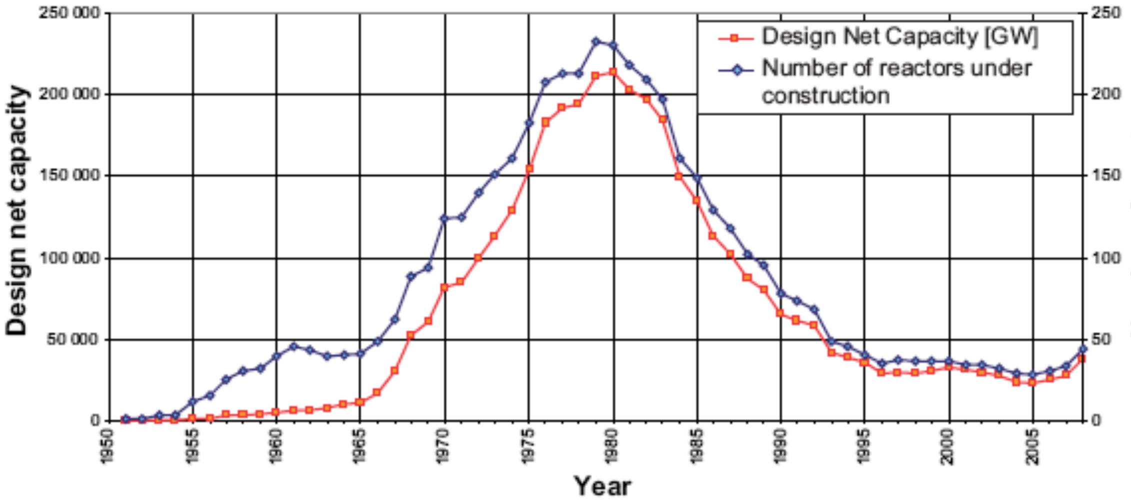
The total capacity of the units under construction is about 46 GW with an average size of ca. 880 MW per unit (see Annex 2 for details). A closer look at the currently listed projects illustrates the level of uncertainty associated with reactor building:

- 13 reactors, one quarter of the total, have been listed as "under construction" for over 20 years. The US unit Watts Bar-2 project holds the record with an original construction start in December 1972 (subsequently frozen), followed by the Iranian Bushehr plant that was originally started by German company Siemens in May 1975 and is now to be finished by the Russian nuclear industry. The list of long-term construction projects further includes four Russian units, the two Belene units in Bulgaria, two Mochovce units in Slovakia and two Khmelnitski units in Ukraine. In addition, two Taiwanese units at Lungmen have been listed for 10 years.
- 24 projects don't have an official (IAEA) planned start-up date, including five of the nine Russian projects, the two Bulgarian reactors and 13 of the 16 Chinese units under construction. One Russian plant (Balakovo-5), which has been listed since 1987 and was to

[29] IAEA, "International Status and Prospects of Nuclear Power", 2008.
[30] Addition of 180 GW over the 2004 installed nuclear capacity of 366 GW.
[31] This corresponds to practically double the currently installed nuclear capacity. The 729 GW figure rather than approximately 730 GW suggests a level of precision that is as far from reality as the figure itself.
[32] UNFCCC, "Analysis of existing and planned investment and financial flows relevant to the development of effective and appropriate international response to climate change", 2007.
http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/background_paper.pdf
[33] The term ppme CO_2 refers to parts per million equivalent CO_2 concentration of greenhouse gases in the atmosphere.
[34] Presentation at the 2009 Carnegie Endowment for International Peace International Non-Proliferation Conference, Washington, DC, 6 April 2009.

go online by the end of 2010, was abandoned and simply pulled off the list in early 2008. It was replaced by a new project (Novovoronezh-2-1) scheduled to start-up at the end of 2012.

Graph 4: Number of units and total nominal capacity in MW[35] under construction 1951—2008



Source: IAEA, International Status and Prospects of Nuclear Power, 2008

- Half (26) of the units listed by the IAEA as "under construction" have encountered construction delays, most of them significant. The remaining units were started within the last five years and have not reached projected start-up dates yet. This makes it difficult or impossible to assess whether they are running on schedule.
- Over two thirds (36) of the units under construction are listed in four countries alone (China, India, Russia, South-Korea). All of these nations have historically not been very transparent about the status at their construction sites.

The geographical distribution of the nuclear power plant projects is concentrated in Asia and Eastern Europe, extending a trend from earlier years. Between 2004 and 2007 a total of 14 units were started up, all in these two regions. Forty-seven of the 52 reactors currently "under construction" are located there as well.

Estimating construction times is not straightforward. Taking a global average—it would be over nine years for the 14 most recent grid connections—does not make much sense because of the differences between countries. The construction period for four reactors that started up in Romania, Russia and Ukraine lasted between 18 and 24 years. In contrast, it took five years on average to complete the ten units that were connected to the grid in China, India, Japan and South Korea.

Lead times for nuclear plants include not only construction times but also long term planning, lengthy licensing procedures in most of the countries, complex financing negotiations and site preparation. In addition, in most cases the grid system has to be upgraded; often new high-voltage power lines have to be built with their own planning and licensing difficulties. In some cases public opposition is significantly higher for the long distance power lines to move the electricity than for the generating station itself.

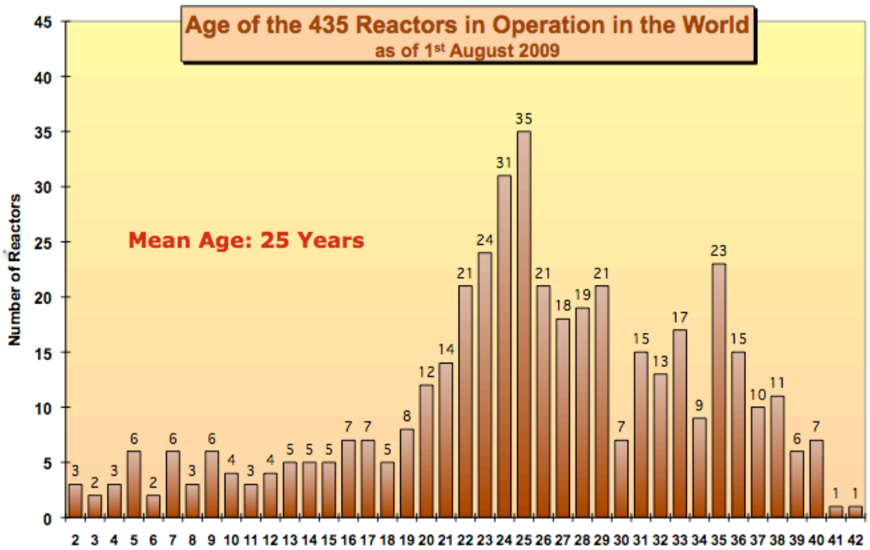
Projected completion times should be viewed skeptically, and past nuclear planning estimates have rarely turned out to be accurate. The USA provides one recent example. In 2001 George W. Bush launched the Nuclear Power 2010 program. According to the Department of Energy's (DOE) October 2001 Roadmap, the objective was to "complete construction and deploy multiple commercially viable new nuclear plants by 2010", and, as a minimum scenario, to deploy "at least one light water and at least one gas-cooled reactor". Reality is quite different and it is obvious now that no new plant will be up and running in the USA by 2010.

[35] The IAEA erroneously indicates GW as the unit for installed capacity in the graph's caption.

As of August 2009, the US Nuclear Regulatory Commission had received 17 applications for a Combined Construction and Operating License (COL) for a total of 26 units.[36] However, as the DOE points out: "Submitting an application does not ensure a reactor will be built (or even started)."[37]

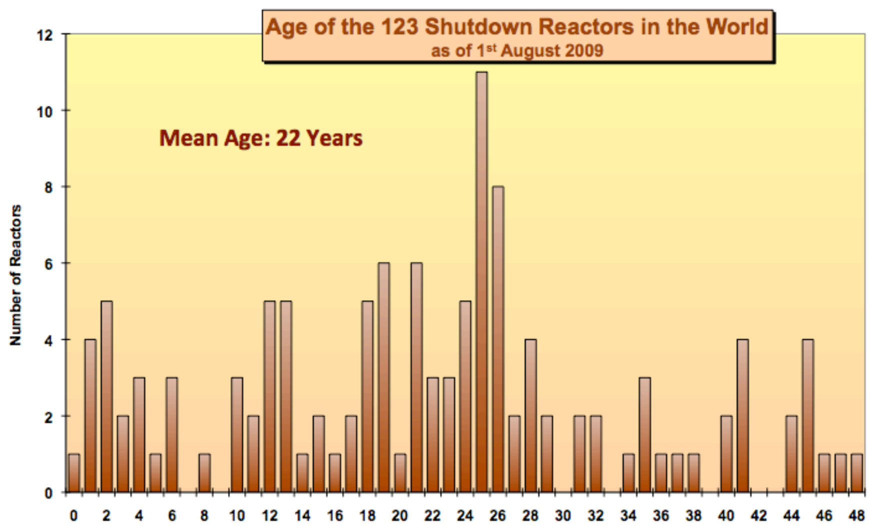
Only one unit is currently planned to operate under a new license before 2015. NRG plans to start construction at its South Texas site as early as 2009 with grid connection planned for 2014. NRG's COL is currently under review by the NRC. "COL filings often include a goal to 'keep the nuclear option open' rather than a full commitment". [38] The capital market service company Moody's expects extensive legal cases: "We believe the first COL filing will be litigated, which could create lengthy delays for the rest of the sector." In late 2007 the London *Financial Times* obtained confidential government documents that confirm a similar situation in the UK: "Fresh legal challenges are expected to hamper plans to build new nuclear power stations in the UK."[39]

Graph 5: Age Distribution of *Operating* Reactors



© Mycle Schneider Consulting — *Source: IAEA-PRIS, MSC, 2009*

Graph 6: Age Distribution of *Shutdown* Reactors



© Mycle Schneider Consulting — *Source: IAEA-PRIS, MSC, 2009*

[36] See http://www.nrc.gov/reactors/new-reactors/col.html , accessed 8 August 2009.
[37] DOE, "Status of Potential New Commercial Nuclear Reactors in the United States", 19 February 2009.
[38] Ibidem.
[39] Financial Times, 24 October 2007.

Past experience has shown that a reactor order or even advanced stage of construction is no guarantee for grid connection and power supply. The French Atomic Energy Commission (CEA) published statistics on "cancelled orders" through 2002. By the time they ended the data series, the CEA listed 253 cancelled orders in 31 countries, many of them in advanced construction stage. The USA alone accounts for 138 cancellations.[40] Many utilities in the USA suffered grave financial harm over 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 in the world has been increasing steadily and stands now at about 25 years.[41]

Some nuclear utilities envisage reactor lifetimes of 40 years or even up to 60 years. The OECD's World Energy Outlook 2008 has given a 40 to 50 year time frame with an average 45 years expected operation. In the USA reactors are usually licensed to operate for a period of 40 years. Nuclear operators in the USA can request a license renewal that can be granted by the Nuclear Regulatory Commission for an additional 20 years. As of early August 2009, a total of 54 units in the USA had received a license renewal to extend operation by 20 years. In many countries there are no time limitations to operating licenses. In France, for example, reactors have to undergo an in-depth inspection and testing every decade. The first operating French PWR was started up in 1977, so 30-year inspections have just begun. The French nuclear safety authorities consider it premature to discuss lifetimes beyond 40 years. "We found it funny that the first time EDF began talking about extending the lifetime of reactors past 40 years was to financial analysts in London," Andre-Claude Lacoste, president of the French Nuclear Safety Authority (ASN), stated in April 2009. "It wouldn't be a bad thing for them to bring us a technical file on this", he added.[42] ASN intends to evaluate reactor-by-reactor to see whether they can operate for more than 30 years. At this stage the question of lifetimes beyond 40 years is considered irrelevant by ASN, although EDF has clearly stated that it will prioritize lifetime extension over massive new build.

In assessing the likelihood of reactors being able to operate for up to sixty years, it is useful to compare the age distribution of reactors currently operating and those that have already shut down (see Graphs 5 and 6). At present, only two operating reactors in the world have exceeded the 40-year mark[43]. These two reactors, Oldbury-1 and -2, are scheduled for closure within two years. Seven additional units have reached age 40. So while a wave of reactors will reach four decades of operation over the next 10 years – 135 units have reached age 30 or more – there is hardly any operational experience with longer operating times.

The age structure of the 123 units already shut down confirms the picture. In total 26 of these units operated for 30 years or more; and within that subset, 15 reactors operated for 40 years or more (see Graph 6). All 14 but one (a 5 MW Russian unit) are Magnox reactors in the UK, most of which had been used for the generation of weapons grade plutonium. These were all small reactors between 50 MW and 225 MW that had operated with very low burn-up fuel, and therefore are not comparable to large 900 MW or 1300 MW commercial reactors using high burn-up fuel that generates significantly more stress on materials.

While many units of the first generation have operated for only a few years or less, even the operating experience beyond 30 years is very limited.

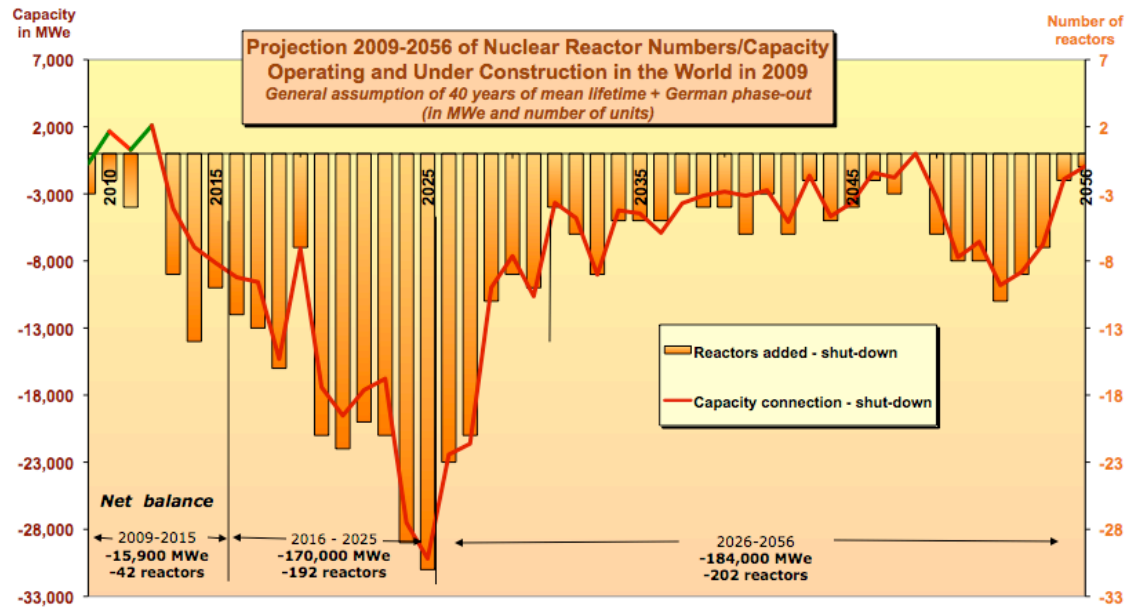
Considering the fact that the average age of all 123 units that have already been closed is about 22 years, plans to nearly double the operational lifetime of so many units seems rather optimistic. However, for the purposes of capacity projections one can assume an average lifetime of 40 years for operating reactors, with a few adjustments. The remaining 17 German units, for example, according to German legislation will be shut down after an average operational lifetime of about

[40] CEA, "Elecnuc – Nuclear Power Plants in the World", 2002 Edition, 2002.
[41] We are calculating the age of a reactor from grid connection to final disconnection from the grid. Throughout the report start-up is therefore synonym with grid connection and shut-down with withdrawal from the grid.
[42] Bloomberg, "EDF Shouldn't Count on Prolonging Old Reactors", 8 April 2009.
[43] We count the age starting with grid connection, and figures are rounded by half years.

32 equivalent full load years.[44] Similarly, there are a number of individual cases where earlier shutdowns have been officially decided (see Graph 7).

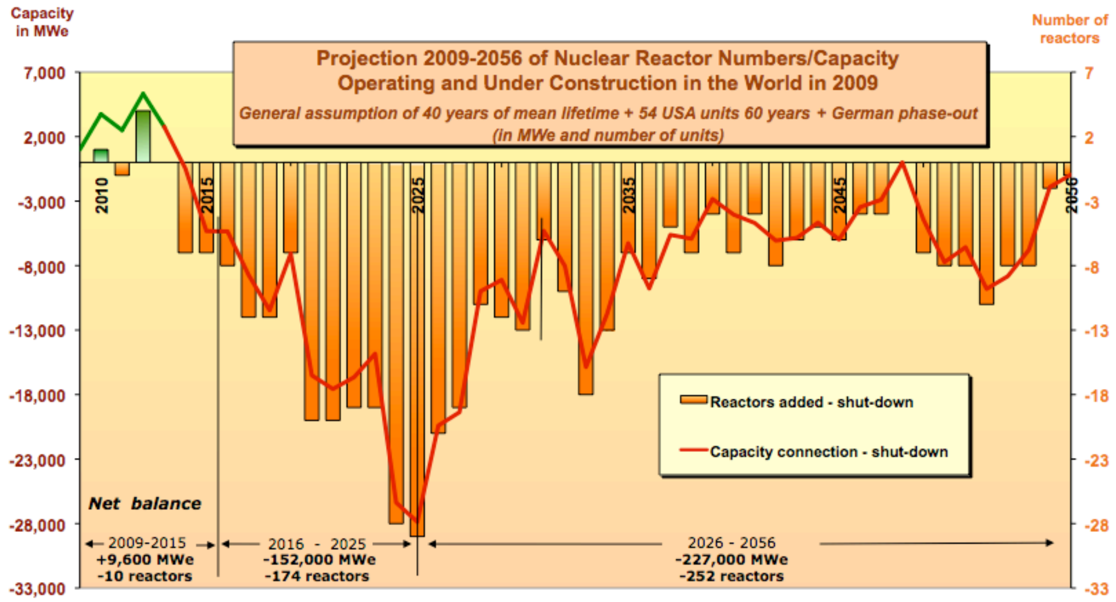
The lifetime projections make possible an evaluation of the number of plants that would have to come on-line over the next decades to offset closures in order to maintain the same number of operating plants. In addition to the 52 units under construction[45] as of 1st August 2009, 42 reactors (15,900 MW) would have to be planned, built and started up prior to 2015. This corresponds to one new plant every month and a half, with an additional 192 units (170,000 MW) over the following 10-year period – one every 19 days.

Graph 7: The 40-Year Lifetime Projection



© Mycle Schneider Consulting Sources: *IAEA-PRIS, WNA, MSC 2009*

Graph 8: The PLEX Projection

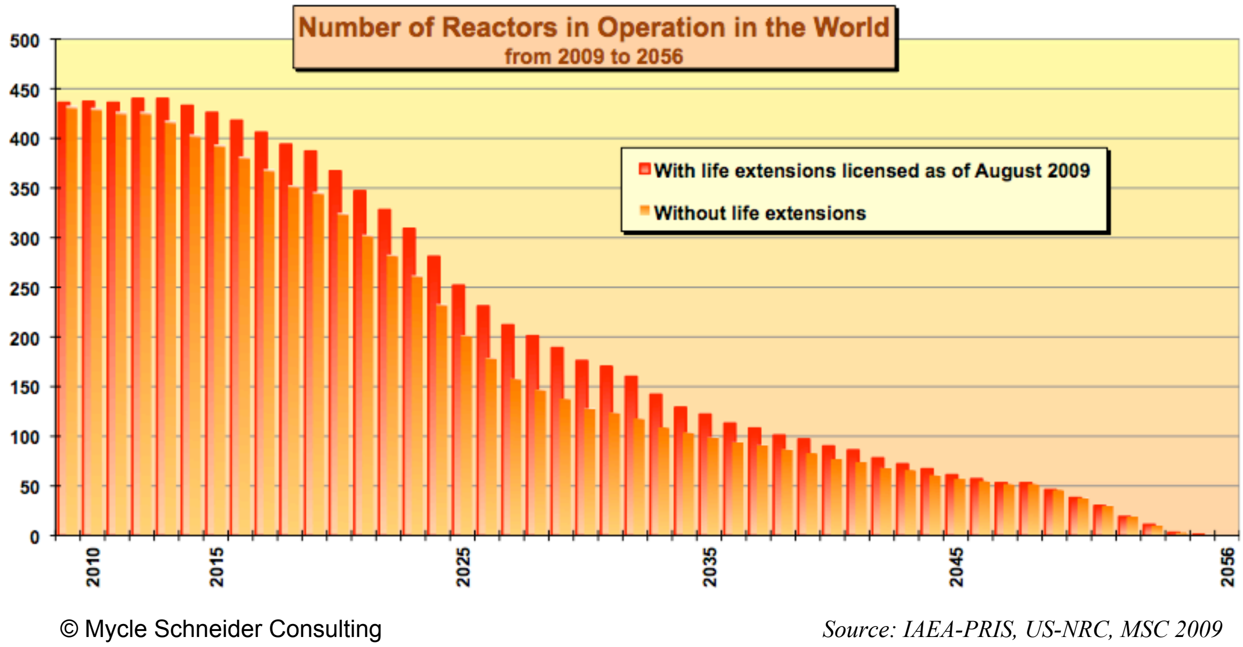


© Mycle Schneider Consulting Sources: *IAEA-PRIS, US-NRC, WNA, MSC 2009*

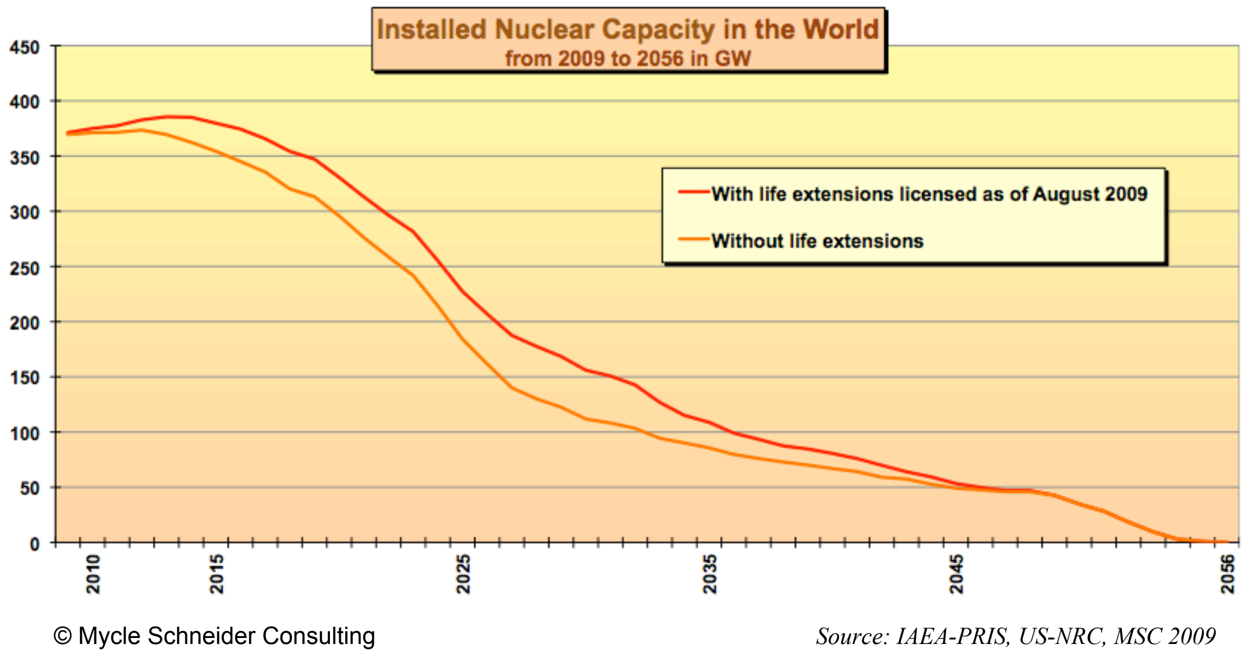
[44] We have used the currently available official projection of individual reactor shutdown dates.
[45] In earlier versions of this report, we have not included units that were listed as under construction but remained without official IAEA start-up dates. In the present scenario *all* of the currently listed units enter operation, by 2016. Respective dates have been compiled by Mycle Schneider Consulting (MSC).

The achievement of the 2015 target is simply impossible given existing constraints on the fabrication of key reactor components. As a result, the number of reactors operating will decline over the years to come — even if the installed capacity level could be maintained — unless lifetime extension beyond 40 years becomes standard. Were life extensions to become standard, many other questions regarding safety, maintenance costs, and other issues would need to be more carefully addressed.

Graph 9: 40-Year Lifetime Projection Versus PLEX Projection *(in numbers of reactors)*



Graph 10: 40-Year Lifetime Projection Versus PLEX Projection *(in installed capacity)*



Developments in Asia, and particularly in China, won't fundamentally change the global picture. The news media *China Daily* stated in October 2007: "China has fast-tracked development of nuclear power in recent years with a target to take its nuclear power capacity from about 9,000 MW

[9 GW] in 2007 to 40,000 MW [40 GW] by 2020, according to China's long-term development plan for the nuclear power industry."[46] In the meantime the official goal was raised to 60 GW in 2008 before being reduced again to 40 GW. However, the average construction time for the first 10 operating units was 6.3 years. Even in the case of further significant advances in building times, in order to be operational by 2020, construction of all of the units would need to have started before 2015. At present, about half of the additional 31 GW is currently under construction. Construction for 16 units totaling 15.2 GW started only over the last four years. Building volume would have to double in order to meet China's ambitious goal - a prospect that seems unlikely[47] although not entirely impossible considering recent building acceleration. But even such an extraordinary undertaking in terms of capital investment, technical and organizational challenge would replace only 10% of the number of units that reach age forty around the world within the timeframe considered.

A nuclear utility-sponsored analysis carried out by the Keystone Center pointed out that to build 700 GW of nuclear power capacity "would require the industry to return immediately to the most rapid period of growth experienced in the past (1981-90) and sustain this rate of growth for 50 years."[48] The international industry lobby organization WNA thinks it can do it and more: "It is noteworthy that in the 1980s, 218 power reactors started up, an average of one every 17 days. (…) So it is not hard to imagine a similar number being commissioned in a decade after about 2015. But with China and India getting up to speed with nuclear energy and a world energy demand double the 1980 level in 2015, a realistic estimate of what is possible might be the equivalent of one 1000 MW unit worldwide every 5 days."[49]

It is questionable whether this can be called a "realistic estimate". The situation in the second decade of the 21st Century will be radically different from the 1980s. In the early days of the industry, less was known about the financial and technical challenges of the nuclear fuel chain, and this vacuum provided the industry with substantial leeway. The nuclear utilities benefitted from the ability to pass much of the investment risk onto ratepayers, to defer nuclear waste and plant decommissioning concerns, and did not face competition from non-utility generators and competitive electricity markets. Given capital losses on past waves of nuclear construction in the hundreds of billions of dollars, and obvious remaining challenges with waste management, proliferation, and financing, challenge to nuclear grand plans is inevitable.

Many analysts consider that the historic key problems with nuclear power have not been overcome and will continue to constitute a severe disadvantage in global market competition. Additional, new difficulties have arisen in particular from market liberalization and the recent economic crisis.

Ken Silverstein, Director of the US-based consultancy *Energy Industry Analysis* wrote:

> "As a result of deregulation of power and other market- and policy-based uncertainties, no nuclear power company can afford to take the financial risk of building new nuclear plants. A report published by Standard & Poor's identifies the barriers. The financial costs for construction delays, for example, could add untold sums to any future project. That, it says, would also increase the threats to any lender. To attract new capital, future developers will have to demonstrate that the perils no longer exist or that energy legislation could successfully mitigate them. Peter Rigby, a Standard & Poor's analyst and author of the report says: 'The industry's legacy of cost growth, technological problems, cumbersome political and regulatory oversight, and the newer risks brought about by competition and terrorism concerns may keep credit risk too high for even (federal legislation that provides loan guarantees) to overcome'."[50]

---

[46] See http://www.chinadaily.com.cn/china/2007-10/16/content_6177053.htm .

[47] A certain number of units currently in the planning stage or in early construction phase are of designs that have never been completed elsewhere (e.g. EPR, AP1000).

[48] Bradford, et al. "Nuclear Power Joint Fact-Finding", Keystone Center, June 2007.

[49] See http://www.world-nuclear.org/info/inf17.html .

[50] UtiliPoint International, 21 June 2004.

In 2005 the USA passed legislation in order to stimulate investment in new nuclear power plants. Measures include a tax credit on the first 6 GW of new electricity generation, a 100% federal loan guarantee of up-to-80%-debt financing for up to $20.5 billion in nuclear-related assets,[51] additional support in case of significant construction delays for up to six reactors and the extension of limited liability (Price Anderson Act) until 2025 (see section III. for details).

The licensing procedure has been simplified to avoid the lengthy processes of the past. The public interest group Public Citizen views the new licensing conditions not only as a heavy subsidy to the industry (see chapter III.) but as a serious impediment to the democratic decision making process. "The Combined Construction and Operating License, or COL, is part of a new, 'streamlined' process designed to encourage construction of new nuclear power plants by heavily subsidizing nuclear owners and removing opportunities for the public to raise important safety concerns. By combining what were previously two steps - construction and operation - there is no chance for the public to raise concerns about problems with the actual construction process after it begins. By the time the shovel hits the dirt, the reactor is already approved to start up."[52]

The renewal of the aging world nuclear fleet or even the extension of the operating power plants encounters three major problems: a short term manufacturing bottleneck, a dramatic skilled worker/manager shortage and a skeptical financial sector. Other issues include widely fluctuating costs for raw materials, the aftermath of the Chernobyl disaster, and the new dimension of the threat of nuclear terrorism. The world economic crisis exacerbates these problems further, in particular in potential "newcomer" countries.

II.4. Overview of Potential Newcomer Countries

We have a very good president in France, Monsieur Sarkozy.
He is our best commercial guy for nuclear.
He is going in all countries and selling nuclear plants.

Colette Lewiner
Global Energy, Utilities and Chemicals Leader, Capgemini
London, June 2008[53]

Pretty soon you will have nine weapons states
and probably another 10 or 20 virtual weapons states.

Mohamed ElBaradei
Director General, IAEA
Vienna, May 2009[54]

Numerous countries have expressed interest in nuclear power in recent years. According to the IAEA, 12 countries are "actively preparing for nuclear power" and a further 38 countries have "indicated an interest in the possible introduction of a nuclear power plant".[55] Of these 51 countries 17 are from the Middle East to the Pacific, 13 are from Africa, 11 are European and nine are in Latin America.

Between 2006 and 2008 alone, the IAEA has received requests for technical cooperation from some 43 Member States. The IAEA accounts for the introduction of nuclear power in 20 new countries by 2030 in its high projection and on five newcomer countries in its low projection. As detailed in the following table, not all countries that ask for assistance are actually planning to

[51] Current authorizations include $18.5 billion for reactor-related assets and $2.0 billion for front-end fuel chain facilities. However, there have been frequent attempts to introduce legislation that would greatly increase this guarantee capacity.
[52] See http://www.citizen.org/cmep/energy_enviro_nuclear/newnukes/articles.cfm?ID=14159 .
[53] "The Nuclear Renaissance Prerequisites", Platts 3rd Annual European Nuclear Power Conference, London, UK, 30 June 2008.
[54] *The Guardian*, "Mohamed ElBaradei warns of new nuclear age", 15 May 2009.
[55] IAEA, "International Status and Prospects of Nuclear Power", 2008.

introduce nuclear power plants. Rather, the IAEA notes that some are merely "interested in considering the issues associated with a nuclear power programme".[56]

Table 2: Positions of Potential Nuclear Newcomer Countries

Definition of Group	**Number of Countries**
Not planning to introduce nuclear power plants, but interested in considering the issues associated with a nuclear power program.	16
Considering a nuclear program to meet identified energy needs with a strong indication of intention to proceed.	14
Active preparation for a possible nuclear power program with no final decision.	7
Decided to introduce nuclear power and started preparing the appropriate infrastructure.	4
Invitation to bid to supply a nuclear power plant prepared.	1
New nuclear power plant ordered	-
New nuclear power plant under construction	1

Source: IAEA, "International Status and Prospects of Nuclear Power", 2008

Only one newcomer country, **Iran**, is already in the course of building a nuclear power plant.

France has been particularly active in negotiating new nuclear trade or cooperation agreements with potential newcomer countries. According to Philippe Pallier, director of the newly created Agence France Nucléaire International (AFNI), France received requests by "several tens of countries" for assistance to implement a civil nuclear power program.[57] Agreements were signed or are under negotiation in particular in North Africa and in the Middle East, including **Algeria, Jordan, Libya**[58]**, Morocco, Tunisia** and the **United Arab Emirates**. In addition, interest in nuclear energy has been demonstrated by **Egypt, Israel, Jordan, Kuwait, Qatar, Syria, and Yemen.**[59] The US government has signed a nuclear agreement with the **United Arab Emirates** and memoranda of understanding on nuclear cooperation with **Saudi Arabia** and **Bahrain**.

Jordan has set up a Committee for Nuclear Strategy and received initial proposals by KEPCO (South Korea), AREVA, Atomstroyexport and AECL (Canada). Construction is projected to start as early as 2012.

In Asia potential candidates for French atomic help include **Thailand** and **Vietnam**. China, Russia and South-Korea are said to have offered assistance to **Bangladesh** to build a nuclear power plant, a "46-year old plan", the *Financial Express* notes.[60]

In Europe **Albania** and **Croatia** are discussing the possibility of building a joint nuclear plant.[61] **Montenegro** and **Bosnia** have been invited to join the project. The Italian utility ENEL is said to have evaluated the feasibility of the project.

---

[56] The IAEA is not more specific and it is unclear what is covered under technical assistance programs in these cases.

[57] Audio statement at http://www.cea.fr/presse/liste_des_communiques/philippe_pallier_est_nomme_directeur_de_l_afni .

[58] For background on French nuclear cooperation see Mycle Schneider, "Nuclear France Abroad - History, Status and Prospects of French Nuclear Activities in Foreign Countries", commissioned by CIGI, Canada, Paris, May 2009.

[59] WNA, "Emerging Nuclear Energy Countries", May 2009, http://www.world-nuclear.org/info/inf102.html .

[60] *Financial Express*, "Government takes fresh move to set up N-power plant", 26 March 2009.

[61] UPI, "Albania, Croatia plan nuclear power plant", 16 April 2009.

Portugal is said to be reviewing a nuclear project that could serve Spain as well. However, in the past the government has rejected nuclear proposals and Spain has currently a firm nuclear phase out policy.

Lithuania invited **Poland, Estonia** and **Latvia** to build a joint "Baltic" nuclear plant to replace the remaining second Ignalina reactor that will be shut down by the end of 2009 according the country's EU accession agreement. However, even after the shutdown of Ignalina, power consumption in the other countries would not justify the construction of a large nuclear plant. Financing is also a major issue.

Belarus, the country that was worst hit by the Chernobyl disaster in 1986, has received offers for a nuclear plant from Atomstroyexport, AREVA and Westinghouse.

Twenty-three potential newcomer countries operate at least one research reactor[62], which can be considered as one of the prerequisites for the operation of a commercial plant. If we look at the 11 countries that operate small nuclear programs with one or two reactors (see Table 3), only two countries, Armenia and Lithuania, operate commercial size reactors but no research reactors. Both were former republics of the Soviet Union and profited extensively from the technical expertise, the legal framework and the integrated power grid of the larger federation. The same countries plus Slovenia are the only ones to operate power grids that are smaller than 10,000 MW and where the respective nuclear unit corresponds to more than 10% of the installed capacity in the country. Slovenia, formerly part of Yugoslavia, was equally integrated into a much larger framework. Bulgaria operates two units, which each represent about 8.5% of the total installed capacity. But the country is also rather well interconnected.

Table 3: Small Nuclear Programs and the Power Capacity Share of the Largest Nuclear Unit

Country	Units	Total Nuclear Capacity	Largest Nuclear Unit (in MWe net)	Total Electric Capacity (in MW 2007)	Share Largest Nuclear Unit/ Total Electric Capacity
Mexico	2	1,300	650	53,800	1.2%
Brazil	2	1,766	1,275	96,600	1.3%
Pakistan	2	425	300	19,500	1.5%
Argentina	2	935	600	28,300	2.1%
Netherlands	1	482	482	22,600	2.1%
South Africa	2	1,800	900	41,100	2.2%
Romania	2	1,300	650	19,200	3.4%
Bulgaria	2	1,906	953	11,200	8.5%
Armenia	1	376	376	3,200	11.8%
Slovenia	1	666	666	3,100	21.5%
Lithuania	1	1,185	1,185	3,800	31.2%

 Sources: derived from IAEA-PRIS 2009, EIA, 2009

The IAEA considers that "the value of 10% of grid capacity is widely believed to be the maximum capacity of an additional unit of any type in order to prevent grid interface problems".[63] In seven of the 11 smallest active nuclear programs the largest nuclear unit represents less than 4% of the installed capacity and the other four were developed under entirely different circumstances. In other words, 10% seems already a rather extreme value for the largest unit in a given country.

Of 38 potential nuclear newcomer countries listed by the WNA, 15 don't have nuclear experience on research-reactor level and 20 have an electricity grid that is smaller than 10,000 MW.[64] The following 17 countries have both research-reactor experience and larger than 10,000 MW grids (see Annex 3): Australia, Chile, Egypt, Indonesia, Israel, Italy, Kuwait, Malaysia, Norway, Philippines, Poland, Portugal, Thailand, Turkey, United Arab Emirates, Venezuela, Vietnam.

What are the prospects of a nuclear power program in these countries?

[62] IAEA, "Research Reactor Data Base", accessed 9 May 2009.
[63] IAEA, "International Status and Prospects of Nuclear Power", 2008.
[64] The IAEA has counted 28 potential candidate countries with grid systems of less than 10,000 MW.

Australia is a large uranium producer but the introduction of nuclear power always faced significant controversy. A December 2006 report to the Prime Minister, the Switkowski Report[65], suggested the rapid introduction of a nuclear power program in the country. An international panel of experts, including three of the authors of this report[66], concluded that the Switkowski Report was highly biased and that the targets were unrealistic.[67] Nothing has happened since. Any significant follow-up over the coming 20 years in industrial terms is highly unlikely. Switkowski acknowledged in March 2009 that once the people accepted nuclear power "it would be at least another 15 years before a reactor could be built".[68] In fact, the newly elected Australian government will put that timeframe even further away. As Martin Ferguson, Minister for Resources and Energy has recently restated, "the Government has a clear policy of prohibiting the development of an Australian nuclear power industry".[69]

It has been reported that in November 2007 the **Chilean** President asked the Energy Minister to look into the nuclear power option. A modest effort seems ongoing, as in 2009 the government allocated CP$430 million (US$665,000) to study nuclear power. Even such a minor expenditure raised significant criticism by the environmental community in the country.[70] There are no short or medium term prospects for a nuclear power program.

In **Egypt** it is already 35 years since the first nuclear power plant was proposed. The plan never materialized. More recently Egypt signed nuclear cooperation agreements with Russia and China. In December 2008 the government announced that it had selected the US company Bechtel (later transferred to Worley Parsons) to provide assistance in selecting a reactor provider and to train staff. A 1,000 MW plant is planned to start up by 2017.

Nuclear power projects in **Indonesia** have a 20-year history. In 1989 the National Atomic Energy Agency (BATAN) carried out the first studies. In 2007 the Korea Electric Power Corp (KEPCO) agreed to develop a new feasibility study for two 1,000 MW reactors. Cooperation agreements were also signed with Japan and Russia. Indonesia's Minister for Research and Technology was quoted in March 2008 as stating that the country would need four 1,200 MW units by 2025 and that the first one was to go online by 2016. Construction would have to start in 2008. "Otherwise, we will be behind schedule", he stated.[71] Indonesia will be behind schedule. No call for tender has been announced yet. The nuclear plans have raised concerns and protests because of intense volcanic and earthquake activities in the areas envisaged to host a plant, in particular in Central Java. There is little prospect for near or medium term nuclear power plant operation and no target dates have been announced.

Israel has developed a full-scale nuclear weapons program and thus has strong nuclear capabilities. Several arguments speak against a short and medium term nuclear power program in the country. With a grid size of just 10,000 MW a nuclear plant would be clearly oversized. The country has not signed the Nuclear Non-Proliferation Treaty and is therefore technically isolated. Nuclear power plants are sometimes called pre-deployed nuclear weapons. There are few places where this perspective seems more pertinent than in the case of Israel. And finally, Israel is a major player in the renewable energy sector. An Israeli company currently plans to construct in California the

---

[65] Ziggy Switkowski, "Uranium mining, processing and nuclear energy review - opportunities for Australia?", Draft report, Department of Prime Minister and Cabinet, November 2006; Switkowski has since been named chairman of the Australian Nuclear Science and Technology Organisation (ANSTO).

[66] See "More nuclear? What international experts say about our energy future", Background Briefing, Greenpeace Australia, 19 November 2006 and "International experts additional comments on draft Nuclear Taskforce Report", Background Briefing, Greenpeace Australia, 6 December 2006.

[67] The establishment of up to 25,000 MW of nuclear power by 2050 would mean grid connection of one 1,200 MW plant every 18 months after 2020, the earliest estimated possible first grid connection.

[68] ABC, "Aussies will accept nuclear power, conference told", 17 March 2009.

[69] See http://www.alp.org.au/media/0109/msrese160.php accessed on 10 May 2009.

[70] The Santiago Times, "Chile Govt doubles 2009 Budget for Nuclear Energy Studies", 6 January 2009.

[71] Thaindian News, "Indonesia to build four nuclear power plants by 2025", 12 March 2008.

world's largest solar project, a 1,300 MW plant[72]. A similar project with 500 MW will be started up by 2012 in Israel.

The Berlusconi Government has introduced legislation that would pave the way for the reintroduction of nuclear power in **Italy.** Four EPRs could be built with construction starting as early as 2013, under an agreement signed in February 2009 by the French utility EDF and the largest Italian utility ENEL. However, Italy is the only country that shut down its nuclear program after the Chernobyl accident in 1986 and a referendum in 1987 reinforced the decision. Four operational reactors and four units under construction were abandoned and no nuclear electricity was generated after 1987. Twenty years later, Italy continues to face significant decommissioning and waste management costs. There is no final repository for high-level waste and the public remains hostile. Italy had built up a significant nuclear industry and still has a strong nuclear lobby. More recently ENEL announced investments in nuclear plants outside the country, in particular in the Slovak Mochovce plant and the French Flamanville-3 unit. This strategy seems much more realistic than any short or medium term revival of nuclear power in Italy itself.[73]

Kuwait announced plans in March 2009 to set up a national nuclear energy commission and has introduced draft legislation to achieve this. The country is in the very early stages of designing a possible nuclear power policy. With only 11,000 MW, its grid is very small. Applications in the short and medium term are unlikely.

The Indian nuclear industry has stated that it would be ready to assist **Malaysia** in developing a nuclear power program "if there is a genuine interest, as nuclear power production is a long term commitment".[74] There are no short or medium term perspectives or ambitions.

In **Norway** a government appointed committee recommended in February 2008 that "the potential contribution of nuclear energy to a sustainable energy future should be recognized."[75] However, as the OECD's Nuclear Energy Agency's Norway country profile states: "Norway does not have a nuclear power generation programme."[76]

The **Philippines** abandoned a nuclear power project in the past. A 600 MW Westinghouse reactor, Bataan-1, was ordered in 1974 and building started in 1976. The nearly complete project was abandoned by the incoming Aquino government days after the Chernobyl accident in 1986. However, payments apparently continued until 2007[77]. In February 2008 the IAEA visited the site at the request of the Philippine government. There have been successive attempts from Members of Congress to introduce bills mandating the rehabilitation of the plan, the latest in December 2008. "The government has to assess what the new licensing requirements should be, how to modernize the two-decades old technology to current standards, and how to confirm that all aspects of the plant will function properly and safely. It is not the IAEA´s role to state whether the plant is usable or not, or how much it will cost to rehabilitate", the IAEA stated.[78] The power plant site is close to an earthquake prone zone and the dormant Pinatubo volcano. Considering the disastrous experience with the initial investment, the absence of an appropriate nuclear framework (legislation, safety authorities, etc.) and significant opposition against the project in the country, it seems unlikely to go ahead.

Poland ordered five Russian designed reactors between 1974 and 1982. Work started on two units at Zarnowiec but all orders were officially cancelled by 1990. The current Polish government has revived the nuclear plans and stated that a first reactor should be operational by 2020. The state

---

[72] Israel21c, "Israel and California cut world's largest solar energy deal", 12 February 2009, http://www.israel21c.org/bin/en.jsp?enDispWho=Articles%5El2460&enPage=BlankPage&enDisplay=view&enDispWhat=object&enVersion=0&enZone=Technology , accessed 10 May 2009.

[73] See Maria Rosaria Di Nucci, "Between Myth and Reality: Development, Problems and Perspectives of Nuclear Power in Italy", in Lutz Mez, Mycle Schneider & Steve Thomas (eds),"International Perspectives on Energy Policy and the Role of Nuclear Power", Multi-Science Publishing, Brentwood, May 2009.

[74] Yahoo Malaysia News, "India keen to sell nuclear reactors to Malaysia", 27 April 2008.

[75] WNA, "Emerging Nuclear Countries", May 2009.

[76] See http://www.nea.fr/html/general/profiles/norway.html.

[77] AFP, "RP revisits nuclear energy option at 'white elephant' plant", 8 January 2009.

[78] IAEA, "IAEA Advises Philippines on Next Steps for 'Mothballed' NPP", 12 July 2008.

owned power utility PGE announced plans in January 2009 to build two 3,000 MW plants in the country.[79] In addition, Poland has joined the Lithuanian Energy Organisation (LEO) alongside Latvia, Estonia and Lithuania with the project of a "Baltic plant" in a Visaginas called project. Originally a new plant replacing the Ignalina plant, which will close by the end of 2009, was planned to start up as early as 2015. No new realistic time frame nor financing schemes are available. No call for tender has been issued.

In **Portugal** "in 2004 the government rejected a proposal to introduce nuclear power but this is now being reviewed", writes the WNA.[80] However, Portuguese public opinion is overwhelmingly opposed to nuclear power and there are no plans. As the OECD's Nuclear Energy Agency's Portugal country profile states: "Portugal does not have a nuclear power generation programme."[81]

In **Thailand** there have been nuclear power plans since the 1970s, none of which ever materialized. Under the previous government, the energy minister revived plans for the construction of four nuclear reactors with a total of 4,000 MW coming online by 2020-2021.[82] However, the incoming government has not reiterated any of these plans.

While the IAEA does not identify the countries in the various categories in Table 2, it is clear that **Turkey** is the only potential newcomer country that has already launched a call for tender. But in September 2008 it had received only one offer, by the Russian Atomstroyexport (ASE), amongst the six potential bidders. In principle, the procedure had to go back to the starting point, since Turkish law does not allow for the attribution of such a contract if there is only one bidder. However, negotiations have been continuing around the offer from the Russian consortium, which includes ASE, Inter RAO UES and the Turkish company Park Teknik. The bid, based on the BOO (Build-Own-Operate) model, covers the construction of four 1200 MWe AES-2006 VVER reactors to be built near Mersin in the Akkuyu district. In February 2009 the project was subject to discussions between the Russian and Turkish presidents. Financing of the project remains a key problem. It has been reported[83] that the initial Russian offer was to sell the power from the to-be-built plant at a price that would represent more than three times the current wholesale power price in Turkey. A revised offer would still be more than double current wholesale levels. However, Akkuyu was the location of an earlier abandoned nuclear project that was based on a 100% pre-financing scheme and still failed. Turkey lacked, and continues to lack, consistent nuclear infrastructure and the project received fierce opposition by the local population. The latest proposal only revived the local protests.

The **United Arab Emirates (UAE),** following recommendations by the IAEA, set up a Nuclear Energy Program Implementation Organization (NEPIO) and the Emirates Nuclear Energy Corporation (ENEC) as a public entity with initial funding of US$ 100 million; and it has initiated steps to develop nuclear legislation. The move is following a government position paper on the "Evaluation and Potential Development of Peaceful Nuclear Energy"[84]. By 2020, the Emirates envisages operating three 1,500 MW units, but no decision was taken as of middle of May 2009.

Although the UAE has signed a far-reaching nuclear cooperation agreement with France, there is strong resistance in the US Congress to the implementation of a similar agreement signed by the previous US administration at the very end of its term on 15 January 2009. "Given the UAE's past history as the major transshipment point for goods destined for Iran's nuclear and missile programs, serious concerns remain about its eligibility for a nuclear cooperation agreement with the U.S.", stated Congresswoman Ileana Ros-Lehtinen, the ranking Republican member of the House

---

[79] PGE was counting then on an installed kW cost of €2,500-€3,000, a costing figure that since has increased significantly (see section III.).
[80] WNA, "Emerging Nuclear Countries", May 2009.
[81] See http://www.nea.fr/html/general/profiles/portugal.html.
[82] Piyasvasti Amranand, "Thailand's Energy Policies", presentation at Power-Gen Asia, 6 September 2007.
[83] WNN, "Russia and Turkey talking cooperation", 17 February 2009.
[84] Government of the UAE, "Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy", undated; https://pcs.enec.gov.ae/ENECDocuments/ContentMgmtDocuments/UAE%20Policy%20on%20the%20Evaluation%20and%20Potential%20Development%20of%20Peaceful%20Nuclear%20Energy.pdf , accessed 15 May 2009

Foreign Affairs Committee.[85] The strong bi-partisan opposition in the USA could seriously hamper any attempts by the UAE to go ahead with a nuclear power program, even if President Obama has officially authorized implementation.[86]

Also, the UAE would have to very substantially increase overall installed capacity and the grid, since a single 1,500 MW plant corresponds to about 10% of the currently installed capacity.

Venezuela passed a decree "on Development of the Nuclear Industry" as early as 1975, but never did develop a nuclear power program. In September 2008 President Chavez was quoted as saying "we certainly are interested in developing nuclear energy, for peaceful ends of course – for medical purposes and to generate electricity".[87] Russia and France have offered assistance in building up a nuclear program in Venezuela. However, apparently there are no concrete decisions or plans yet.

In 1996 **Vietnam** signed an agreement with South Korea for "Cooperation in Research into the Peaceful Uses of Nuclear Energy". Later cooperation agreements were also signed with other countries including Canada, China, France, Japan and Russia. In mid 2008 a nuclear law was passed with the view of constructing two 1,000 MW units starting in 2014 with a targeted grid connection of 2018. Vietnam is lacking general nuclear infrastructure and would have to invest considerably in grid expansion in order to absorb the production of the two units that represent almost 20% of the currently installed capacity.

It remains unlikely that any of the potential new nuclear countries can implement fission power programs any time soon within an appropriate technical, political, legal and economic framework. None of the potential newcomer countries have proper nuclear regulations, an independent regulator, domestic maintenance capacity and the skilled workforce in place to run a nuclear plant. The head of the French Nuclear Safety Authority has estimated it would take at least 15 years to build up the necessary regulatory framework in countries that are starting from scratch.

Furthermore, few countries have sufficient grid capacity to absorb the output of a large nuclear plant. This means that the economic challenge of financing a nuclear plant would be exacerbated by the large ancillary investments in the distribution network that would be required.

The countries that have a grid size and quality that could apparently cope with a large nuclear plant in the short and medium term encounter other significant barriers[88]: a hostile or passive government (Australia, Norway, Malaysia, Thailand), an essentially hostile public opinion (Italy, Turkey), international non-proliferation concerns (Egypt, Israel), major economic concerns (Poland), a hostile environment due to earthquake and volcanic risks (Indonesia), lack of all necessary infrastructure (Venezuela). Many countries face several of these barriers at the same time.

II.5. Status and Trends in Nuclear Manufacturing Capacities

Whether or not the nuclear renaissance will come to fruition
is also dependant in large part on the success or failure
of the industrial infrastructure that provides the necessary parts
and equipment for construction of a nuclear power plant.

Kristine L. Svinicki
Commissioner, NRC
May 2009[89]

The industrial issue has radically changed since nuclear construction peaked around 1980. Many of the companies that were leading organizations in the nuclear industry in 1980 have moved away

[85] Brad Sherman, "Key Members of Congress call on President Obama to Conduct Nuclear Trade Policy Review", 7 April 2009, http://www.house.gov/list/press/ca27_sherman/morenews/40709UAELetter.html .
[86] Platts, "Obama approves US-UAE agreement on civilian nuclear cooperation", 20 May 2009.
[87] CNN, "Chavez interested in nuclear help from Russia", 28 September 2008.
[88] See Sharon Squassoni, "Nuclear Energy – Rebirth or Resuscitation", Carnegie Endowment for International Peace, 2009. The report provides a useful summary of potential implications of various expansion scenarios.
[89] Kristine L. Svinicki, "The Nuclear Renaissance in America", NRC NEWS, Paris, 4 May 2009.

completely from the nuclear business, amalgamated with others in the nuclear field or redirected their business approach to activities related to decommissioning and waste management where there has been an increase in activity in the last few years. This has resulted in a smaller group of companies, in fewer countries, with the capability of managing the construction of a complete nuclear power plant.[90]

According to the American Society of Mechanical Engineers (ASME), the number of ASME Nuclear Certificates held by companies fell worldwide from nearly 600 in 1980 to less than 200 in 2007. The decline was essentially due to the loss of US-held certificates, as the number of certificates held in other countries remained rather stable around 100. Since 2007 the number of ASME certificates has slightly increased to 225, hardly a quantum leap.[91]

A US-DOE nuclear power plant construction infrastructure assessment concluded that major equipment (reactor pressure vessels, steam generators, and moisture separator reheaters) for the near-term deployment of Generation III[92] units would not be manufactured by US facilities. "Reactor pressure vessel (RPV) fabrication could be delayed by the limited availability of the nuclear-grade large ring forgings that are currently only available from one Japanese supplier (Japan Steel Works, Limited - JSW). Additional lead-time may need to be included in the reactor pressure vessel procurement schedule depending on ability of this one supplier to supply the required reactor pressure vessel large ring forgings in a timely manner. This potential shortfall is a significant construction schedule risk and could be a project financing risk."[93] The US Nuclear Regulatory Commission's Chairman Dale Klein has also warned that it will take more time to inspect foreign made components than to provide quality control at home.[94]

JSW has supplied about 130 or 30% of the currently operating nuclear reactor vessels in the world.[95] While about 90% of the operational vessels in the USA were manufactured in the country, none of the replacement vessel heads that were ordered after the detection in 2002 of a major hole in the Davis Besse vessel head has been manufactured in the USA.

In fact, only JSW can forge components from ingots up to 450 t[96] as needed for the EPR and other Generation III reactor pressure vessels and it has announced further investments in manufacturing capacity. However, JSW's annual manufacturing capacity remains unclear. It has been reported that "more modest investments in 2006, 2007, and 2008", will bring its capacity up to the equivalent of four nuclear steam supply system sets (pressure vessel plus steam generators) per year in 2007 and 5.5 sets by 2008. JSW is aiming to produce sufficient forgings to supply the equivalent of about 8.5 sets a year by 2010 and the maximum ingot size is to be increased to 650 t. Already by the end of 2007 JSW's capacity for nuclear products was fully booked to the end of 2010.[97] AREVA has signed an agreement with JSW "until 2016 and beyond" that has provided JSW "certain confidence on proceeding to the next round of our major capacity expansion program".[98]

The problem is the term "equivalent" because it is unclear how much of the forging capacity is dedicated in practice to new nuclear projects. JSW also supplies, for example, about 100 forgings a year for fossil fuel turbine and generator rotors to China alone.

---

90 IAEA, "International Status and Prospects of Nuclear Power", 2008.

91 Kristine L. Svinicki, "The Nuclear Renaissance in America", NRC NEWS, Paris, 4 May 2009.

92 The currently operating generation of nuclear plants is considered Generation II. The EPR under construction in Finland is considered a Generation III reactor. Other designs under consideration in the USA include the AP1000 by Westinghouse, the Advanced Boiling Water Reactor (ABWR) and the Economic Simplified Boiling Water Reactor (ESBWR) by General Electric (see also chapter III.).

93 MPR, "DOE NP2010 Nuclear Power Plant Construction Infrastructure Assessment", 21 October 2005.

94 Financial Times, 24 October 2007.

95 WNN, "Japan Steel Works prepares for orders", 16 May 2007

96 According to the trade press, one vendor in China, Erzhong (the former Second Heavy Machinery Works) in Dayan, Sichuan, "has announced" that capacity, but evidence remains unclear and the lack of international reputation excludes Erzhong de facto as a competitor of JSW on the international market.

97 Nucleonics Week, 8 November 2007.

98 AREVA, "The Japan Steel Works, Ltd. (JSW) and AREVA sign a major industrial agreement on large forged part procurement", Press Release, 4 November 2008.

The maximum ingot size AREVA can handle in its Chalon forgery is 250 t. AREVA has stated that the annual capacity at the Chalon plant is limited to 12 steam generators[99] plus "a certain number of vessel heads" and small equipment, or the *equivalent* of between 2 and 2.5 units per year, if it did manufacture equipment for new plants only. In reality, the Chalon capacities are booked out, in particular for plant life extension measures – steam generator and vessel head replacement – also for the US market.[100] In July 2007 AREVA announced that the heavy forgings it had ordered in 2006 from JSW for a US-EPR had begun to arrive at its Chalon facility. AREVA claims that the order of forgings made the company the only vendor to have "material in hand to support certainty of online generation in 2015."[101] Since 1973 the Chalon plant has manufactured in total over 600 heavy components including 76 reactor pressure vessels, 63 replacement vessel heads and 292 steam generators. Over 500 of the pieces were installed on French units.

In July 2008 AREVA announced that it would enlarge its Le Creusot facilities, located in the same region as Chalon, in order to increase its annual ingot capacity from 35,000 tons to 50,000 tons. AREVA claims that while currently "80% of the components required to build an EPR can be produced in Le Creusot", in the future "100% will be manufactured in the region including components for reactor vessels".[102] A few months later, AREVA stated that the annual production capacity of the Chalon facilities would be upgraded to "an equivalent of 2.7 EPRs, up from around 1.7".[103]

The AREVA figures illustrate the difficulty of assessing real manufacturing capacities. AREVA's capacity increases, from components for a maximum of 2.5 Generation II units to those for 2.7 Generation III EPR units. That looks like a modest increase.

In the USA, in alliance with Northrop Grumman, AREVA is projecting the construction of a Chalon mirror facility in Newport News, Virginia. The $360 million plant would manufacture reactor vessels, steam generators and pressurizers for future EPRs to be built in the USA. However, AREVA is facing a severe cash shortage (see sections III & IV) and at this point it is unlikely that it will be able to follow through with all of its ambitious investment projects.[104]

Other initiatives to correct the obvious bottleneck in manufacturing capacity include:

- **Chinese** firms Harbin Boiler Works, Dongfang Boiler Group and Shanghai Electric Heavy Industries Corp. (SEC) are preparing to enter the very large forgings market. At present only two Chinese companies can pour ingots at around 350 tons, of which only SEC is said to handle up to 500-ton ingots. In 2008 Chinese manufacturers set an ambitious target for around 2015: production of 20 or more sets of pressure vessels and steam generators per year. European and US industry executives that have been working with Chinese firms on the issue believe that such a production rate cannot be achieved until much later. Until recently only one Chinese company, China Erzhong, had ASME certificates for nuclear forgings, a key precondition for exports; but the size is limited to 600 MW pressure vessels. In early June 2009 Shandong Nuclear Power Equipment Manufacturing Co announced that it got the ASME certification for the manufacturing of AP1000 pressure vessels.[105] The first four AP1000 vessels for the Chinese market were ordered from a manufacturer in Korea. The 1,000 MW size still remains far short of the 1,600 MW vessels for the EPR.

---

[99] Most of the large nuclear plants under construction or in planning have four steam generators.
[100] See CPDP, Compte Rendu du Débat Public EPR "Tête de série", Paris, 29 November 2005.
[101] Nucleonics Week, 8 November 2007.
[102] AREVA, "AREVA invests in Le Creusot to manufacture EPR reactor vessels in France", Press Release, 3 July 2008.
[103] AREVA, "AREVA launches the Chalon 1300 plan", 2 April 2009.
[104] AREVA has already shelved certain projects including, in November 2008, the Midwest uranium mining project in Saskatchewan, Canada.
[105] WNN, "Accreditation for Chinese nuclear components", 5 June 2009.

The nuclear power sector will have to continue to compete with other industries for new forge capacity. Over 90% of the forgings for coal fired plants beyond 600 MW are imported into China, mainly from Japan.[106]

- The **Russian** heavy component manufacturer ZiO-Podolsk, a subsidiary of Atomenergomash, is reported to be investing 2.9 billion roubles (€65 million) by 2015 to enlarge its capacities to the equivalent of four nuclear island sets per year.[107]
- In early 2009 the **Spanish** company ENSA signed a strategic agreement with GE-Hitachi Nuclear Energy (GEH) for the manufacturing of pressure vessels for Advanced Boiling Water Reactors (ABWR) and Economic Simplified Boiling Water Reactors (ESBWR). In February 2009 JSW delivered the first of six forgings for an ESBWR. ENSA does not expect to complete the pressure vessel until 2012.
- In the **USA**, Westinghouse has signed contracts with Chicago Bridge & Iron (CB&I) for the fabrication of four AP1000 pressure vessels. CB&I claims it has fabricated 75% of the operating US reactor vessels and intends to rebuild capacity. Deliveries are planned for between 2014 and 2018.[108] The time lags illustrate the long lead-times involved.
- In the **UK** the nuclear industry is desperately looking for assistance in gaining back nuclear competence. The outcome of the tender process for the Finnish EPR at Olkiluoto was a big blow to the British industry. Less than 1% of the 2,183 companies involved are based in the UK. AREVA has indicated it is willing to assist the British industry in rebuilding qualification.[109] Prime Minister Brown visited the Sheffield based Forgemasters in May 2009. However, no decision has yet been made on whether the company will receive the requested state subsidy of over 20% of the estimated investment cost of £140 million for a 15,000-ton press. The upgrade would enable it to compete with the most exclusive circle of nuclear forges in the world.[110]

The nuclear manufacturing industry is clearly in a state of profound reorganization and up-grading. Investments in heavy equipment manufacturing capacity are very capital intensive. Manufacturers will not go ahead with investments worth hundreds of millions of dollars if they do not have firm orders for several years ahead. However, the current decline in electricity consumption, limited government support, coupled with the growth in the renewable energy market, creates uncertainty for investors in the viability of new nuclear power projects. The recent cancellations of advanced projects in South Africa, Canada and the USA as well as repeated delays in many other projects are not prone either, to establish the indispensable confidence level for the necessary capital-intensive investments.

II.6. Status and Trends in Nuclear Competence

The aging workforce issue is keeping countless CEOs awake at night.
Eric Schmitt, Capgemini[111]

Investment and construction ratios of the 1980s cannot simply be repeated thirty years later.[112] The nuclear industry and utilities face challenges in a radically changed industrial environment. Today the sector, public or private, has to deal with waste management and decommissioning expenses that far outweigh estimates of the past, even if the lion's share is often covered through public funds. It also has to compete with a largely modernized gas and coal sector and with new powerful

[106] Paragraph based on Mark Hibbs, "Chinese equipment fabricators set ambitious capacity targets", Nucleonics Week, 22 May 2008.
[107] WNN, "Russian heavy equipment manufacturer ZiO-Podolsk is increasing capacity to be able to produce four nuclear equipment sets per year", 9 March 2009.
[108] WNN, "More AP1000 containment vessels", 19 December 2008.
[109] The Times, "British suppliers risk missing out on nuclear revival", 3 April 2009.
[110] Financial Times, "Manufacturer hopes to forge £30m nuclear plan", 24 November 2009.
[111] Eric Schmitt, "Preparing for the Nuclear Power Renaissance", Capgemini, March 2008.
[112] Also, the repetition of the history of cancelled projects, bankrupt utilities and cost overruns, especially in the USA, could hardly be a goal for the current nuclear industry.

competitors in the new and renewable energy sector.[113] In particular, it has to face the problems of rapid loss of construction and operating competence.

Several assessments have confirmed the skills gap as an international problem.

In 2000 the **OECD's Nuclear Energy Agency (NEA)** in a 16-country survey reached an alarming conclusion:

> In most countries there are now fewer comprehensive, high-quality nuclear technology programmes at universities than before. The ability of universities to attract top-quality students to those programmes, meet future staffing requirements of the nuclear industry, and conduct leading-edge research in nuclear topics is becoming seriously compromised. (…) Unless something is done to arrest it, this downward spiral of declining student interest and academic opportunities will continue.[114]

The **IAEA** launched a number of initiatives in order to tackle the skills and competence issue under the term "Nuclear Knowledge Management".[115] In 2004 it set up an international conference on nuclear knowledge management that provided a helpful overview with a number of explicit country reports.[116] However, while some of the presentations provided interesting background (see hereunder), conclusions and recommendations remained very general in nature ("IAEA Secretariat and IAEA Member States must take all possible steps towards nuclear knowledge preservation, dissemination and sharing through effective participation of experts and individuals"). In 2007 the IAEA organized a second international event on knowledge management.[117] An IAEA staff contribution still identifies "reliable supply of competent workforce – one of the biggest challenges for the entire nuclear power industry".[118] The findings and recommendations by the rapporteur note the "growing importance of this topic" and despite a rebound in nuclear energy enrolment, "people are likely to be the worst bottleneck. Even in 'established' nuclear countries, there are generation gaps". The conference rapporteur recommends that the IAEA and NEA "'advertise' the renaissance, to attract young talents". And he failed to recall a Young Generation Network survey that found that over 40% of young professionals in the nuclear industry find their jobs merely "okay" to "very disappointing".[119]

A 2004 **NEA** study recognizes that more students graduate in nuclear matters than before but that studies in member countries have shown that "in spite of the myriad initiatives underway in the area of nuclear education and training, more engineers and scientists having nuclear knowledge are required than are graduating."[120] In-house training is not necessarily an option anymore as the general competition stiffens:

> As fewer and fewer high quality technical graduates become available, the competition for them is ever greater and there are signs already that the nuclear industry is losing out. (…) As well as losing out directly the industry loses out indirectly because this also means that the ability of organisations to circumvent the shortage of graduates with a sizeable nuclear component to their degree by hiring good quality technical graduates and training them in house is compromised. (…) The provision of necessary specialist nuclear education is under threat.[121]

---

[113] See Amory B. Lovins' analysis "Nuclear Power: Climate Fix or Folly?", April 2008, http://www.rmi.org/images/PDFs/Energy/E09-01_NuclPwrClimFixFolly1i09.pdf .
[114] OECD-NEA, "Nuclear Education – Cause for Concern?", NEA Report 2428, Paris, 2000.
[115] See www.iaea.org/inisnkm/nkm/ for details.
[116] The presentations are available at http://www.iaea.org/inisnkm/nkm/cnkm/ .
[117] See www.iaea.org/inisnkm/nkm/conference2007.html for conference presentations.
[118] A. Kazennov et al., "Evolution of NPP personnel training: trends, new needs and performance improvement focus", IAEA, presentation at IAEA, International Conference on Knowledge Management in Nuclear Facilities, Vienna, Austria, 18-21 June 2007.
[119]Betrand Barré, "Findings and Recommendations", Conference Rapporteur, IAEA, International Conference on Knowledge Management in Nuclear Facilities, Vienna, Austria, 18-21 June 2007.
[120] OECD-NEA, "Nuclear Competence Building", NEA Report 5588, Paris, 2004.
[121] Ibidem.

In 2007 the NEA Steering Committee issued an unusual, unanimous statement "regarding a government role in ensuring qualified human resources in the nuclear field", addressed to all NEA member governments. The tone remains as alarming as in its analysis from seven years earlier:

> The sector is witnessing a loss of expertise following downsizing to reduce salary costs, a loss of research facilities to reduce operating costs, and a decline in support to universities to reduce overheads.[122]

The NEA recommends that governments should carry out regular assessments of human resource supply and demand in the nuclear field; stakeholders should cooperate on the national and international scale to enhance nuclear education; and large international R&D programs should be supported in order to attract young graduates and professionals into the field.

The Indian nuclear executive Shreyans K. Jain, then newly elected President of the World Association of Nuclear Operators (**WANO**), stated in his acceptance speech in September 2007:

> The key issues that demand world attention today, in my opinion, are those related to the ageing work force, ageing reactors, global increase in the fleet of nuclear power plants and probably, the hesitation of the younger generation to embrace this technology as a profession. It is also a fact that with the increased turnover of work force, the invaluable tacit knowledge, built up through years of experience, is steadily being lost. It is therefore absolutely essential for all of us to put on our thinking caps and evolve methods to tackle these serious issues.[123]

A March 2008 **Capgemini** report concluded:

> The stage is set for a worldwide 'talent war' in all industries and nuclear power will need to attract its reasonable share in order to support the renaissance. (…) Stimulating interest among the Millennial workforce to come to the nuclear power sector and ramping up university programs will take five to ten years, but the industry will probably need to raise attention through a new reactor concept before such interest occurs.[124]

To date the NEA has not updated its 2004 report, but intends to do so by the end of 2010.[125] Surprisingly the **European Nuclear Education Network (ENEN)** has not produced any up-to-date international statistical data on nuclear education either. ENEN, based at the French Atomic Energy Commission (CEA) in France, was set up in 2003 with the mission to preserve and further develop expertise in the nuclear fields by higher education and training, and counts 51 member organizations. Accordingly ENEN has set up a European MSc in Nuclear Engineering. In September 2008 ENEN summed up the situation five years after its founding:

> At present, all stakeholders of the nuclear community in Europe (vendors, utilities, suppliers, regulators, national and European bodies, safety organizations, consultants, etc.) have a tremendous demand for qualified junior engineers – and basically all stakeholders have serious difficulties in meeting their demands.[126]

The **World Nuclear University (WNU)** was started up in 2003 with the mission to enhance international education and leadership in the peaceful applications of nuclear science and technology. The WNU has four founding supporters, the IAEA, the NEA, WANO and WNA. The WNU organizes an annual six-week summer institute at Oxford University, UK, for about 100 participants under age 35, "selected from among promising young nuclear professionals who

---

[122] OECD-NEA, "Statement by the NEA Steering Committee for Nuclear Energy regarding a government role in ensuring qualified human resources in the nuclear field", 18 October 2007.

[123] WANO, "Dr S.K. Jain became the 10th President of WANO at the recent Biennial General Meeting in Chicago", 25 September 2007, http://www.wano.org.uk/wano/Contact_Info/WanoPresident.asp .

[124] Eric Schmitt, "Preparing for the Nuclear Power Renaissance", Capgemini, March 2008.

[125] Stan Gordelier, Head of Nuclear Development Division, OECD-NEA, private communication, e-mail dated 7 May 2009.

[126] Csaba Sükösd, "European approaches and initiatives for Nuclear Education & Training and Knowledge Management", ENEN, presentation at the IAEA School of Nuclear Knowledge Management, Triest, Italy, 5 September 2008.

demonstrate strong leadership potential".[127] The WNU could not provide any international statistics on the demand for, and offers to, nuclear experts.

In the absence of available international data the following are exemplary case studies on the USA, France and the UK as well as short notes on two further G8 countries Germany and Japan.

The **US nuclear power industry** will need to attract about 26,000 new employees over the next 10 years for existing facilities. These estimates do not include additional resources necessary to support new plants.[128] For the first time in 30 years the **US NRC** has to review new license applications. As for US federal employees in general, a third of the NRC staff is eligible for retirement over the next five years. In fact 15% of the NRC workforce is *currently* retirement eligible. "The obvious point here is that many of the NRC staff involved in those original licensing reviews have retired or are rapidly approaching retirement", says Commissioner Kristine L. Svinicki.[129]

Keynote speakers at the American Nuclear Society's 2007 Annual Meeting pointed out that "a nuclear renaissance is far from being a sure thing". [130] Art Stall, Florida Power & Light Company's senior vice president and chief nuclear officer, told the event's opening plenary that the euphoria that has surrounded the nuclear renaissance has been slowed down by the realities of the challenges that are involved in building new nuclear power plants. "Stall said one of the biggest challenges is finding qualified people, including craft labor, technicians, engineers and scientists, to support construction and operation. He pointed out that 40% of the current nuclear power plant workers are eligible for retirement within the next five years.[131] Furthermore, he said only 8% of the current nuclear plant workforce is under 32 years old. While technical and engineering college graduate numbers are increasing, Stall said that there is much competition from other industries for these graduates and the nuclear industry must become creative if it is going to entice these graduates to enter and remain in the nuclear field."[132]

In 1980, there were about 65 university nuclear engineering programs operating in the **USA.** In 2008, there were only 31. The entire utility industry is hunting students at the university doors before they even graduate. "Westinghouse looks for qualified third and fourth year college students at career fairs, and by posting internship opportunities on the corporate website, in newspapers and trade journals, and through various colleges and universities", explains Steve Tritch, President and CEO of Westinghouse.[133] Starting from a virtual hiring freeze in the 1980s followed by a slow resumption by the end of the 1990s, the company jumpstarted the process in the period 2001-2005 with 400 new hires per year. The rate increased to 500 hires in 2006, a level that shall be maintained over the coming years. However, candidates are difficult to identify and Westinghouse is looking for new staff in about 25 colleges and universities throughout the world. The NRC also hires engineering students months before they even get the bachelor degree.[134]

[127] WNU, "Announcement of the Fifth Annual WNU Summer Institute, 5 July – 15 August 2009", September 2008

[128] Eric Schmitt, "Preparing for the Nuclear Power Renaissance", Capgemini, March 2008.

[129] Kristine L. Svinicki, "The Nuclear Renaissance in America", NRC NEWS, Paris, 4 May 2009.

[130] Teresa Hansen, "Nuclear renaissance faces formidable challenges", Power Engineering, see http://pepei.pennnet.com/Articles/Article_Display.cfm?ARTICLE_ID=297569&p=6&dcmp=NPNews .

[131] AREVA's US recruiting official puts the figure at 27% within the next three years (see http://marketplace.publicradio.org/display/web/2007/04/26/a_missing_generation_of_nuclear_energy_workers/).

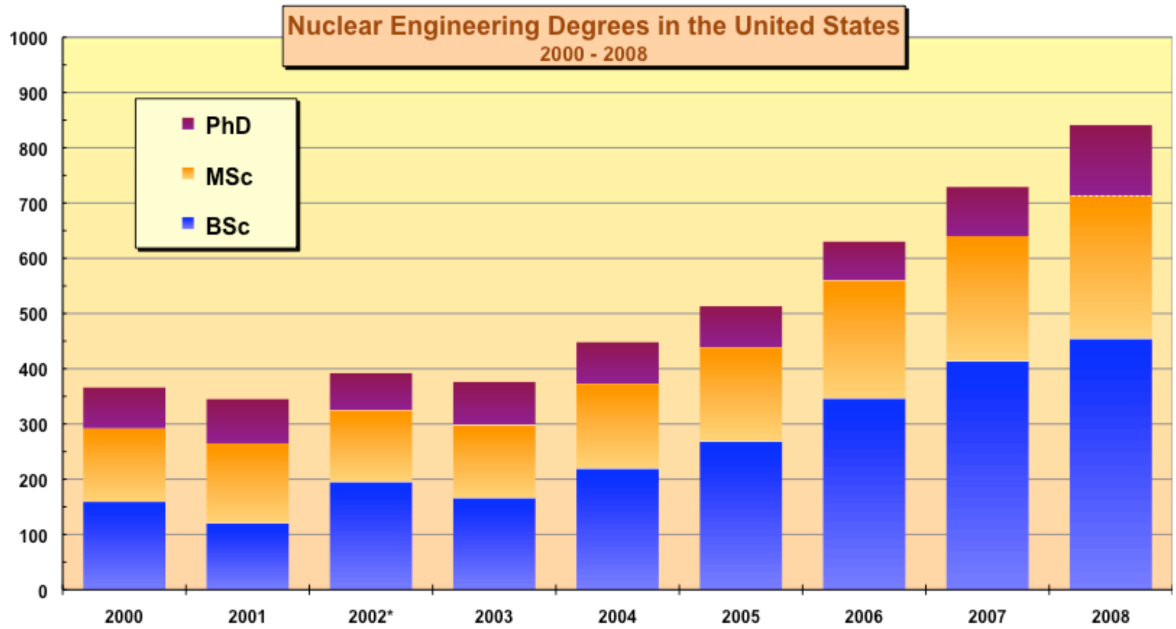
[132] Teresa Hansen, op.cit.

[133] Steve Tritch and Jack Lanzoni, "The Nuclear Renaissance: A Challenging Opportunity", paper presented at the WNA Annual Conference *Building the Nuclear Future, Challenges and Opportunities*, 7 September 2006.

[134] The NRC has also hired one of the most prominent independent critical nuclear experts in the USA, David Lochbaum, former head of nuclear studies with the Union of Concerned Scientists.

According to a national assessment carried out by the Oak Ridge Institute for Science and Education (ORISE)[135], over 1,300 students enrolled in nuclear engineering studies in the USA in 2008, almost triple the 2000 number, but 2% lower than in 2007. The number of Bachelor of Sciences (BSc) degrees for 2008 is, with 454, the highest reported in 20 years but represents the lowest annual increase in five years. In addition, 260 Master of Science (MSc) and 127 Doctorate (PhD) degrees were delivered (see Graph 11).

Graph 11: Nuclear Engineering Graduates in the USA for the Years 2000 - 2008



© Mycle Schneider Consulting *Source: ORISE 2009*

A strong increase in the number of nuclear graduates, more than doubling since the year 2000, does not say anything about the career plans of the graduates. Nuclear utilities attract a remarkably low share of nuclear graduates: less than 19% of BSc, 8% of MSc and 3% of PhD graduates, according to the ORISE survey, in spite of the fact that the utilities in 2008 hired three times as many BSc graduates than on average since 2000.

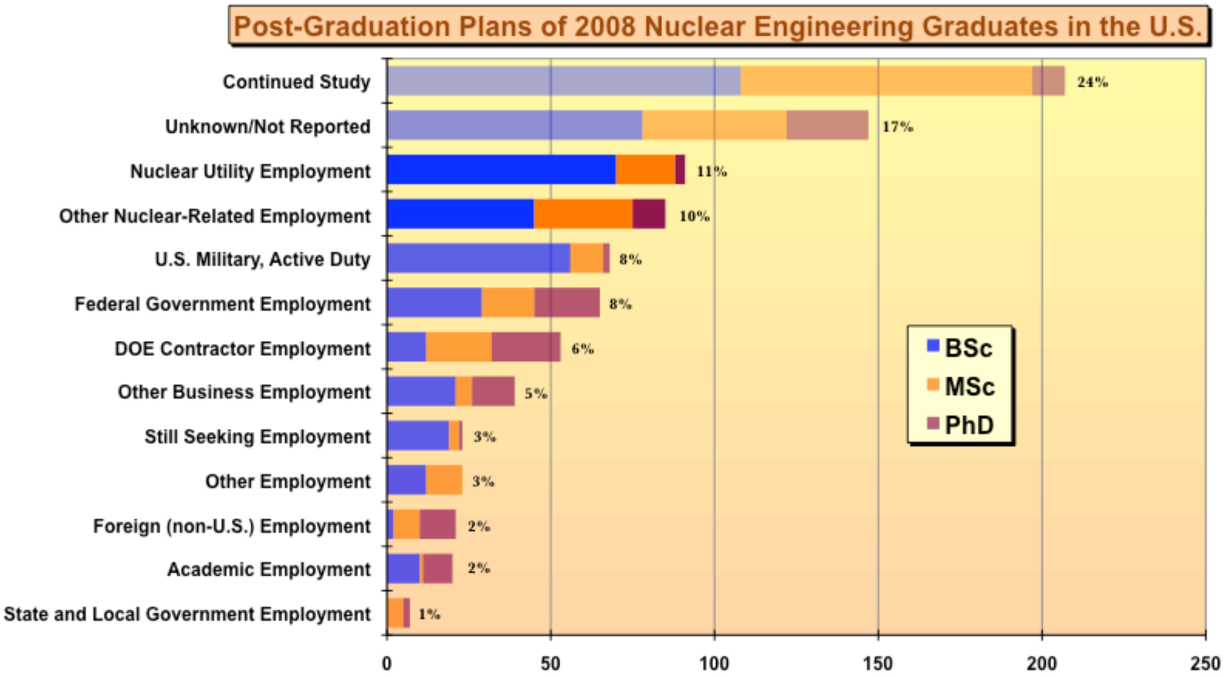
If one adds "other nuclear-related employment", only 169 (about one quarter) of the 2008 US nuclear graduates actually enter, or plan to enter, the nuclear industry in the USA (see Graph 12). The figure is to be compared to the 500 graduates that Westinghouse alone is planning to hire annually.

A nuclear power plant construction infrastructure assessment carried out in 2005 on behalf of the US Department of Energy concludes that not only are engineers lacking; but also qualified boilermakers, pipefitters, electricians, rebar ironworkers, health physicists, operators and maintenance personnel are all "in short supply".[136]

[135] Oak Ridge Institute for Science and Education (ORISE), "Nuclear Engineering Enrollments and Degrees Survey – 2008 Data", commissioned by the NRC, ORISE – Science Education Programs, NE 64, March 2009.

[136] MPR, "DOE NP2010 Nuclear Power Plant Construction Infrastructure Assessment", 21 October 2005.

Graph 12: Career Projections by 2008 Nuclear Engineering Graduates in the USA



© Mycle Schneider Consulting *Source: ORISE 2009*

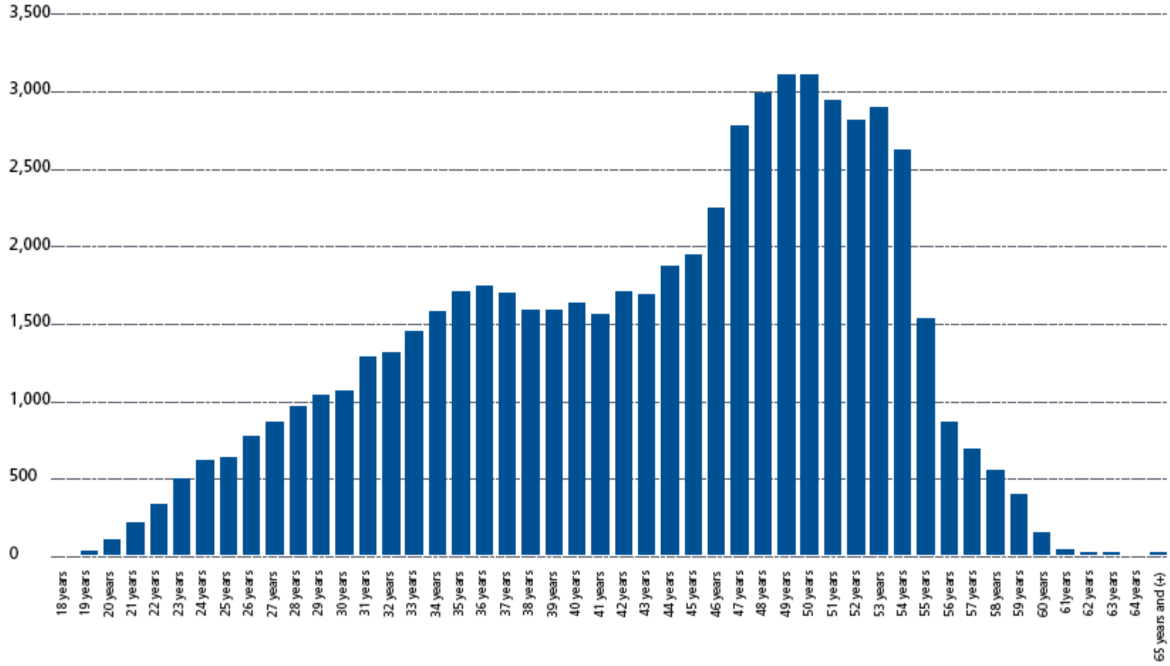
In **France**, the situation is quite similar to other countries. About 40% of the national utility EDF's current staff in reactor operation and maintenance is expected to retire by 2015. In its Reference Report 2008 EDF states that "about half" of the operational and maintenance staff in production and engineering will retire between 2008 and 2015. EDF speaks clearly of an "unbalanced age structure" since more than 65% of the workforce is over 40 (see Graph 13) and introduces the problem of young skilled workers explicitly as risk factor:

> The EDF group will do its utmost to recruit, retain, redeploy or renew these staff and skills in time and under satisfactory conditions. However, it cannot guarantee the measures adopted will always prove totally adequate, which may have an impact on its business and financial results.[137]

Starting in 2008, the utility has a hiring target of 500 engineers annually for the nuclear sector alone. In mid May 2009, EDF advertised for example open positions for 50 operator trainer engineers.[138] Where such a large number of experienced nuclear operators capable of training others could possibly come from remains a mystery. Reactor builder AREVA tried to hire 400 engineers in 2006 and another 750 in 2007. The level of success of the hiring efforts is not known. AREVA, like other nuclear companies, has formed partnerships with certain universities and engineering schools and 'shepherds' students through their studies. AREVA's strategic marketing specialist Liz Smith explains that students can work effectively during studies and immediately upon graduation. "The strong bonds they form with AREVA during their studies increase loyalty to the company".[139] AREVA calls it "growing its own engineers", starting in middle and high school and through a "unique college program in order to meet tomorrow's demand for resources".

[137] EDF-Group, "2008 Document de Référence – Leading the energy change", April 2009.
[138] Open positions advertised on www.edfrecrute.com on 15 May 2009.
[139] Liz Smith, "Growing Engineers through Education", AREVA, abstract of presentation at "Nuclear Revival: Maintaining Key Competencies For the Nuclear Energy: A Challenge and an Opportunity for Diversity Development", WIN Global Annual Meeting, Marseilles France, 26-30 May 2008.

Graph 13: Workforce Age Structure at EDF and EDF subsidiary RTE-EDF Transport (as of the end of 2008)



Source: RTE, Document de Référence 2008", April 2008

It is obvious that the biggest share of newly hired staff is not trained nuclear engineers or other graduated nuclear scientists. There are no official statistics on the overall number of graduates in nuclear science and technology in France but it is estimated at around 300. The CEA affiliated national Institute for Nuclear Sciences and Techniques (INSTN), the most important nuclear education institution in France, has produced fewer than 70 nuclear graduates per year. EDF first called upon INSTN to double the number of graduates over the coming years[140] and then to multiply the number by five to ten "as quickly as possible".[141] The head of nuclear studies at INSTN has indicated a more modest target of 150 graduates per year.[142] INSTN has been able to raise the number of graduates from a 30-year low of 41 in 2003 to a 30-year high of 108 in 2009 (see Graph 13), about one third of the national nuclear graduate output, but far short of the estimated annual need of some 1,200 to 1,500 graduates.

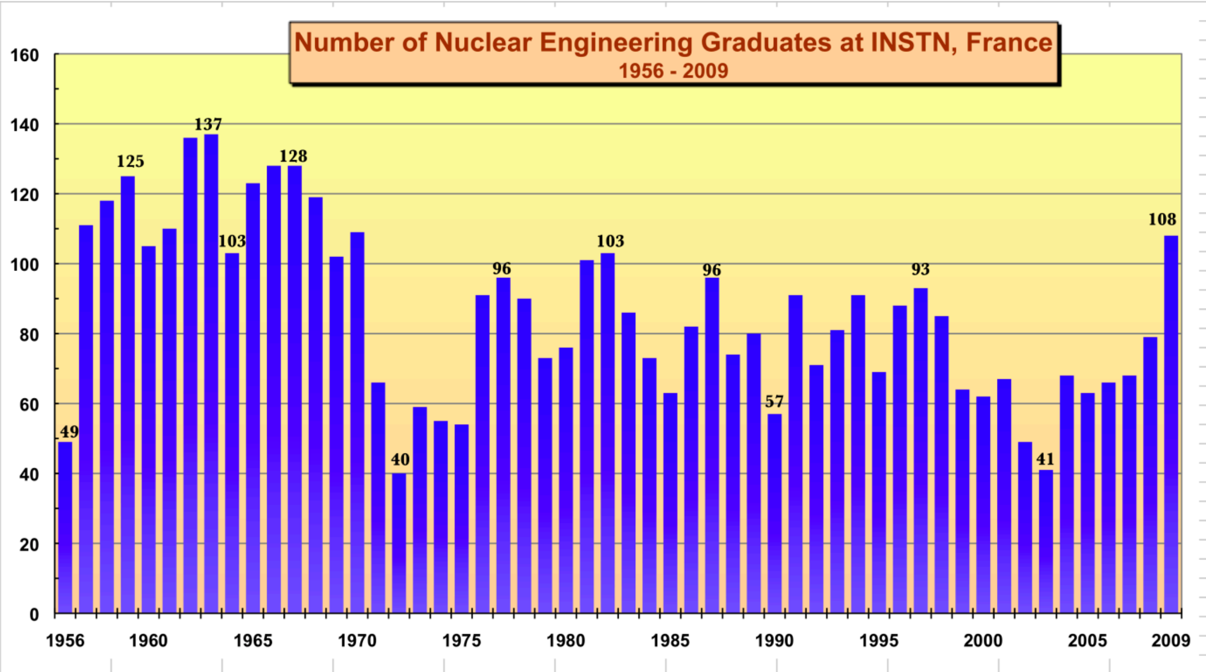
The French nuclear industry has been very concerned for a number of years about the lack of motivation of young students. While a number of initiatives have been taken to stimulate coordination of recruiting and training of students, the most spectacular measure is undoubtedly the construction of the Flamanville-3 reactor. While the EPR "show case at home" was an important part of the decision, the investment was mainly motivated by the growing concern within the nuclear industry and the national operator to maintain key competences in the sector and thus succeed in motivating young talent. It was feared that without a major "project" it would be difficult to convince the young generation of an imminent revival and thus the guaranteed long-term future of the nuclear industry (see also part IV).

[140] GIGA, "L'industrie nucléaire française : perspectives, métiers / Le besoin d'EDF en 2008", October 2007, http://www.giga-asso.com/fr/public/lindustrienucleairefranc/emploisperspectives1.html?PHPSESSID=2f7kmsonapea7ihktecmvdks45 .

[141] Marie-Madeleine Sève, "Le plan d'EDF pour faire le plein d'ingénieurs", Management, April 2008.

[142] Bruno Tarride, Letter to Bernard Bourret, dated 24 October 2008.

Graph 14: Number of Nuclear Engineering Graduates from INSTN, France, 1956-2009



Source: CEA-INSTN, 2009

The **French Nuclear Safety Authority (ASN)** apparently is not encountering staffing problems and has considerably increased the number of employees from 312 in 2003 to 436 (+40%) at the end of 2008. Over the same time period the share of civil servants also increased from two thirds to 78% of total staff.[143] The remaining employees are either made available by other institutions like the CEA or work on a contractual basis. The civil servant status certainly shields ASN to some extent from attempts by utilities or industry to entice away staff.

The **French Institute for Radiation Protection and Nuclear Safety (IRSN)** that serves as Technical Support Organisation (TSO) to ASN, reports an annual turnover of 3% to 6%. IRSN has hired between 52 and 79 (in 2008) engineer-level staff per year since 2004. IRSN human resources director Patricia de la Morlais explains that they hire every year "a few beginners, young professionals with three to five year experience and some experienced professionals".[144] According to other sources, IRSN has lost 59 experienced experts to the industry over the last few years. While de la Morlais did not explicitly confirm the figure, she stated that "it is not without interest for [nuclear] safety that experienced experts from IRSN, within reasonable numbers, pursue their careers within the industry or nuclear operators".[145] However, the mechanism raises concern in particular in the case of smaller safety authorities and TSOs in other countries that cannot compete with salary level and career perspectives in the nuclear industry and utility sector.

In the **UK**, as of 2002, there was not a single undergraduate course in nuclear engineering left. A study of Nuclear and Radiological Skills by the Department of Trade and Industry reported the same year that the power, fuel, defense and clean-up sub-sectors of the nuclear industry would require approximately 1,000 graduates a year until 2017. Of these, about 700 would be replacements for retirements and 300 in response to the growth in nuclear clean-up. Six years later, the head of the Nuclear Installations Inspectorate confirmed in oral evidence that he was struggling to recruit sufficient inspectors. He stated in July 2008 that he had 153 full-time equivalent inspectors and was expecting to recruit about 20 more people. He added: "For existing predictive business *excluding new build* I need 192".[146] A 2009 UK House of Commons nuclear skills assessment "found plenty of evidence to suggest that there are very real skills shortages in the

[143] Emmanuel Bouchot, personal communication, e-mail, dated 29 April 2009.
[144] Patricia de la Morlais, personal communication, e-mail, dated 4 May 2009.
[145] Ibidem.
[146] Ibidem.

nuclear industry”. [147] As in other countries, the nuclear industry will have to compete with other economic sectors. Forty percent of National Grid’s workforce will reach retirement age over the next 10–15 years. The UK, the House of Commons learned, faces a “crucial skills shortage from 2015 to 2025 that will make power supplies less reliable and more expensive”.[148]

The National Skills Academy for Nuclear estimated in February 2009 that the UK nuclear industry needs to recruit between 590 to 970 graduates and 270 to 450 skilled trades personnel annually over the next ten years. For Philip Thomas, Chairman of the Nuclear Academia-Industry Liaison Society (NAILS), “the risk is not so much that the nuclear companies will be unable to recruit sufficient numbers, but that future recruits will not match the very high quality the nuclear industry has been used to” and “the absence of a market for a BEng/MEng in nuclear engineering serves to confirm that nuclear energy carries no buzz of excitement for new students, making it all the harder for it to attract the brightest and best.”[149]

In **Germany** the nuclear competence situation is dramatic. A 2004 analysis of the nuclear education and workforce development in the country showed that the situation continues to erode rapidly. Employment is expected to decline in the nuclear sector - including in the reactor building and maintenance industry - by about 10% to 6,250 jobs in 2010. These still include 1,670 hires, while the number of academic institutions teaching nuclear related matters is expected to further decline from 22 in 2000 to 10 in 2005 and only five in 2010.[150] While 46 students obtained their nuclear diplomas in 1993, there were zero graduates in 1998. In fact, between the end of 1997 and the end of 2002, only two students successfully graduated in a nuclear major (see Graph 14). In total about 50 students from other majors continued to attend lectures in nuclear matters. It is clear that Germany will face a dramatic shortage of trained staff, whether in industry, utilities, research or public safety and radiation protection authorities.[151]

In order to combat the obvious nuclear competence bottleneck in Germany, in March 2000 the Alliance for Competence in Nuclear Technology (Kompetenzverbund Kerntechnik) that pulls together nuclear research centres, universities, TSOs and federal ministries was established. The Alliance has not updated figures on its website since 2004 and refuses to communicate any more recent figures on the development of nuclear education in Germany.[152] However, according to a recent report in *Nature*, in February 2009 AREVA established a "Nuclear Professional School" at the Karlsruhe Institute of Technology (KIT) providing post-graduate training in various nuclear specialties. According to *Nature,* "the 30 PhD students enrolled at the school at any one time are paid by AREVA and have guarantees that they will be employed when their training is completed."[153]

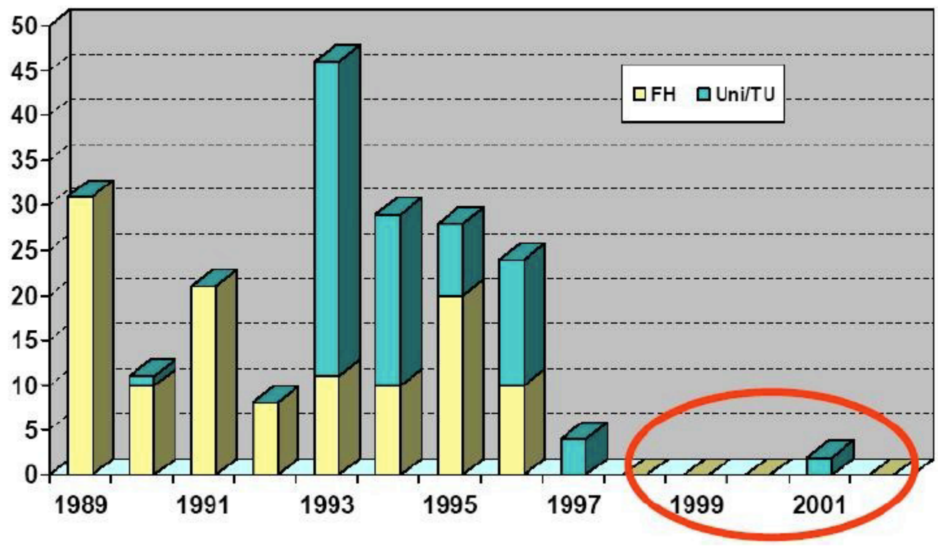
As Lothar Hahn, managing director of the German TSO GRS (Society for Reactor Safety), points out, the consequences could be serious:

> First studies indicate that deficiencies in maintaining knowledge at state-of-the-art levels and a subsequent degradation in education and training of operating personnel may endanger the safe operation of nuclear installations. Furthermore, knowledge

[147] Innovation, Universities, Science and Skills Committee, “Engineering: turning ideas into reality”, House of Commons, Fourth Report of Session 2008-09, Volume I, published 27 March 2009.
[148] Ibidem.
[149] Philip Thomas, “The Future Availability of Graduate Skills”, presentation to the BNIF/BNES Conference *Energy Choices*, 5 December 2002.
[150] P. Fritz and B. Kuczera, “Kompetenzverbund Kerntechnik – Eine Zwischenbilanz über die Jahre 2000 bis 2004”, Atomwirtschaft, June 2004.
[151] Lothar Hahn, presentation at the IAEA sponsored “International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development”, 7-10 September 2004.
[152] Explicit refusal by spokesperson Joachim Knebel, private communication, 24 April 2009; Knebel argued that, while remarkable, the results of the Alliance were based exclusively on third party financing and covered issues that were not supported by public funding including new reactor lines, fast breeders and “closed fuel cycle” issues. The German legislation prohibits public funding for these issues.
[153] Nature, "Going Nuclear – Workforce shortages could slow growth of an industry poised for a comeback", 7 May 2009.

deficits at authorities and expert organisations due to a lack of qualified successors to retired experts have been depicted as an imminent threat to the qualified supervision of reactor plants and thereby to safe plant operation.[154]

Graph 15: Graduates in Nuclear Technology in Germany 1989-2002



Source: Lothar Hahn, GRS, 2004
Note: FH stands for Fachhochschule (Technical College); Uni/TU designates general and Technical Universities

In **Japan** the situation is similar to that of other large nuclear countries. Although organized in a much more centralized way than a country like Germany, Japan is struggling to obtain results on structural changes that guarantee long term nuclear competence where it is needed. The Japanese contribution to the 2004 IAEA international conference on nuclear knowledge was surprisingly blunt:

> At present, many things are being done to attract and retain people in nuclear areas, to educate and train them, but these activities are neither systematic nor adequately organized. It is necessary to provide means whereby anyone who wants to study nuclear engineering has access to a high level of education, notwithstanding geographical or time considerations. Ideally, the foundation for nuclear understanding should be part of education at the elementary and secondary levels. The trend in Japan, unfortunately, is to eliminate or minimize science courses, and a positive view of nuclear energy is rarely presented as a result of publicity about accidents and other problems. The entire nuclear industry must actively tackle the issue of educating the next generation.[155]

In conclusion, the nuclear skills and competence gap is an internationally well established and recognized problem. Numerous initiatives have been launched on national and international scale in order to reverse the trend. However, apparently, the results remain far short of the necessary employment levels for all stakeholders involved. The number of nuclear graduates and technicians is insufficient and many graduates do not enter or quickly leave the nuclear sector. In-house training only partially compensates for the problem since the nuclear industry has to compete in a harsh market environment with many other sectors that lack scientists, engineers and technicians.

---

[154] Lothar Hahn, "Knowledge Management for Assuring High Standards in Nuclear Safety", paper presented at the IAEA sponsored "International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development", 7-10 September 2004.

[155] H.Mori, K.Miura, "Preservation of Nuclear Talented Experts in Japan by Cooperation of Industries, Research Institutes and Universities", presentation at the IAEA sponsored "International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development", 7-10 September 2004.

III. Economic Analysis

III.1. Introduction

When Lewis Strauss spoke in 1954 of power 'too cheap to meter'[156], it was a phrase that was quickly embedded in the psyche of the public. Today, despite ample evidence to the contrary, many people still assume nuclear power is cheap and that the barriers to its take-up are largely those of public opinion and opposition. The assumption of low cost is one that electric utilities that own nuclear power plants, however expensive, are generally happy to go along with and promote — if only to prevent having to acknowledge that they made bad investment decisions in the past.

There were early hints that nuclear was actually quite expensive. These came through large cost overruns and project cancellations even in a regulated utility environment. However, it is only recently that nuclear economics have begun to face the market test. Thus far, this test has come mostly through financial decisions to build non-nuclear assets. The first reactor order in an ostensibly fully liberalized electricity market did not occur until December 2003 with the signing of construction contracts for the Olkiluoto reactor in Finland. However, as shown in section III.3.1.1, far from competing in the liberalized market, the terms of the deal deliberately avoid exposure to the competitive market. With regulated markets, electric utilities were monopolies with much greater (though not unlimited) flexibility to pass along whatever costs they incurred to consumers. Many other costs were effectively borne by the taxpayer. This allowed a complacency in regard to plant economics that is supposed to no longer exist in a deregulated market. Investors now bear a much higher likelihood of having to absorb the losses should their initial market or cost assumptions turn out to be wrong.

Evidence began to emerge from the late 1970s onwards that nuclear power was not the cheap option it was portrayed to be. In the USA, the economic regulatory system required extensive disclosure of costs by utilities, and limited their ability to recover those costs from ratepayers. Only funds that regulators agreed had been spent well (assets that were 'used and useful' and costs 'prudently incurred') were eligible for cost recovery. By the late 1970s, nuclear power plants were coming on line not only late but often at several times their estimated cost. When this happened, the over-budget reactors caused huge increases in electricity tariffs (so-called 'rate shock') within the regions they served. Regulators became increasingly unwilling to allow the utilities to recover these excessive costs. Often, they forced at least a portion of the cost overruns to be paid not by ratepayers, but out of the regulated profit margins of the utility. This shift quickly brought nuclear ordering to a halt and led to more than 100 cancellations of plants at various stages in the construction process.[157] Bankers were simply unwilling to lend money to utilities because of the risk of default. Utilities were prepared to make deals with regulators that allowed them to recover at least some of the cost of these abandoned plants provided they did not proceed with them. This is an important contrast with deregulated markets as well, since abandoned capital infrastructure projects bring in no revenues at all to the investor.

Further evidence of the poor economics of nuclear came with the attempt to privatize Britain's nuclear power plants in 1987-90. The costs associated with these plants were determined more rigorously by the private sector and investors made it clear they would be unwilling to buy the nuclear assets, partly because the operating costs alone were about double the expected market price for electricity. Interest was also low because the company that bought the existing plants would have been expected to build four new nuclear plants as well - a risk the new owners were unwilling to take. The lack of buyers led the UK government to retain these plants within the public sector. Over the next six years, plant capacity factors and market conditions improved enough to bring at least operating costs below revenues. As a result, the most modern of these plants were privatized in 1996, though at a price constituting a small fraction of the funds invested to date.

[156] Lewis L. Strauss, Speech to the National Association of Science Writers, New York City, 16 September 1954.

[157] All orders after 1973 were subsequently cancelled. Over the years, in total 138 unit orders have been cancelled in the USA.

At about the same time, a few US nuclear plants were closed at the instigation of the economic regulators because they believed it would be cheaper to build and operate new gas-fired plants than to continue to just operate the nuclear plants.

This evidence of high construction costs and high operating costs was often seen as a characteristic of the US and UK markets rather than as a basic feature of the nuclear fuel chain. The basis for this view was that these countries had done a poor job with their civil nuclear power programs; and that the UK relied on Advanced Gas-cooled Reactors (AGRs), a technology not used elsewhere in the world. However, as electricity markets began to be liberalized and the assumption that utilities could pass any costs they incurred on to consumers no longer applied, nuclear orders dried up in other countries as well. The cost of both debt and equity capital rose to reflect the risk inherent in the projects – a risk investors believed to be quite high. The result was very few reactor starts anywhere in the world for a period of decades.

In the past decade, however, there has been renewed interest in nuclear power plants, labeled by some the 'nuclear renaissance'. Three main factors are driving this trend. First, a new generation of nuclear power plant designs, so-called Generation III+ designs, are claimed to be more reliable and less expensive; second, there is a perceived need to increase generation from low-carbon sources to combat climate change; and third, in the absence of efficient use of electricity, there is also a need to replace a large number of base-load power plants in North America and Western Europe as they are retired.

The remainder of this section explores a number of central issues relating to nuclear economics including sharply rising build costs and sensitivity to capital costs. These factors provide important insights on how effectively new nuclear power plant construction will meet the industry-stated objectives of providing cost-effective energy security and climate change mitigation.

III.1.1. Problems of estimating and comparing nuclear costs

Construction costs for nuclear power plants have remained a central problem with the technology. While the costs to build non-nuclear power plants have generally declined a little in real terms from the mid-70s until about five years ago,[158] real nuclear construction costs have increased consistently throughout the 50-year commercial history of nuclear power. Accurately estimating the construction cost is a challenging task, as over the past couple of decades there have been few reactor orders for which reliable cost estimates have been published. Nonetheless, the information that is available illustrates that estimated costs have increased dramatically in the past decade. Other fuel chain costs, such as nuclear waste disposal and plant decommissioning, have risen even more rapidly than the costs of the plants themselves in the past two decades. Operating costs remain low relative to other forms of electric power, though they are expected to rise significantly should many additional reactors be built. Operating costs are also sensitive to the question of how much of the risk associated with possible accidents and with nuclear waste management is shifted to the public sector, rather than borne by plant owners, and through power charges, by the plant's customers.

One clear lesson from the history of nuclear power is that estimated costs are invariably less than actual costs incurred during plant construction. In addition, 'generic' estimates, such as those regularly provided by industry trade associations, are always lower than estimates provided by companies that are involved in real projects such as vendors or utilities. Finally, comparisons of reactors costs across the world are not always normalized properly, sometimes resulting in inaccurate trend comparisons.

Comparing a relatively small number of discrete plants across many countries and decades requires careful adjustments to take account of shifts (sometimes quite large ones) in inflation and exchange rates. For example, if the annual rate of inflation was 3%, over a decade, nominal prices would have increased by 34% simply because of inflation. The value of the dollar fell from November

[158] Energy Information Administration, "Impacts of Rising Construction and Equipment Costs on Energy Industries", Issues in Focus AEO2007; http://www.eia.doe.gov/oiaf/aeo/otheranalysis/cecei.html, accessed 31 March 2009.

2005 when €1 was worth US$1.17 to July 2008, when €1 was worth US$1.57. By November 2008 the value of the dollar had increased sharply so that €1 was worth US$1.27 yet by December 2008, it had fallen again to US$1.40. The shifts meant that a plant that cost US$1000/kW in November 2005 would then have cost €855/kW whereas in July 2008, the same cost would have been equivalent to €637/kW.

Another big challenge is ensuring that the data presented are really counting the same portion of the many steps needed to bring a new plant into operation. An "overnight" cost approach is frequently used to compare prices on an equal basis across projects. The metric includes the first fuel charge but does not include financing charges (which would vary according to the circumstances of the project). In determining the cost per kW, it should be the 'net' rating (i.e., net of energy used in the plant itself) of the plant that is used. Note, however, that because the financing costs associated with nuclear are higher than for other energy resources (both because the plants are deemed higher risk, and often take longer to build), overnight cost comparisons across energy options by definition will overstate the viability of nuclear projects.

Technology risk is another factor that makes comparison of plant costs more difficult. The industry often refers to these as 'first of a kind' (FOAK costs). FOAK costs apply to some extent to all technologies but because lot sizes for nuclear plants are much smaller than, for example, for airplanes, these initial costs become a much more important factor in the overall economics of a particular design. FOAK costs are sometimes included in cost estimates, while at other times the numbers presented for plants exclude these costs. The industry may have incentives to use FOAK factors to 'game' reported costs. For example, in December 2008, EDF claimed that the cost of a first of a kind plant might be double that of a 'series' unit (one of at least 10 units of the same design).[159] How far this estimate was meant as an excuse for the high cost of Flamanville-3 is not clear. However, it is likely to be an over-estimate. In most cases, development costs are recovered over several units, not just one. Another problem with the FOAK argument is that sales of more than 10 of a given reactor design are quite rare. For example, although EDF built 34 PWRs of the 900 MW design, they were actually made up of four separate sub-models. The 20 units of the 1300 MW series were of two sub-models and only four units were ever built of the 1450 model. There are also location specific factors, such as whether the plant uses sea-cooling or cooling towers (more expensive), what geological and seismic issues there are and what new transmission facilities are required. Where more than one reactor is built on a site, there is likely to be the possibility of sharing some costs and this will reduce the cost per unit.

The influential Keystone report[160] suggested that in today's market environment, later orders of a particular design may turn out to be more expensive because factors such as shortages of skills and manufacturing capacity force prices up.

All these factors mean that care should be taken in attaching any significance to price differences of less than, say, 20%, unless it is clear that all these factors have been taken account of.

III.1.2. Generation III+ plants

The nuclear industry has categorized reactor designs into four generations, with the first generation the prototypes and early commercial designs, and the second the majority of plants ordered from the mid 1960s onwards. The third generation represents designs made available from about 1980 onwards, while a fourth generation is not expected to be commercially available for 20 years or more. Within Generation III, there is now a Generation III+, which has become available since about 2000, and the Generation III+ designs are the ones on which the hopes for the 'nuclear renaissance' are based. There are no hard and fast definitions about what criteria should be used to define what category a particular design falls into. However, Generation III+ is said to be distinguished from Generation III by the greater use of 'passive safety' systems – where

[159] Nucleonics Week, "EDF: Flamanville-3 cost rise due to inflation, technical/regulatory changes", 11 December 2008, p 1.

[160] The Keystone Center, "Nuclear Power Joint Fact-Finding", Keystone Center, Keystone, 2007; http://www.ne.doe.gov/pdfpdfFi/rpt_KeystoneReportNKeystoneReportNuclearPowKey_2007.pdf , accessed on 3 April 2009.

operational safety in the plant relies more on inherent laws of physics rather than on active engineered systems, such as emergency core cooling systems.

Five designs are being reviewed by the US safety authorities, the Nuclear Regulatory Commission (NRC). Which of these should be regarded as Generation III and which are III+ is not clear. The five designs under scrutiny by the NRC are:

- European Pressurized water Reactor (EPR)[161]. EPR is supplied by Areva NP[162]. This design has been ordered for Finland (Olkiluoto-3), France (Flamanville-3) and China (Taishan), although the first unit is not expected to be completed before 2012. It is being evaluated in the USA by the NRC and in the UK by the Nuclear Installations Inspectorate (NII)[163], although neither body is likely to complete its review before mid-2011. The outcome remains uncertain.
- Advanced Passive 1000 (AP-1000). This design is offered by Westinghouse (now owned by Toshiba) and has been ordered for China (Sanmen and Yangjiang), although construction only started in December 2008 and in April 2009 respectively. It has been approved by the NRC although some detailed issues are not expected to be resolved before 2010. The issues concern protection against impact by aircraft.[164] It is being reviewed with a view to licensing by the NII in the UK, but this process will probably not be complete before 2012.
- Advanced Boiling Water Reactor (ABWR). Four units are in operation in Japan, one more is under construction there and two are under construction in Taiwan. It is being offered in the USA by GE-Hitachi and, independently, by Toshiba. It was first ordered in 1989 and given regulatory approval by the US NRC in 1997. That certification was for 15 years and GE-Hitachi notified the NRC in December 2008 that it intends to apply for a renewal of the certification in mid-2010.[165] Toshiba has to replace some elements of the design that are specific to GE-Hitachi and will also have to renew NRC certification.
- The ESBWR (Economic Simplified Boiling Water Reactor) is a Boiling Water Reactor (BWR) generating about 1550 MW supplied by a US-Japanese consortium, GE-Hitachi, formed in January 2007. No orders have yet been placed and the design is not expected to complete scrutiny by the US NRC until 2010. It was also being considered by the UK regulatory authorities, but in 2008, GE-Hitachi withdrew it from the procedures. Of the 28 units for which applications for construction licenses have been submitted to the US regulator, six were based on the ESBWR design. However, the utility proposing two of these (Exelon's Victoria site) said in November 2008 that it was looking for a more proven design. In February 2009, the utility proposing two more of the units asked the NRC to suspend consideration of its application (see below for more details). Given these problems in the UK and USA, the prospects for this design look poor. It may be that the more proven, but less advanced ABWR will replace the ESBWR in the USA.
- The APWR (Advanced Pressurized Water Reactor) is a 1700 MW PWR to be supplied by Mitsubishi. First orders for this design are expected in Japan within the next couple of years but these orders have long been delayed. Regulatory approval in the USA is not expected before 2012. Of the 28 units for which applications for construction licenses have been submitted to the US regulator, only two at the Comanche Peak site are based on the APWR design. The Comanche Peak plants were amongst five sites shortlisted in February

---

[161] In the US market, EPR stands for Evolutionary Pressurized Water Reactor.

[162] AREVA NP is a joint venture of the French company, AREVA, which is majority owned by the French government with 66% and the German company Siemens with the remaining stake.

[163] According to reports by the London Times, NII has issued serious doubts about the conformity of the EPR automation technology with UK standards, see The Times, "UK regulator raises French nuclear concerns", Times Online, 1 July 2009.

[164] Nucleonics Week, "Westinghouse seeks Chinese consent to design changes on AP1000", 2 April 2009, p. 1.

[165] GE Hitachi "GE Hitachi Seeks to Renew NRC Certification for ABWR Reactor Design", *Business Wire*, 15 December 2008.

2009 by the US Department of Energy for loan guarantees but in May 2009, they were relegated to 'first alternate' for unspecified reasons.[166]

The Russian nuclear company, Atomstroyexport, is also offering what it claims to be Generation III+ designs. The AES92, which has been licensed in Bulgaria for the Belene project, and the more recent WWER-1200, which is under construction in Russia, both fall into this category. However, while the Russian designs may be important in markets such as Russia, China and India, they are not under active scrutiny for licensing by Western safety regulatory authorities so they are not considered further. Other designs under development are: AECL's (Canada) ACR-1000, which is a 1000 MW pressurized light- water cooled, heavy-water moderated reactor; and AREVA NP's 'Kerena' design (previously known as SWR-1000) which is a boiling water reactor (BWR) developed from Siemens' BWR design built at Gundremmingen.

III.2. The Determinants of Nuclear Economics

It has long been known that 'fixed' costs – those that are incurred whether or not the plant is operated – would dominate the overall cost of electricity (per kWh) from a nuclear power plant. The 'rule of thumb' was generally that fixed costs made up at least two thirds of the total cost per kWh. The fixed costs themselves comprised mainly costs associated with construction and decommissioning but were dominated by the former. There are three elements to the fixed cost per kWh: the cost of construction; the power produced for sale; and the cost of capital. In the past, debates on nuclear economics have been dominated by estimates of construction costs. However, the much poorer than expected reliability of nuclear plants in some countries as well as the increasing focus on the economic risk of building a nuclear power plant, indicate the other two factors deserve comparable attention.

Other significant elements in the economics of nuclear power are the operating cost, including the cost of fuel and the expected lifetime.

Government plays a vital role in making nuclear orders viable by guaranteeing, explicitly or implicitly, some costs. It explicitly provides guarantees by limiting the liability of operators in the event of an accident to sums that are trivial in comparison with the possible actual costs.[167] This has been done through a mixture of international treaties (Brussels and Vienna) and national agreements. In general national limits are in the order of a few hundred million Euro, less than 10% of the cost of building a plant and far less than the cost of the Chernobyl accident.

Governments implicitly guarantee the long-term liabilities against the failure of the companies. For example, if a company owning a nuclear power plant fails, taxpayers will inevitably have to pick up the bill for any decommissioning and waste disposal for which provisions do not exist. This has happened already in the UK where arrangements for funding decommissioning of civil nuclear facilities have almost entirely failed. The UK failure has effectively shifted a liability of about €90bn from beneficiaries of nuclear power onto future taxpayers.[168] Governments may also fix the price of waste disposal. In the USA, utilities pay the government a fixed fee of US$1/MWh for disposal of spent fuel, while in the UK, the government has proposed that the price utilities pay for waste disposal for any new plants be fixed on the day construction starts.[169]

---

[166] Reuters, "DOE drops Luminant Texas from nuclear loan talks" 8 May 2009. http://uk.reuters.com/article/governmentFilingsNews/idUKN0741783620090507?utm_source=newsletter&utm_medium=email&utm_campaign=sendNuclearHeadlines&pageNumber=1&virtualBrandChannel=0 , accessed on 9 May 2009.

[167] Stephen Thomas, Peter Bradford, Antony Froggatt & David Milborrow, "The economics of nuclear power', Amsterdam, Greenpeace International", 2007.

[168] Stephen Thomas, "Nuclear Power in Britain since Chernobyl: A Rollercoaster Ride", in Lutz Mez, Mycle Schneider & Steve Thomas (eds) (2009) "International Perspectives on Energy Policy and the Role of Nuclear Power", Multi-Science Publishing, Brentwood.

[169] Department for Business, Enterprise and Regulatory Reform, Press release, "Clean up fund is precondition for new nuclear – Hutton", 22 February 2008; http://www.nce.co.uk/clean-up-fund-is-precondition-for-new-nuclear-hutton/766426.article .

III.3. Fixed Costs

III.3.1. Construction costs

As noted above, nuclear construction costs are hard to estimate, but have been rising sharply in the situations in which plants have progressed. When the Generation III+ designs were first being discussed, the nuclear industry argued strongly that these could be built for an overnight cost of US$1000/kW so that a plant of 1000 MW (1 million kW) would cost US$1bn. For example, even as late as 2003, a senior vice president of Westinghouse, Regis Matzie was claiming construction costs would be US$1000-1200/kW[170]. The designers of the EPR were more cautious in their estimates but still claimed about US$1400 was achievable.[171]

In 2002-04, a series of nuclear power economics studies was published[172] with somewhat higher prices but these were still generally below US$2000/kW and sometimes below US$1000/kW. The first cost estimate for a real plant was the contract price for the Olkiluoto-3 reactor in Finland.

III.3.1.1. European experience

Olkiluoto, Finland

The Olkiluoto-3 order for Finland was seen as particularly important for the nuclear industry because it seemed to contradict the conventional wisdom that liberalization and nuclear power orders were incompatible. Placed in December 2003, the Olkiluoto-3 reactor was the first nuclear order in Western Europe and North America since the Civaux-2 order in France in 1993, and the first order outside the Pacific Rim for a Generation III/III+ design. The Finnish electricity industry had been attempting to obtain Parliamentary approval for a fifth nuclear unit in Finland since 1992. This was finally granted in 2002. The Olkiluoto-3 order, when it was placed in December 2003, was a huge boost for the nuclear industry in general and the vendor, AREVA NP, in particular. Industry anticipated that, once complete, the plant would provide a demonstration and reference for other prospective buyers of the EPR.

Finland is part of the Nordic electricity market covering Norway, Sweden, and Denmark as well. The region is generally seen as the most competitive electricity market in the world. Finland also has a good reputation for the operation of the four units located in the country. So there were high hopes that this would answer many of the questions concerning the 'nuclear renaissance.' However, closer examination of the deal, elaborated in the following sections, reveals some very special features that raise questions as to how representative this deal is of conditions in other markets.

The contract price for Olkiluoto-3 was reported in 2004 to be €3bn for a 1600 MW plant.[173] Subsequently the price was reported to be €3.2bn[174] or €3.3bn.[175] Safety approval was given by the Finnish regulator, STUK, in March 2005 and substantive work on-site started in August 2005. At the time the contract was signed, the value was equivalent to about US$3.6-4.0bn (depending on the contract price) or about $2250-2475/kW (€1=US$1.2). This cost included finance and two reactor cores and so the cost per kW in overnight terms would have been somewhat lower, although given, as we can see below, the very low rate of interest charged (2.6%), finance costs would be low.

[170] Regis Matzie, "The AP1000 Reactor: Nuclear Renaissance Option", Presentation to Tulane Engineering Forum, 26 September 2003; http://www.sse.tulane.edu/FORUM_2003/Matzie%20Presentation.pdf. accessed on 31 March 2009.
[171] Nucleonics Week, "Giant EPR said to be competitive: EDF to decide on order next year", 6 November 1998, p 1.
[172] See review of various studies in Stephen Thomas, Peter Bradford, Antony Froggatt & David Milborrow, "The economics of nuclear power", Amsterdam, Greenpeace International, 2007.
[173] Project Director Martin Landtman stated: "The value of the whole Olkiluoto 3 investment including the Turn-key Contract is about EUR 3 billion in year 2003 money. No other figures are published", personal communication, e-mail to Mycle Schneider, dated 8 October 2004.
[174] Nucleonics Week, "EC probing claims Olkiluoto loan guarantees were state aid", 26 October 2006.
[175] Nucleonics Week, "AREVA reveals 47% cost overrun on contract for Olkiluoto-3", 5 March 2009, p 1.

Although this cost was well above the nuclear industry's target of US$1000/kW of only a few years previously, it was still regarded by critics as a 'loss-leader'. AREVA NP had been trying to persuade either EDF or one of the German utilities to place an order for an EPR since the late 1990s[176] and there were fears that if an order for the EPR was not placed soon, AREVA NP would start to lose key staff[177] and the design would become obsolete[178]. AREVA NP also needed a 'shop window' for EPR technology and Olkiluoto-3 would serve as a reference plant for other orders. As an additional incentive and at the request of the customer, AREVA NP offered the plant on 'turnkey' terms, that is, fixed price. It also took responsibility for the management of the site and for the architect engineering, not just the supply of the 'nuclear island'. This was not a role it was accustomed to. In the 58 PWRs AREVA NP's predecessor, Framatome, had supplied for France, as well as for the foreign projects including those in China and South-Africa, it was EDF that had provided these services.

As has been documented elsewhere[179], the Olkiluoto project has gone seriously wrong since construction started. By March 2009[180] the project was acknowledged to be at least three years late and €1.7bn over budget. It is now expected to cost about US$4000/kW.[181] The contract is also the subject of an acrimonious dispute between AREVA NP and the customer, Teollisuuden Voima Oy (TVO). AREVA NP claims compensation of about €1bn for alleged failures of TVO. TVO, in a January 2009 counterclaim, is demanding €2.4bn in compensation from AREVA NP for delays in the project.[182]

It seems unlikely that all the problems that have contributed to the delays and cost-overruns have been solved; the final cost could be significantly higher. The result of the claim and counter-claim arbitration between AREVA NP and TVO will determine how the cost over-run will be apportioned. Regardless, however, it is clear that investor concerns on plant costs and delivery remain valid.

Flamanville, France

EDF finally ordered an EPR reactor in January 2007, to be located at their Flamanville site. This reactor was uprated to 1630 MW[183] and construction commenced in December 2007[184]. In May 2006, EDF estimated the cost would be €3.3bn.[185] At that time (€1=US$1.28), this was equivalent to US$2590/kW. This cost however did not include the first fuel, so the overnight cost would have been somewhat higher. The cost estimate did not include finance either.

EDF did not seek a turnkey contract and chose to manage the contracting, letting contracts, for example, for the turbine generator, and also the architect engineering. How far these decisions were influenced by the poor experience at Olkiluoto and how far they were influenced by the need it saw to maintain in-house skills is not clear. For the contract AREVA NP won to supply two EPRs to

176 Nucleonics Week, "Giant EPR said to be competitive: EDF to decide on order next year", 6 November 1998, p 1.
177 Petroleum Economist, "France mulls nuclear future", March 2001.
178 Nucleonics Week, "EPR safety approval won't last beyond 2002, regulator warns", 6 March 1997.
179 Stephen Thomas, "Can nuclear power plants be built in Britain without public subsidies and guarantees?", Presentation at a Conference *"Commercial Nuclear Energy in an Unstable, Carbon Constrained World"* Co-Hosted by the Nonproliferation Policy Education Center and Radio Free Europe/Radio Liberty.
17-18 March 2008 – Prague, Czech Republic.
180 Nucleonics Week, "AREVA's Olkiluoto-3 manager says engineering judgment undermined", 26 March 2009, p 4.
181 Nucleonics Week, "AREVA reveals 47% cost overrun on contract for Olkiluoto-3", Nucleonics Week, 5 March 2009, p 1
182 Agence France Presse, "Setbacks plague Finland's French-built reactor", 30 January 2009.
183 Nucleonics Week, "EDF orders Flamanville-3 EPR NSSS, with startup targeted in 2012", 5 January 2007, p 1.
184 Nucleonics Week, "Flamanville-3 concrete pour marks start of nuclear construction"; 6 December 2007, p 3.
185 Nucleonics Week, "EDF to build Flamanville-3, says first EPR competitive with CCGT", 11 May 2006, p 1.

China the company is only supplying the nuclear island and the contract is not turnkey. EDF is involved in the management of the project and has an equity stake in the plants.[186]

In May 2008, the French safety regulatory authorities temporarily halted construction at Flamanville because of quality issues in pouring the concrete base mat.[187] Delays had led the vendor, AREVA NP to forecast the plant would not be completed until 2013, a year late, but in November 2008, EDF claimed the delays could be made up and the plant finished to the original schedule of 2012.[188] EDF did acknowledge that the expected construction costs for Flamanville had increased from €3.3 billion to €4 billion.[189] This was then equivalent (€1=US$1.33) to US$3,265/kW, substantially more than the Olkiluoto contract price, but far below the levels being quoted in the USA and the actual cost of Olkiluoto. An AREVA official has suggested that the cost of an EPR will now be at least €4.5bn, although it was not specified whether this was an overnight cost. [190]

Comparison of Olkiluoto and Flamanville

Comparisons between Olkiluoto and Flamanville need to be made with care. Currency movements may have a significant impact if the cost is translated to dollars, and in the three years gap between the orders, inflation might have increased prices by about 10%. There is also the difference in scope of the contract in respect of fuel and finance costs. The rating of both plants is likely to be around 1700 MW when the plant is commissioned so the small difference in cost because the rating of the Flamanville plant is 2% higher than that of Olkiluoto is not significant. EDF's cost estimates also tend to be regarded with some suspicion as being underestimates of the true cost. This is partly because of their aspirations in the international market to offer nuclear construction services – they clearly would want to portray themselves as being very efficient and low-cost. More innocently, in such a large organization costs that should rightly be attributed to a specific project may be lost under more general headings. This process was clearly illustrated in the UK prior to privatization. The Central Electricity Generating Board (CEGB) published estimates of the cost of nuclear power that showed it to be competitive, at least on a marginal cost base.[191] However, when the costs were rigorously split, it was found that the marginal cost was double the market price of electricity. This was reported to have been as much of a shock to the staff of the CEGB as to the public.

Overall, given the rapid increase in nuclear construction cost estimates in the period between the Olkiluoto and Flamanville orders, discussed below under North America, the relatively small difference between the contract prices for Olkiluoto and Flamanville is surprising. However, in both cases, the contract price is likely to have little in common with the actual price. It would not be surprising if the total cost of the Olkiluoto plant was significantly more than the latest estimate of 50% over-budget, while the Flamanville plant has also already increased in cost from the original estimate.

For future EPRs, AREVA estimated in September 2008 that the overnight cost would be €4.5bn (US$6.5bn at September 2008 exchange rate of €1=US$1.43). At the new rating of the EPR, 1700 MW, this works out at US$3800/kW[192]. E.ON estimated in May 2008 that an EPR built in the UK would cost €5 to 6bn. Whether this is an overnight cost or includes finance is not clear.[193]

---

[186] European Daily Electricity Markets, "EDF's past efforts pay off with two EPR deals sealed in China", 15 August 2008.

[187] Nucleonics Week, "Concrete pouring at Flamanville-3 stopped after new problems found", 29 May 2008, p 18.

[188] Nucleonics Week, "EDF confirms target of starting up Flamanville-3 in 2012", 20 November 2008, p 1.

[189] Associated Press Worldstream, "EDF to lead up to euro50B in nuclear plant investment", 4 December 2008.

[190] Nucleonics Week, "AREVA official says costs for new EPR rising, exceeding $6.5 billion", 4 September 2008, p.1.

[191] Gordon MacKerron, "Nuclear Power under review", in John Surrey, "The British Electricity Experiment", Earthscan, London 1997.

[192] Nucleonics Week, "AREVA official says costs for new EPR rising, exceeding $6.5 billion", 4 September 2008, p 1.

[193] The Times, "Reactors will cost twice estimate, says E.ON chief", 5 May 2008, p 32.

III.3.1.2. US estimates

While there is little experience of construction of Generation III/III+ plants in Europe, there is no experience at all in the USA. At present, it seems unlikely that construction will start on any plants in less than three years. Nevertheless, there is a high level of interest in the Nuclear 2010 program launched by the last administration. More than a dozen utilities have announced their possible interest in building nuclear power plants; this has generated a large number of cost estimates from sources that have a real interest in building nuclear plants.

While there have been many studies of nuclear plant costs conducted by a variety of parties in the USA, we focus on a handful of assessments that were conducted in a systematic and detailed manner by well-respected institutions. These studies help illustrate the variability in cost values, as well as trend lines.

MIT 2003[194]

A study based at MIT was published in 2003. It was written primarily by an interdisciplinary group of professors mainly from MIT, but included an advisory committee of distinguished members drawn from the full range of interests from environmental groups to nuclear power associations.

For its base case, the study assumed an overnight cost of US$2000/kW. For its low case it assumed (p 41) "that construction costs can be reduced by 25% from the base case levels to more closely match optimistic but plausible forecasts". These figures were not based on the most recent US costs, which were regarded as untypical, but on industry estimates and from experience of recent foreign Generation III plants, from Japan and South Korea. Whether this foreign data is reliable is far from clear. In retrospect, the estimates seem very low, compared even to the Olkiluoto-3 contract price of later the same year as the study. However, the industry was still aggressively projecting low construction costs. In an Appendix (p. 138), MIT presented cost estimates from vendors most of which, for an 'nth' of a kind order (i.e., an order without FOAK costs), were for less than US$1250/kW. Despite the low assumed construction costs, the study concluded (p. IX):

> In deregulated markets, nuclear power is not now cost competitive with coal and natural gas. However, plausible reductions by industry in capital cost, operation and maintenance costs, and construction time could reduce the gap. Carbon emission credits, if enacted by government, can give nuclear power a cost advantage.[195]

Keystone Center 2007[196]

The Keystone study "Nuclear Power Joint Fact-Finding" (NJFF) was, as the name implies, an attempt to gain a consensus from a wide range of experts from diverse interests, a number of whom had advised the MIT study. It assumed an overnight cost of US$2950 for both its low and high cases but generated a higher total capital cost for its high case by assuming a shorter plant life, a higher cost of capital, more rapid depreciation, a longer construction period of six years rather than five years and real cost escalation over the construction period of 3.3%. In the low case, this gave a total construction cost, including finance of US$3600/kW and in the high case, US$4000/kW, an 11% difference.

The basic figure of US$2950/kW was obtained, as with the MIT study, from the reported cost of Generation III plants completed in Japan and South Korea between 1994 and 2005. The study did not make firm conclusions on the competitiveness of nuclear but did find (p. 11):

> We found that a reasonable range for the expected levelized cost of nuclear power is between 8 and 11 cents per kilowatt-hour (kWh) delivered to the grid.

---

[194] Massachusetts Institute of Technology, "The future of nuclear power" MIT, Boston. 2003. http://web.mit.edu/nuclearpower/ accessed on 3 April 2009.

[195] It should be noted that the MIT study did not compare nuclear power with anything except coal or gas fired central plants.

[196] The Keystone Center, "Nuclear Power Joint Fact-Finding", Keystone Center, Keystone, 2007; http://www.ne.doe.gov/pdfpdfFi/rpt_KeystoneReportNKeystoneReportNuclearPowKey_2007.pdf , accessed on 3 April 2009. The eleven sponsors of the study include seven nuclear utilities and one nuclear builder.

However, its findings on how far nuclear power could contribute to combating global warming were interesting. It stated (p. 11):

> The NJFF participants agree that to build enough nuclear capacity to achieve the carbon reductions of a Pacala/Socolow wedge (1 GtC/year or 700 net GWe nuclear power; 1,070 total GWe) would require the industry to return immediately to the most rapid period of growth experienced in the past (1981-90) and sustain this rate of growth for 50 years.[197]

Pacala/Socolow argued that at least seven 'wedges' would be needed to stabilize global atmospheric CO_2 concentrations.[198]

MIT 2009 Update

In May 2009, MIT published an update to the 2003 study.[199] However, the team that produced the report was very different from the 2003 team with much weaker economics and policy credentials. This bias is reflected in the report. While the report makes significant changes to the economic assumptions, for example doubling the estimated construction cost to $4000/kW, this deterioration in the economics is not mentioned in the summary or the conclusions. Even more remarkably, the report still asserts (p. 8):

> The 2003 report found that capital cost reductions and construction time reductions were plausible, but not yet proven – this judgment is unchanged today.

The economic analysis is not even contained in the main report, but was published separately.[200] The conclusions betray the prejudices of the authors:

> The sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation.

While the 2003 report had serious faults, it was a significant and carefully argued piece of work. The update is much more a statement of beliefs by the authors, often in contradiction to the analysis they present.

Standard & Poor's and Moody's

As credit rating agencies, the research capabilities of these two agencies have to be strong, although the financial crisis has damaged their credibility somewhat. In October 2007, Moody's estimated overnight construction costs for a nuclear plant at US$5000-6000/kW.[201] In its report of October 2008[202], Standard & Poor's accepted the figure from a study by the Federal Energy Regulatory Commission (FERC) that — after including interest during construction (allowance for funds used during construction in the case of regulated utilities in some states), and other escalation/inflation factors — can range from around $5,000 per kW to $8,000 per kW.

---

[197] The Keystone Center, op cit, p. 21. "Pacala/Socolow presented 15 possible technology wedges, not all completely independent of each other, and argued that at least seven of these wedges, or a larger number of partial wedges, would be necessary to stabilize global atmospheric CO_2 concentrations".

[198] Steve Pacala & Rob Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies", in *Science*, 13 August 2004.

[199] Massachusetts Institute of Technology, 2009 "Update of the MIT 2003 Future of Nuclear Power Study", MIT, Boston, http://web.mit.edu/nuclearpower/pdf/nuclearpower-update2009.pdf , accessed 26 May 2009.

[200] Yangbo Du & John Parsons, 2009 "Update on the cost of nuclear power", MIT Boston; http://web.mit.edu/nse/pdfs/NFC-108.pdf, accessed 26 May 2009.

[201] Moody's, "New Nuclear Generation in the United States: Keeping Options Open vs Addressing An Inevitable Necessity", Moody's Global Credit Research, New York, 2 October 2007.

[202] Standard & Poor's, "Construction Costs To Soar For New U.S. Nuclear Power Plants", Standard & Poor's, New York, 2008.

Utility estimates

US utilities have announced their intention to build a total of 31 new nuclear units (see Table 4). Many of the utilities have announced forecast costs. What is included in these costs is not always clear, whether they include finance for example, but since their source is companies actually expecting to build plants, they must be regarded as reasonably realistic.

The plants for which no specific construction cost estimates have been reported in the press include Comanche Peak, Harris, North Anna, Fermi, Calvert Cliffs, Callaway, Nine Mile Point, Bell Bend, Amarillo and Elmore. In February 2009, the Department of Energy shortlisted five projects (some for 2-unit sites) for eligibility for loan guarantees. The full list of the plants chosen has not been published[203] but it is reported to include the Summer project[204], South Texas, a UniStar project, most likely Calvert Cliffs and Comanche Peak, although this project was relegated to first alternate in May 2009.[205]

AP-1000

Levy.[206] Progress Energy estimated that the overnight cost for the two AP-1000 reactors would be US$10.5bn plus US$2.5bn for transmission facilities and US$3.9bn carrying cost/AFUDC (allowance for funds used during construction). A Securities and Exchange Commission filing from the end of 2008 showed that Progress Energy had signed a $7.65 billion contract with Westinghouse Electric to build two 1105 MW, AP-1000 reactors at the Levy site. It was not clear what the contract covered but the cost was reported to be the same as earlier utility estimates.[207] On 1 May 2009 the company announced that the planning would be delayed by “a minimum of 20 months”. The move aims to “spread some of the costs over a longer period of time”, as the company’s president stated.[208] The deferral would result in a nuclear charge of $6.69/month for a typical 1,000-kWh/month residential customer in 2010, down from a $12.63/month charge allowed by the state's nuclear cost recovery law.

Summer.[209] SCE&G estimated the cost for constructing the two Summer plants alone, without transmission and finance charges, would be US$9.8bn. The Summer project is reported to have been shortlisted by the US Department of Energy for loan guarantees.

Turkey Point.[210] Florida Power & Light told the Florida Public Service Commission that it forecast an overnight construction cost for Turkey Point in the range of $3108-4540/kW. The total project cost including inflation and interest payments meant the cost of the two AP1000s would be $12.3-18.0bn.

Vogtle.[211] Georgia Power estimated that its 45.7% share of the Vogtle project for two AP-1000 units would cost it US$6.4bn, making the total cost about US$14bn. This cost is described as the ‘in-service cost’ and therefore should include finance costs.

Bellefonte.[212] TVA has estimated the overnight construction cost for the two AP-1000 units would be US$5.6-10.4bn.

Lee.[213] Duke power has estimated in November 2008 that the overnight costs for the two-unit Lee station would be US$11bn, double its previous estimate. It would appear that the expected

[203] Global Insight, “Five Nuclear Plant Proposals Make Shortlist for U.S. DOE Loans”, 19 February 2009.
[204] Nucleonics Week, “STP project ranked in top tier for loan guarantee, NRG says”, 19 February 2009, p 2.
[205] Reuters, “DOE drops Luminant Texas from nuclear loan talks”, 8 May 2009; http://uk.reuters.com/article/governmentFilingsNews/idUKN0741783620090507?utm_source=newsletter&utm_medium=email&utm_campaign=sendNuclearHeadlines&pageNumber=1&virtualBrandChannel=0 , accessed 9 May 2009.
[206] Nuclear Engineering International, ”Power Market Developments - The American way”, June 2008.
[207] Natural Gas Week, “Progress Signs Contract for New Florida Nukes”, 9 January 2009.
[208] Platts, “US NRC move to delay Florida units at least 20 months: Progress”, 1 May 2009.
[209] Nuclear Engineering International, “Power Market Developments - The American way”, June 2008.
[210] Ibidem.
[211] Ibidem.
[212] Chattanooga Times, “Estimates for new nuclear plant rise”, 12 December 2008, p. A1.

overnight cost for the two AP-1000, net rating about 1120 MW each, is about US$11bn, which makes the cost per kW US$4,900.

ESBWR

In November 2008, Exelon effectively abandoned the ESBWR for its Victoria site and was reported to be looking at alternative designs.[214] In February 2009, Entergy asked the NRC to suspend reviews of its ESBWR applications at Grand Gulf and River Bend because of concerns about rising prices.[215] None of the utilities that referenced the ESBWR as their preferred design has given a cost estimate although when Entergy withdrew, the CEO, Wayne Leonard said: "The price for the ESBWR kept rising, reaching upward of $10 billion", which he called well beyond the original cost expectation.[216] If this was an overnight cost, that would make the cost of an ESBWR, about 1520 MW, about US$6600/kW. If it included finance, say an extra 25%, it would still be about US$5200/kW. It now seems possible that the ESBWR design, which has been withdrawn from the UK certification process, will be abandoned and even that GE will drop out of the reactor sales business altogether.

EPR

The Calvert Cliffs EPR project is reported to have been shortlisted for loan guarantees.[217] However, of the seven EPR units announced, at least three projects appear to have been stopped. The utilities proposing the other four have not announced the expected cost. In April 2009, the Chairman of UniStar said Constellation has not publicly announced the estimated **cost** for Calvert Cliffs and that those figures are confidential.[218]

ABWR

The South Texas plant is the only ABWR proposal. It is for two units each of about 1380 MW**.** NRG now estimates the cost to be around $8 billion, or $2900/kW. The estimate is about 50% higher than the figure of $5.2 billion given in a 21 June 2006 NRG press release. The project is reported to have been shortlisted for loan guarantees.

APWR

The two-unit Comanche Peak project is the only APWR project that has been announced but there has been no specification of the estimated cost. The application for loan guarantees was reported to have been shortlisted but was relegated to first reserve subsequently.

It is probably significant that of the 31 units announced in the USA, less than half have provided estimated costs and all of these use designs that have received certification from the NRC (ABWR and AP-1000), albeit with some design revisions to be made. Whether these revisions will raise the cost significantly remains to be seen – they are highly unlikely to reduce it.

The ABWR, which was certified more than a decade ago and must more realistically be categorized as Generation III, looks particularly vulnerable to safety upgrades when it has its certification renewed. It is surprising that none of the EPR applicants, a design that at least has construction experience and has been certified in Europe, has announced an estimated cost. The overnight cost estimates seem to be clustering around the US$5000/kW mark. The Department of Energy, in short-listing projects seems to be placing emphasis on providing the initial loan

[213] WNN, "Duke raises cost estimate for Lee plant", 7 November 2008.
[214] Nucleonics Week, "Exelon drops ESBWR, looks at other reactor designs for its Texas project", 27 November 2008, p. 1.
[215] Nucleonics Week, "Entergy revises construction plans, looks again to acquisitions", 26 February 2009, p. 1.
[216] Ibidem.
[217] At http://uk.reuters.com/article/governmentFilingsNews/idUKN1846256420090218?sp=true .
[218] Daily Record (Baltimore), "Constellation Energy CEO: French firm won't influence Baltimore Gas & Electric Co.", 28 April 2009.

guarantees to a range of designs and the four shortlisted projects reported are for four different technologies.

Table 4: US Nuclear Power Plant Projects Announced Since 2006

Plant	Owner	COL Application submitted	Loan Guarantee	Design	Estimated cost ($bn)	Estimated cost $/kW
Calvert Cliffs 3†	UniStar	3/08	Applied	EPR	n/a	
South Texas 3, 4†	NRG/Exelon	9/07	Applied	ABWR	n/a	
Bellefonte 3, 4	TVA	10/07	Not eligible	AP-1000	5.6-10.4+	2500-4600
North Anna 3	Dominion	11/07	Applied	ESBWR	n/a	
Lee 1, 2	Duke	12/07	Applied	AP-1000	11+	4900
Harris 2, 3	Progress	2/08	Not applied	AP-1000	n/a	
Grand Gulf 3	Entergy	2/08	Applied	ESBWR	n/a	
Vogtle 3, 4 †	Southern	3/08	Applied	AP-1000	14*	6250*
Summer 2, 3†	SCANA	3/08	Applied	AP-1000	9.8+	4400
Callaway 2	AmerenUE	7/08	Applied	EPR	n/a	
Levy 1, 2	Progress	7/08	Applied	AP-1000	10.5+	4750+
Victoria 1, 2	Exelon	9/08	Applied	ESBWR	n/a	
Fermi 3	DTE Energy	9/08	Not applied	ESBWR	n/a	
Comanche 3, 4	TXU	9/08	Applied	APWR	n/a	
Nine Mile Point 3	Unistar	10/08	Applied	EPR	n/a	
Bell Bend	PPL	10/08	Applied	EPR	n/a	
Amarillo 1, 2	Amarillo	?		EPR	n/a	
River Bend	Entergy	9/08	Applied	ESBWR	n/a	
Elmore	UniStar	?		EPR	n/a	
Turkey Point 6, 7	FPL	3/09	?	AP-1000	6.9-10.1+	3100-4500

Source: Steve Thomas

Notes:

1. COL: Combined Construction & Operating License.
2. Estimates marked '*' include interest while those marked '+' are overnight costs.
3. In January 2009, Entergy asked the NRC to suspend reviews of the COL for Grand Gulf & River Bend[219]

Projects marked † are reported to have been shortlisted by the US Department of Energy for loan guarantees.

III.3.1.3. Factors behind the increase in costs

In less than a decade, the estimated cost of new nuclear power plants has increased from US$1000/kW to an average of about US$5000/kW, before significant construction experience has been accumulated. Even by the standards of the nuclear industry, this is a remarkable rate of increase. What are the factors behind this increase? Clearly one factor is general inflation, which may have increased prices by about a third in that time so the real increase is about four fold. The US$1000/kW estimates were always regarded with suspicion by outside observers and the nuclear industry increasingly seems to view these predictions in the same way as it does Lewis Strauss's 'too cheap to meter' prediction – they would prefer they had not been made. However, a four-fold increase arising simply from appraisal optimism (i.e., the natural inclination of proponents of a technology to underestimate costs) seems implausible and other factors are likely to have contributed. Five factors seem particularly relevant.

Rapidly Rising Commodity Prices. Since 2003, global commodity prices have escalated at an unprecedented rate. In the period 2003–2007, nickel and copper increased in price by over 60% per year, cement by more than 10% and steel by nearly 20%.[220] These price rises have increased the construction cost of all generation options but because nuclear plants are physically larger than other options, the impact on the economics of nuclear power is much greater. In the second half of 2008, as the financial crisis began to lead to recession, commodity prices began to fall steeply.

[219] Nucleonics Week, "Entergy revises construction plans, looks again to acquisitions", 26 February 2009, p 1.
[220] Standard & Poor's, "Construction Costs to Soar for New US Nuclear Power Plants," Ratings Direct, 15 October 2008.

While the rise in commodity price is plausible as a contributor to price escalation, quantifying its impact would need a full inventory of the costs broken down by materials, land and labor.

Lack of Component Production Facilities. The low number of nuclear orders in the past twenty years has meant that many component manufacturing facilities have closed down and there are now only one or two certified suppliers of key components (see chapter II.). For example, the ultra heavy forgings needed to fabricate the pressure vessels are only produced in one factory (in Japan). AREVA announced in April 2009 that it was increasing its capacity to manufacture some heavy components. However, this investment would increase nominal capacity from the equivalent of 1.7 EPRs per year to only 2.7 EPRs per year.[221] This shows how long it takes to build up capacity to manufacture components even for experienced suppliers. New suppliers must be accredited by the American Society of Mechanical Engineers (ASME) and France's RCCM (Règles de Conception et de Construction des Matériels) Certification. This requires a major effort in documentation and quality control to prove that the supplier is capable of meeting the required quality standards. This will tend to raise prices, particularly once any spare capacity is taken up and, for example, Standard and Poor's assumes that the first units ordered will be cheaper than their successors.[222] In the long-term, if there are large numbers of new nuclear orders placed, component production facilities will be built. However, building and certifying such facilities will take some time and involve huge investment costs. As a result, until ordering on a large scale is re-established, building such facilities will represent a significant risk because there is no guarantee that demand will be there for these facilities when they actually come on-line.

Shortages of the Necessary Nuclear Skills. As with components, the lack of recent nuclear orders and the ageing of the existing workforce have led to a serious shortage of qualified personnel (see chapter II.). For example, Standard & Poor's states:[223]

> We expect that the first few new nuclear units in the USA will rely somewhat on project management experience from countries such as France and Japan where construction of nuclear units has continued relatively unabated since the US program's demise. Specifically, we expect companies like Electricité de France S.A. (EDF) and Tokyo Electric Power Co. Inc. (TEPCO) to provide operational expertise.

In the UK, the British government has been unable to recruit sufficient safety inspectors to meet targets regarding reviews of reactor designs. *Nucleonics Week* reported:[224]

> NII [the Nuclear Installations Inspectorate] has been chronically understaffed, a situation that threatens the timing of the GDA [generic design assessment] process. NII spokesman Mark Wheeler said in September that the agency needs 40 inspectors to complete the GDA on time, in addition to 20 now working on design assessments. Excluding the GDA work, the agency is about 22 inspectors short of the 192 needed, he said. NII Chief Inspector Mike Weightman has said, however, that he believes about 232 inspectors are needed to do all the regulatory work required by existing and new nuclear installations.

The UK Commons Innovation, Universities, Science and Skills Committee found a serious shortage of skills for all nuclear activities.[225]

Weakness of the US Dollar. The increase in costs measured in US dollars may in part have been due to the weakness of the US dollar since the end of 2005. This has meant that costs measured, for example, in Euro will have escalated somewhat less than dollar prices. Weakness of the dollar may

---

221 AREVA, "AREVA launches the Chalon 1300 plan", AREVA Press Release, Paris, 2 April 2009.

222 Standard & Poor's, "Construction Costs to Soar for New US Nuclear Power Plants," Ratings Direct, 15 October 2008.

223 Ibidem.

224 Ann MacLachlan, "HSE Preparing to Contract for Technical Safety Expertise", Inside NRC, 10 November 2008.

225 House of Commons Innovation, Universities, Science and Skills Committee, 2009 "Engineering: Turning ideas into reality", Fourth report of session 2008/09 HC 50-I, The Stationery Office, London; http://www.publications.parliament.uk/pa/cm200809/cmselect/cmdius/50/5002.htm, accessed on 3 April 2009.

also have contributed to commodity price increases measured in dollars. The value of the dollar fell from November 2005 when the Euro was worth US$1.17 to July 2008, when it was worth US$1.57. By November 2008 the value of the dollar had increased sharply so that the Euro was worth US$1.27, yet by December 2008 it had fallen again to US$1.40.

Greater Caution by Utilities. Utilities can no longer assume that they will be allowed to pass on whatever costs they incur when building a power plant. Where there are competitive markets, if costs are too high, utilities risk bankruptcy, as happened in 2002 to the privatized British nuclear generator, British Energy.[226] Where tariffs are still regulated, the utility will be relying on electricity regulators to allow them to recover their costs. This will force utilities to be more conservative in their cost estimations to reduce the risk that the actual costs will exceed the forecast costs.

It remains to be seen how far these factors are reversible and whether prices might fall. If they were to fall it would be unprecedented in the history of nuclear power. Commodity prices have already begun to decline from their peak of mid-2008 and this may moderate pressure on prices. However, the second and third factors, shortages of manufacturing capacity and skills can only be solved over a period of a decade or more and, if ordering does recommence to any great extent, the price pressure will grow as utilities compete for scarce resources. The level of the dollar is impossible to predict, but this volatility is itself a serious issue. Vendors or buyers who choose the wrong currency for their sales or purchases (i.e., one that loses a significant amount of value against other currencies) will stand to lose a lot of money. Utilities will also know that even if energy market liberalization measures do stall and competition is muted, they will no longer be able to rely on governments and regulators allowing them to pass unforeseen costs on to consumers.

So, overall, it seems highly unlikely that prices will *fall* significantly. All previous experience suggests that prices will tend to *rise* as the designs are translated from the drawing board to construction site.

III.3.1.4. Cost of capital

Large projects such as nuclear power plants are financed by a mixture of debt (i.e. borrowing) and equity (e.g. financing from cash flow or from partners). Debt is usually cheaper than equity. For example, for its base case, the MIT study[227] assumed that the debt and equity shares in financing new nuclear plants would be equal and that cost of capital (net) for equity would be 12% and for debt would be 5% giving a real weighted average cost of capital (WACC) of 8.5%. The Keystone study[228] follows these assumptions for its high case but assumes for its low case that the cost of equity can be reduced to 9% giving a real WACC of 7%. Keystone does note that (p 37):

> In the past few years, Wall Street has become significantly less comfortable with the merchant plant model, and even very strong non-utility generators building plants in competitive wholesale markets now need 65% to 70% equity to access the bond market.

However, it does not use this case in its scenarios. If we assume a requirement for 70% equity at 12%, this gives a real WACC of just under 10%.

Whether these figures are realistic is not clear. When the British electricity market was opened to competition in 1990, there was a huge wave of orders for combined cycle gas-fired plants and it was widely reported that the real discount rate for these plants was 15%.[229] The nuclear forecasts of

---

[226] Stephen Thomas, "The Collapse of British Energy: The True Cost of Nuclear Power or a British Failure?" *Economia delle fonti di energia e dell' ambiente*, no. 1–2, 2003, pp. 61–78.
[227] Massachusetts Institute of Technology, "The future of nuclear power" MIT, Boston, 2003, http://web.mit.edu/nuclearpower/ accessed on 3 April 2009.
[228] The Keystone Center, "Nuclear Power Joint Fact-Finding", Keystone Center, Keystone, 2007, http://www.ne.doe.gov/pdfpdfFi/rpt_KeystoneReportNKeystoneReportNuclearPowKey_2007.pdf , accessed on 3 April 2009.
[229] John Surrey, "The British Electricity Experiment", Earthscan, London, 1997.

2002-2004 seemed to be oblivious to this experience and, for example, several studies still projected a real cost of capital of 8% or less.[230]

In the past, before energy-market liberalization took hold, the cost of finance for nuclear projects was low because utilities were guaranteed to be able to recover any costs they incurred from consumers. Any problems of financing nuclear power plants arose from the general credit rating of the company or the country involved. Thus, countries such as Turkey did have problems financing nuclear plants. The only specific problem for nuclear power was that the World Bank and the other major public international development banks do not lend money for nuclear power plants and this cut off a low cost source of finance. The World Bank's lending advice states:[231]

> Nuclear plants are thus uneconomic because at present and projected costs they are unlikely to be the least-cost alternative. There is also evidence that the cost figures usually cited by suppliers are substantially underestimated and often fail to take adequately into account waste disposal, decommissioning, and other environmental costs.

In a similar way, the Asian Development Bank (ADB) recently restated its "policy of non-involvement" in the financing of nuclear power:[232]

> Nevertheless, in spite of its sustainable and operational benefits, nuclear power development faces a number of barriers, such as public concerns related to nuclear proliferation, waste management, safety issues, high investment costs, long lead times, and commercial acceptability of new technologies. Overcoming these barriers is difficult and open public debate will be required to convince the public about the benefits of nuclear power. MDBs [Multilateral Development Banks] have traditionally avoided financing nuclear power plants. In the context of the former Soviet Union states, the EBRD's [European Bank for Reconstruction and Development] current energy policy includes financing safety measures of nuclear plants, decommissioning and environmental rehabilitation, and promoting an efficient nuclear regulatory framework. In view of concerns related to nuclear technology, procurement limitations, proliferation risks, fuel availability, and environmental and safety concerns, ADB will maintain its current policy of non-involvement in the financing of nuclear power generation.

In a March 2008 presentation, Rinaldo S. Brutoco, President of the World Business Council, stated:

> From a business perspective, nuclear power has failed to fulfill its potential in the marketplace. In the early 1980s, following Washington Public Power Supply System's $2.25 billion bond default (the largest default in utility history), Wall Street rated nuclear power plants 'high risk' and turned off the money machine.[233]

However, for liberalized markets or systems such as some of the US states where regulators cannot be guaranteed to pass on costs, it was long believed that nuclear power orders were infeasible because of the risks markets posed for such an economically inflexible technology as nuclear power.

There are three main ways that banks can be protected, at least in part, from this risk: by electricity consumers, by government credit guarantees, i.e., taxpayers and by vendors through fixed price contracts. In all of these scenarios, the protection is only as strong as the counterparty is. Electricity consumer protections work through rate setting boards that have in the past disallowed cost overruns. Vendor guarantees can be litigated, as they are in the case of Olkiluoto. More on these issues below.

---

230 Stephen Thomas, Peter Bradford, Antony Froggatt & David Milborrow, "The economics of nuclear power", Amsterdam, Greenpeace International, 2007.

231 World Bank, "Guidelines for Environmental Assessment of Energy and Industry Projects", World Bank technical paper No. 154/1992. Environmental Assessment Sourcebook, Vol. III.

232 Asian Development Bank, "Energy Policy", Working Paper, January 2009.

233 Rinaldo S.Brutoco, "Nuclear Power Finance and Development in the Climate Change Era", American Bar Association Presentation, 5 March 2008.

Consumers

In general, the impact of electricity market liberalisation means that consumers cannot now be assumed to be willing or able to bear the risk. However, some very particular arrangements for the Olkiluoto-3 project mean that in this case, they have been. The buyer, Teollisuuden Voima Oy (TVO), is an organization unique to Finland. PVO (Pohjolan Voima Oy), the largest shareholder, holds 60% of TVO's shares. PVO is a not-for-profit company owned by Finnish electric-intensive industry, which generates about 15% of Finland's electricity. Its shareholders are entitled to purchase electricity at cost in proportion to the size of their equity stakes. In return, they are obliged to pay fixed costs according to the percentage of their stakes and variable costs in proportion to the volume of electricity they consume. The other main shareholder in TVO is the largest Finnish electricity company, Fortum, with 25% of the shares. The majority of shares in Fortum are owned by the Finnish Government. This arrangement is effectively a life-of-plant contract for the output of Olkiluoto-3 at prices set to fully cover costs.

If it is assumed that for other cases, consumers will not bear the risk, this leaves credit guarantees and turnkey contracts.

Credit guarantees

Even before the financial crisis, the risk premium involved in nuclear projects was a severe barrier to new orders. At the top of the utilities' and vendors' wish lists for government support was credit guarantees. These shift the risk of utility failure from the vendor to taxpayers. One of the factors that made the Olkiluoto-3 order financeable (see below) was export credit guarantees from the French and Swedish governments. This made loans at only a 2.6% interest rate possible.

The US program

In February 2002, the Bush Administration announced the Nuclear 2010 program, aimed at re-starting nuclear ordering in the USA. The rationale was that Generation III+ designs would be economically competitive but that initial financial and regulatory hurdles would prevent their being ordered. The policy to overcome these barriers was therefore to streamline regulatory processes, ensure regulatory approval for a number of new designs and provide subsidies for units at up to three sites (perhaps up to four or five units). The objective was:[234]

> to complete the first-of-a-kind Generation III+ reactor technology development and to demonstrate the untested Federal regulatory and licensing processes for the siting, construction, and operation of new nuclear plants.

The program was unrealistically optimistic on time-scales and was based on an assumption that a new nuclear unit could be on-line by 2010. Loan guarantees were offered so that utilities could borrow at government Treasury bond rates. If we assume that the Treasury bond rate is 4% and the cost of equity is 9%, this might bring the WACC down to about 7%.

When the program was launched, the estimated construction cost of a nuclear unit was about US$2bn and to provide guarantees to cover 80% of the debt, if debt made up half the finance cost, would have required guarantees for five plants worth about US$4bn. Since that time, the cost per reactor, as well as the coverage of the loan guarantees grew rapidly, as did industry expectations about the number of projects the program was supposed to cover. In 2003, the Congressional Research Service estimated that the taxpayer liability for loan guarantees covering up to 50% of the cost of building six to eight new reactors would be US$14-16 billion.[235] The Congressional Budget Office concluded that the risk of loan default by industry would be "well above 50 percent" and

[234] United States Department of Energy, "A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010", Washington, US-DOE, 2001.
[235] Congressional Research Service, "Potential Cost of Nuclear Power Plant Subsidies in S.14", 7 May 2003. Requested by Senator Ron Wyden.

that taking account of the recovery from costs by selling equipment (i.e., government could recover half its costs) would bring the net cost to government to about 25%.[236]

The Department of Energy estimates that loan guarantees could reduce total generation cost by 40%:[237]

> A new merchant nuclear power plant with 100% loan guarantee and 80/20 debt to equity ratio could realize up to a 39% savings in the levelized cost of electricity when compared to conventional financing with a 50-50 debt to equity ratio.

There are restrictions on the type and number of plants that would be eligible for loan guarantees. The Congressional Budget Office stated:[238]

> The Department of Energy has indicated that it will deny a utility's application for a loan guarantee if the project is not deemed to be both innovative (essentially, in the case of nuclear technology, a plant design that has not been built in the United States) and commercially viable, and that no more than three plants based on each advanced reactor design can be considered innovative.

If three units of each of the five designs of plant under consideration were built, 15 units would be eligible for loan guarantees. But while utilities have been keen to stand in line for these handouts, with 30-40 plants now at various stages of planning, it seems increasingly likely that only plants with loan guarantees will be ordered. For fiscal year 2008/09, Congress made US$42.5bn available in Federal loan guarantees for 'innovative' generation sources, of which US$18.5bn would be for new nuclear plants, and $2bn for front-end fuel chain facilities such as enrichment.[239] If the new US government really wants to get a significant proportion of the proposed 30-40 reactors built, the $18.5bn will not go far. Utilities have already filed applications for about US$122bn worth of loan guarantees for 21 new nuclear power plants.

If we assume that a new plant will cost no more than US$7-9bn and industry gets its wish that 80% of this cost (compared to 80% of the *debt* originally) is covered by federal loan guarantees, guarantees worth about US$100bn will be needed to build just the 15 'innovative' units. If 80% of the cost is covered by loan guarantees and money is borrowed at, say, 4% with equity 9%, this would bring the real WACC down to 5%. To build 35 units, guarantees of US$230bn would be needed. The utilities hope that loan guarantees for the remaining 20% of the total cost will be offered by the Japanese and French governments, which are the countries where the vendors are based. US legal requirements state that utilities must provide a 'significant' equity stake. Whether the utilities can persuade government to forget this requirement in favor of loans guaranteed by the French or Japanese governments remains to be seen. By October 2008, 17 power companies had already applied for $122bn in federal loan guarantees.[240] If, as argued by Standard & Poor's,[241] skills and component bottlenecks mean that only 'a few' units can be supplied per year to the US market the need for this very large number of guarantees may not arise.

In practice, the ESBWR now looks increasingly likely to be abandoned in favor of the ABWR, while the APWR only has one interested buyer, so perhaps only 10 units will qualify for loan guarantees and this might bring the loan guarantee requirement down to less than US$60bn.

---

236 Congressional Budget Office, "Cost estimate of S.14, Energy Policy Act of 2003", (Washington, Congressional Budget Office), http://www.cbo.gov/doc.cfm?index=4206 .

237 Prepared remarks of Deputy Energy Secretary Dennis Spurgeon at the second annual "Nuclear Fuel cycle monitor global nuclear renaissance summit", Alexandria, Virginia, 23 July 2008.

238 Congressional Budget Office,"Nuclear Power's Role in Generating Electricity", 2008, p. 33, http://www.cbo.gov/ftpdocs/91xx/doc9133/05-02-Nuclear.pdf .

239 Platt's Global Power Report, "Nuclear Energy Institute president says Congress needs to boost loan guarantees", 16 October 2008.

240 At http://www.lgprogram.energy.gov/press/100208.pdf .

241 Standard & Poor's, "Construction Costs To Soar For New U.S. Nuclear Power Plants", 2008.

Olkiluoto

The details of how the plant is being financed were not published, but the European Renewable Energies Federation (EREF) and Greenpeace separately made complaints to the European Commission in December 2004 that the financing arrangements contravened European State Aid regulations. The Commission did not begin to investigate the complaints until October 2006 and, in September 2007, the Competition Commission dropped the case. According to EREF, the Bayerische Landesbank (BLB, owned by the state of Bavaria) led the syndicate (with Handelsbanken, Nordea, BNP Paribas and J.P. Morgan) that provided the majority of the finance. It provided a loan of €1.95 billion, about 60% of the total cost at a remarkably low interest rate of 2.6%.

Two export credit institutions are also involved: France's Coface, with a €610 million export credit guarantee covering AREVA supplies, and the Swedish Export Agency SEK for €110 million. Again, this is a surprising feature as export credit guarantees are usually offered only for exports to developing countries with unstable economies, not a category that Finland falls into.

South Africa

South Africa has, for the past decade, been trying to commercialize Pebble Bed Modular Reactor (PBMR) technology, but progress has been slow and the publicly-owned South African utility, Eskom prioritized orders for 'conventional' nuclear plants, either the AREVA NP EPR or the Westinghouse AP-1000. It has a budget of R343bn (US$34bn) to build 16 GW of new coal and nuclear plants by 2017. In the longer term, it plans to build 20 GW of nuclear plants by 2025. But at US$5000/kW, its budget would provide less than 7 GW of new nuclear capacity. Eskom faces an additional challenge of a falling credit rating, reduced by Moody's August 2008 to Baa2. Finally in November 2008, Eskom admitted defeat and scrapped its tender because the scale of investment was too high. This was despite the willingness of Coface to offer export credit guarantees[242] and despite AREVA's claims that it could have arranged 85% of the finance.[243] In February 2009, Eskom also abandoned plans to build PBMRs.[244] *Engineering News* reported that the issue was the credit rating of Eskom[245]:

> In fact, ratings agency Standard & Poor's said on Thursday that South Africa's National Treasury needed to extend "unconditional, timely guarantees" across all Eskom's debt stock if it hoped to sustain the utility's current BBB+ investment-grade credit rating. The National Treasury was still to announce the details of the package.
>
> The Eskom board had, as a result, decided to terminate the commercial procurement process to select the preferred bidder for the construction of the Nuclear-1 project.

This illustrates the fact that while loan guarantees protect vendors from utility default and allow the utility access to lower cost finance than would otherwise have been on offer, they do nothing to protect the utility from bankruptcy. Thus, if taking the loan would damage the credit rating of the utility, a loan guarantee might not be sufficient to persuade the utility to go ahead.

Other loan guarantee agencies

There has also been speculation that the French and Japanese governments would offer loan guarantees in the USA for plants supplied by their national companies.[246] AREVA NP is controlled by French interests, indeed, it is majority owned by the French state.[247] The French government has

---

[242] Nucleonics Week, "French export credit agency to insure loans for Cgnpc, Eskom", 21August 2008.
[243] The Star, "Nuclear bid had funding – AREVA", 30 January 2009.
[244] PBMR pty [?xx], "PBMR considering change in product strategy", News release, 5 February 2009, http://www.pbmr.co.za/index.asp?Content=218&Article=104&Year=2009
[245] Engineering News, 2008 "Eskom terminates Nuclear 1 procurement process, but SA still committed to nuclear", 5 December 2008.
[246] Nucleonics Week "US working with allies to change global rules for nuclear financing", 23 October 2008.
[247] AREVA NP is 66% owned by AREVA with the remaining 34% held by Siemens. In January 2009, Siemens announced its intention to sell its stake to AREVA. The Economist, "Power struggle; Nuclear energy" 6 December 2008 (US Edition).

already proved itself willing to offer loan guarantees through Coface, for example to China, Finland and South Africa.[248]

The Japanese government is much less experienced with supporting Japanese nuclear vendors. Despite the extensive nuclear program in Japan as well as large exports of nuclear components, this is the first time Japanese vendors have tried to win foreign orders as a main contractor. Nevertheless, Japanese vendors are involved in four out of five of the designs being considered in the USA – the Franco-German EPR is the fifth. Mitsubishi has its own design, USAPWR. Hitachi is collaborating with GE to offer the ESBWR and, perhaps, the ABWR. Westinghouse, which is offering the AP-1000, although largely based in the USA, is now owned by Toshiba, which is also offering the ABWR. Standard & Poor's believes the Japanese government will provide finance for orders from Japanese vendors through the Japan Bank for International Cooperation.

Japan set up the Japan Finance Corp on 1 October 2008 to provide investment credits for nuclear projects in developed countries.[249] These guarantees would complement the US guarantees and might reduce the scale of US loan guarantees needed.

In general export credit agencies are used to reduce the financial risks – and therefore costs – associated with exporting technologies. Historically, and currently, this is true for the nuclear sector. For example between 1959 and 1993 the US EX-IM Bank made available US$7.7 billion for nuclear exports, while in Canada the Export Development Corporation has made available financing for the sale of reactors to India, Pakistan, Korea, Argentina, Romania and China over the last fifty years. Similar support can be seen for German reactor builders.

III.3.1.4. Political issues

There are problems with the OECD's agreement on export credits, the Arrangement on Guidelines for Officially Supported Export Credits (established 1978). The Arrangement is a gentlemen's agreement, not an official OECD document. It provides special treatment for certain sectors, notably nuclear power plant equipment, materials and services. The Arrangement allows a 15-year payback period for nuclear export credits—three more than for conventional power plants and five more than for other types of equipment—but this is not seen as long enough for nuclear plants.[250] The Participants to the Arrangement were due to meet in Paris in November 2008, but by end January 2009, there had been no reports on whether the meeting took place and, if it did, what the outcome was.

Providing guarantees for one order, like Olkiluoto-3, which was seen as opening up the market for French exports might be acceptable to French and Japanese taxpayers. However, if such guarantees are a condition for all orders to be placed, taxpayers will see this as a blank cheque. If the Olkiluoto-3 order does lead to a default or the US Congressional Budget Office's estimate that the risk of loan default by industry would be "well above 50 percent", loan guarantees will be seen as a highly risky option.

III.3.1.5. Turnkey contracts

The financial assurance a turnkey contract seemed to give was an important element in AREVA NP's winning the Olkiluoto contract and also the French and Swedish governments' offering loan guarantees. However, it was surprising that AREVA NP was so desperate for the order that it was prepared to take the massive financial risk a turnkey contract involves. There have been few (if any) genuine 'whole plant' (as opposed to individual component) turnkey contracts since the notorious 12/13[251] turnkey orders that launched commercial ordering in the USA in 1964-66[252]. These lost the vendors large amounts of money although they did achieve one of their aims, which

[248] Nucleonics Week, "French export credit agency to insure loans for Cgnpc, Eskom", 21 August 2008.
[249] Nucleonics Weeks, "Japan clears way for loan guarantees in US", 25 September 2008.
[250] Nucleonics Week, "US working with allies to change global rules for nuclear financing", 23 October 2008.
[251] There were 12 strictly turnkey orders but a 13th, San Onofre, is sometimes included.
[252] Irvine Bupp & Jean-Claude Derian, "Light Water: How the Nuclear Dream Dissolved", NY. Basic Books, 1978.

was to convince utilities that nuclear was little more challenging than, say, a coal-fired plant and could be ordered with confidence as a proven technology. Turnkey orders for nuclear plants are much more risky for vendors compared to other power plants because so much of the work in nuclear construction is on-site engineering and construction, a process that is notoriously difficult to control. It is also not easy for the vendor to control the quality of work given the large number of contractors involved.

Standard & Poor's was clear in a recent report that turnkey contracts would not be on offer.[253]

> We expect no EPC [engineering, procurement and construction] contracts to be fully wrapped through a fixed-price, date certain mechanism.

Top AREVA representatives in private talks also made it clear that the Olkiluoto-3 fixed price contract was a one-off agreement not to be repeated.

III.3.1.6. Reliability

Reliability has always been the neglected element of the fixed cost equation. The nuclear industry always projected high reliability for plants. A good measure of the reliability of the plant and how effective it is at producing saleable output is the load factor (capacity factor in US parlance). The load factor is calculated as the output in a given period of time expressed as a percentage of the output that would have been produced if the unit had operated uninterrupted at its full design output level throughout the period concerned.[254]

Higher utilization improves the economics of nuclear power because the large fixed costs can be spread over more saleable units of output than if utilization is lower. In addition, nuclear power plants are physically inflexible. Frequent shutdowns or variations in output reduce both efficiency and the lifetime of components. As a result, nuclear power plants are operated on 'base-load' (continuously at full power) except in the very few countries (e.g., France) where the nuclear capacity represents such a high proportion of overall generating capacity that this is not possible. Unlike construction cost, load factor can be precisely and unequivocally measured and load factor tables are regularly published by trade publications such as *Nucleonics Week* and *Nuclear Engineering International*.

As with construction cost, load factors of operating plants have been much poorer than forecast. The assumption by vendors and those promoting the technology has been that nuclear plants would be extremely reliable with the only interruptions to service being for maintenance and refueling (some designs of plant such as the AGR and Candu are refueled continuously and need only shut down for maintenance) giving load factors of 85-95%. However, performance was poor and around 1980, the average load factor for all plants worldwide was about 60%. To illustrate the impact on the economics of nuclear power, if we assume fixed costs represent two thirds of the overall cost of power if the load factor is 90%, the overall cost would go up by a third if load factor was only 60%. To the extent that poor load factors are caused by equipment failures, the additional cost of maintenance and repair resulting would further increase the operations and maintenance cost.

However, from the late 1980s onwards, the nuclear industry worldwide has made strenuous efforts to improve performance. Worldwide, load factors now average more than 80%. The USA has an annual average of about 90% compared to less than 60% in 1980, although the average lifetime load factor of America's nuclear power plants is still only 70%.

Only 7 of the 414 operating reactors with at least a year's service and which have full performance records have a lifetime load factor in excess of 90% and only the top 100 plants have a lifetime load factor of more than 80%. Interestingly, the top 13 plants are sited in only three countries: six in South Korea, five in Germany and two in Finland. This suggests that performance is not random

[253] Standard & Poor's, "Construction Costs To Soar For New U.S. Nuclear Power Plants", 2008.

[254] Note that where reactors are derated, some organisations (e.g., the IAEA) quote the load factor on the authorized output level rather than the design level. While this may give some useful information on the reliability of the plant, for economic analysis purposes, the design rating should be used because that is what the purchaser paid to receive.

but is determined as much by the skills that are brought to bear and how well the plants are managed as by the technology and the supplier.

New reactor designs may emulate the level of reliability achieved by the top 2% of existing reactors, as industry frequently assumes. However, they may equally suffer from 'teething problems' like earlier generations. The French experience in the late 1990s with the N4 design is particularly salutary. The four units of this design took from 6-12 years to build. A series of technical problems led to the period between first criticality and commercial operation, usually a few months, taking from 29-49 months. Reliability in this period was very poor and the average load factor for these four units for the first four calendar years after criticality was only 46%.

Note that in an economic analysis, the performance in the first years of operation, when teething problems are likely to emerge, will have much more weight than that of later years because of the discounting process. This problem may be compounded if advance sales contracts have been put in place, and replacement power must be procured on the spot market in the event of delays. Performance may decline in the later years of operation as equipment wears out and has to be replaced, and improvements to the design are needed to bring the plant nearer current standards of safety. This decline in end-of-life performance will probably not weigh very heavily in an economic analysis because of discounting.

III.3.2. Operating costs

III.3.2.1. Non-fuel O&M costs

Operating costs can be split into non-fuel operating costs and fuel costs. The non-fuel operations and maintenance (O&M) costs are seldom given much attention in studies of nuclear economics. As discussed below, the cost of fuel is relatively low and has been reasonably predictable. However, the assumption of low running costs was proved wrong in the late 1980s and early 1990s when a small number of US nuclear power plants were retired because the cost of operating them (not including repaying the fixed costs) was found to be greater than cost of building and operating a replacement gas-fired plant. It emerged that non-fuel O&M costs were on average in excess of US$22/MWh while fuel costs were then more than US$12/MWh.[255] Strenuous efforts were made to reduce non-fuel nuclear O&M costs and by the mid-1990s, average non-fuel O&M costs had fallen to about US$12.5/MWh and fuel costs to US$4.5/MWh.

However, it is important to note that these cost reductions were achieved mainly by improving the reliability of the plants rather than actually reducing costs. Some larger repair costs are categorized as 'net capital additions' and are reflected in an increased capital value rather than higher O&M costs where they should, more appropriately, be placed. Unlike operating costs in many industries, a large proportion of the O&M costs in the nuclear sector are largely fixed. The cost of employing the staff and maintaining the plant, for example, vary little according to the level of output of the plant. As with fixed costs, the more power that is produced, the lower the O&M cost per MWh. The threat of early closure on grounds of economics has now generally been lifted in the USA because, on a marginal cost basis, the plants are low cost generators.

It is also worth noting that British Energy, which was essentially given its eight nuclear power plants when it was created in 1996, collapsed financially in 2002 because income from operation of the plants barely covered operating costs. This was in part due to high fuel costs, especially the cost of reprocessing spent fuel, an operation only carried out now in Britain and France. British Energy has subsequently acknowledged that expenditure in that time was not sufficient to maintain the plants in good condition[256]. Average O&M costs for British Energy's eight plants, including fuel,

[255] For statistics on O&M costs, see Nuclear Energy Institute, http://www.nei.org/index.asp?catnum=2&catid=95 .

[256] In its re-launch prospectus, British Energy stated: "We believe that the loss of output is indicative of a deterioration of the materiel condition of plant over time in part caused by inadequate investment over the last few years which has resulted in an increase in our maintenance backlog and failure to carry out required maintenance on a timely basis." Available at http://www.british-energy.co.uk/documents/Prospectus_-_Part_II.pdf .

varied between about £16.5 and 20.0/MWh from 1997-2004. By 2008, they had doubled and in the first six months of fiscal year 2008/09, operating costs including fuel were £41.3/MWh, two and a half times the level of only five years previously, because of poor performance at some plants (see Table 5). It is only the good fortune of rapidly rising wholesale prices since 2005 that has prevented British Energy from falling into a much worse position than in 2002. Now that wholesale electricity prices are falling sharply, British Energy, owned since the end of 2008 by EDF, may well suffer from financial problems again.

Table 5 Operating Costs of British Energy Nuclear Power Plants

Year	Output (TWh)	Operating cost (£/MWh)	Average selling price (£/MWh)
1997/98	66.7	19.8	26.3
1998/99	69.1	19.9	26.4
1999/00	63.0	19.9	25.7
2000/01	63.5	18.7	21.7
2001/02	67.6	16.7	20.4
2002/03	63.8	18.6	18.3
2003/04	65.0	16.5	16.9
2004/05	59.8	20.5	20.4
2005/06	60.4	22.8	32.0
2006/07	51.2	27.1	44.2
2007/08	50.3	30.0	40.7
2008/09 First half	19.2	41.3	47.2

Source: British Energy (various) "Annual Report and Accounts", British Energy, Livingston.

While UK operating costs are fully documented and reliably reported (the company's only business is effectively generating nuclear power so there is nowhere to 'hide' the costs), the fact that seven out of eight of the stations are of a British design not built elsewhere means that these operating costs may not be more broadly representative. The only other country that has, in the past, reliably fully reported operating costs is the USA. US utility figures on operating costs have, in the past, had to be submitted to state and federal energy regulators who oversee energy prices. In some cases, electricity markets in the USA have been opened to competition and in these cases, utilities argue that operating costs are commercially sensitive and the utilities no longer publish them. Only 34 out of 65 US nuclear power stations (stations with more than one unit do not report separate figures for each unit) now publish their operating costs, but this should still be a representative sample. In 2007, the average non-fuel operations and maintenance cost for these 34 stations was US$13.97/MWh (US$18.81 including fuel) compared to US$13.59/MWh in 2006 (US$18.18 including fuel).[257] While this appears significantly lower than current UK costs, the difference is partly accounted for by the higher UK fuel costs and by the higher US load factors. As argued below, US fuel costs are artificially depressed because the government takes responsibility for the spent fuel for a fixed fee of US$1/MWh, a figure that is likely to be significantly less than the actual cost. UK fuel is mostly reprocessed at a much higher cost than the forecast cost of direct disposal so UK fuel costs are higher than in countries that do not reprocess their fuel. The higher load factors of the US plants, in 2007 the average for the plants that reported costs was over 92%, means that the costs can be spread much more thinly than is the case for the UK where the average load factor is less than 70%. The total annual expenditure on operating and maintaining the US plants, excluding fuel, is not so different between the UK and the USA, at least it was not until UK costs began to escalate dramatically from 2005 onwards. Utilities in other countries claim lower operating costs but these figure are not independently verified so they must be treated with some skepticism.

III.3.2.2. Fuel costs

Fuel costs have fallen as the world uranium price has been low since the mid-1970s although in recent years, the price of uranium has risen, more than doubling in 2006. These higher uranium

[257] Nucleonics Week, "US operating costs increased modestly in 2007", 30 October 2008, p. 1.

costs have yet to be reflected in fuel costs for reactors, although given that much of the cost of fuel relates to processing, such as enrichment, the effect will be limited.

US fuel costs average about $5.0/MWh but these are arguably artificially low because the US government assumes responsibility for disposal of spent fuel in return for a flat fee of $1/MWh; and because secondary supplies of uranium, such as from blending down Russian high enriched uranium, have depressed prices. The waste fee is an arbitrary price set more than two decades ago. While it is periodically reviewed for "adequacy", the value is not based on actual experience – no fuel disposal facilities exist in the USA or anywhere else – and all the US spent fuel remains in temporary store pending the construction of a spent fuel repository. This was expected to be at Yucca Mountain in Nevada but the Obama administration has effectively killed this proposal by cutting all but some R & D funding.

Fuel costs are a small part of the projected cost of nuclear power. The issue of spent fuel disposal is difficult to evaluate. Reprocessing is expensive and does little to help waste disposal. Reprocessing merely splits the spent fuel into different parts and does not reduce either the amount of radioactivity that must be dealt with or the heat load. Indeed, reprocessing creates a large amount of low and intermediate level waste because all the equipment and material used in reprocessing becomes radioactive waste. The previous contract between BNFL and British Energy, before its collapse, was reported to be worth £300m per year, which equates to about £5/MWh. The new contract is expected to save British Energy about £150-200m per year, although this will be possible only because of underwriting of losses at BNFL by the government. The cost of disposing of high-level waste is hard to estimate because no facilities have been built or are even under construction and any cost projections should have a very wide margin for error.

III.3.3. Decommissioning costs

These are difficult to estimate because there is little experience with decommissioning commercial-scale plants. The cost of disposal of waste, especially intermediate or long-lived waste, which accounts for a high proportion of estimated decommissioning costs, is similarly uncertain. However, even schemes that provide a very high level of assurance that funds will be available when needed, will not make a major difference to the overall economics. For example, if the owner was required to place the (discounted) sum forecast to be needed to carry out decommissioning at the start of the life of the plant, this would add only about 10% to the construction cost. The British Energy segregated fund, which did not cover the first phase of decommissioning, required contributions of less than £20m per year equating to a cost of only about £0.3/MWh.

The problems come if the cost has been initially underestimated, if the funds are lost or if the company collapses before the plant completes its expected lifetime. All of these problems have occurred in Britain. The expected decommissioning cost of the UK's first generation plants has gone up several-fold in real terms over the past couple of decades. In 1990, when the CEGB was privatized, the accounting provisions made from contributions by consumers were not passed on to the successor company, Nuclear Electric. The subsidy that applied from 1990-96, described by Michael Heseltine[258] as being to 'decommission old, unsafe nuclear plants' was in fact spent as cash flow by the company owning the plant and the unspent portion has now been absorbed by the UK Treasury. The collapse of British Energy has meant that a significant proportion of the decommissioning costs of the old nuclear power plants will be paid by future taxpayers.

III.3.4. Lifetime

One of the features of Generation III/III+ plants compared to their predecessors is that they are designed to have a life of about 60 years while their predecessors generally had a design life of about half that. For a technology dominated by fixed costs, it might be expected that doubling the life would significantly reduce fixed costs per unit because they would be operating much longer to recover these costs. In practice, this does not apply. Commercial loans must be repaid over no more than 15-20 years and in a discounted cash flow calculation, costs and benefits more than 10-15

[258] President of the Board of Trade, Michael Heseltine, Hansard, 19 October 1992.

years forward have little weight. One of the benefits of government loan guarantees, such as those on offer in the United States, is that their term can be as long as 30 years.

There is a trend to life-extend existing plants and PWRs are now often expected to run for more than 40 years, compared to their design life of around 30 years. Life extension may require significant new expenditure to replace worn out equipment, in particular large components like steam generators and vessel heads, and to bring the plants closer to current safety standards. The entire US reactor fleet was ordered in the years 1963-1973, a period difficult to compare with current technological standards.

Despite these costs, however, life extension in the USA appears, from a utility perspective, to be an economically sound decision and is being widely pursued by utilities. Whether in practice this perception proves to be correct or whether high and perhaps prohibitive maintenance expenditures will be necessary to keep the plants in a serviceable and licensable condition remains to be seen.

In terms of capital costs, extending a reactor's life (PLEX) is far cheaper than constructing a new power plant. Some estimates say that the average cost of PLEX is as low as \$10-50 per installed kW, compared to the gas power plant costs of around \$400-500/kW. In one case, at Duke Power in the USA, the utility estimates that the cost for obtaining an extended license to operate would be as low as \$4-6/kW[259]. Furthermore, by the end of a reactor's operating life, the decommissioning fund should be fully stocked so another large part of the nuclear operating costs may be written off, as the utility will no longer need to put funds aside to pay for decommissioning.

III.4. Implications for Existing and Future Reactors

Nuclear projects remain highly sensitive to construction cost, cost of capital and duration of construction. Industry efforts to gain support from government are likely to remain focused in the latter two areas, through loan guarantees and efforts to streamline licensing. Policy makers need to take care that stepping in to ameliorate these conditions does not raise issues of accountability, and does not adversely affect the viability of competing power resources.

Plant construction is likely to move forward first in regions with regulated utilities or governments willing to absorb much or all of the risks of the construction. The handful of projects that have entered into actual construction illustrate that historic concerns regarding cost-competitiveness and delays remain today. Cost estimates, while essential for some purposes and useful in delineating trends remain a poor indicator of actual costs. They are also difficult to compare across time or space in a consistent manner. Core government policies to shift long-term structural risks of nuclear energy, primarily accident liability and responsibility for waste management, away from investors remains an enabling factor essential for the viability of nuclear power.

The economic viability of nuclear power plants depends very much on the owner of the plant and the conditions in which the owner operates. For a utility with a good credit rating in a traditional monopoly electricity market and where the regulator is not aggressive in its objective of minimizing costs for consumers, utilities can, provided there is political consent for the plants, continue to build and operate plants as they wish. The only constraints on them are whether it is feasible to borrow money to build new plants. For some developing countries, this constraint may be sufficient to make orders non-viable. But for the countries that have seen the vast majority of orders in the past 25 years - Russia and Asian countries such as China, Japan, South Korea and India – energy market liberalization measures have had little impact yet in preventing utilities from placing uneconomic orders or from keeping uneconomic reactors in operation. The trend to open electricity systems to competition seems to have stalled outside Europe so it is likely that the countries noted above will continue to place nuclear orders as long as there is political support for these orders. The next section on the economic viability of existing plant, plants under construction and future orders therefore is not valid for these countries.

Apart from reactors in operation, those under construction and those yet to be ordered, there is a fourth group of reactors that needs to be considered separately. Partially-completed plants, on

259 Nuclear Engineering International, "US Nuclear Power – Can Competition give it renewed Life?", June 1999.

which work has been halted for some time, have seen proposals or actual construction restarts driven by the rising value of electricity through the first half of 2008. Most of the plants falling into this category are in the former Soviet Union (Ukraine) or the former Eastern Bloc (Bulgaria, Romania, and Slovakia) but there are also plants in Brazil, Argentina, and the United States that have been stalled long-term.

III.4.1. Existing reactors

Nearly all the reactors in operation, particularly those in the West, were completed more than 20 years ago. Partly due to the age of the capital, and partly due to a series of capital write-offs, the fixed costs are of much less importance to the existing fleet of reactors than for reactors under construction or yet to be ordered. If the owners of these operating reactors can continue to convince the responsible regulators of the safety of these plants, the main issues are whether their operating costs will remain low enough for them to be competitive and whether the cost of major expenditures to replace worn out components or to upgrade safety is economically viable. Because of the rigidity of the cost structure – unlike fossil fuel plants, the majority of costs are incurred whether or not the plant is operated – nuclear plants are vulnerable to factors such as fluctuations in fossil fuel prices and over-capacity in generation, which may lead to a fall in the wholesale electricity price.

As has been clearly illustrated in the UK by the experience with Britain's ageing AGRs, operating costs can escalate at an alarming rate and since 2002, the average operating costs for Britain's seven AGR stations and its single PWR have tripled. In 2002, low fossil fuel prices and a generating capacity surplus bankrupted the nuclear company, British Energy. So it can be seen that British Energy, which was rescued at a cost to taxpayers of more than £10bn, is only surviving because of the good luck of very high fossil fuel prices in the past 3-4 years. Fossil fuel prices have now fallen significantly from their peak and the future of British Energy now looks precarious.

US plants are now having their operating licenses extended from 40 to 60 years[260] and there is a wide perception that this will apply in other countries and will mean that plants will actually operate for this long. It remains to be seen how well the materials perform over this fifty percent life extension. However, plants may also be retired before 60 years if repair and maintenance costs start to rise steeply, and the plants are not competitive or, where markets are still regulated, regulators are not prepared to allow companies to pass on unjustifiable costs.[261]

III.4.2. Reactors under construction

Only two reactors of modern design are under construction in the West, Olkiluoto-3 and Flamanville-3. Unless and until EDF loses its position of overwhelming dominance in the French market it must be seen as a *de facto* monopoly and can pass on any additional costs from Flamanville to its consumers.

As was noted above, Olkiluoto-3 has very particular arrangements that protect it from the market. The economic risks of building this plant are borne by consumers, through the cost-plus terms of the power purchase contract, French (and Swedish) taxpayers through the credit guarantees, and the vendor, AREVA NP (majority owned by the French public), through the turn-key contract. Whether the loan is economic to the banks is a moot point. So, far from surviving in the market through its competitiveness, the plant has been very fully and deliberately insulated from the market. Despite this, the severe construction problems mean that the possibility of a default of the customer can no longer be discounted. The Olkiluoto project is acknowledged to be nearly 60% over budget and at least three years late after only three and a half years of construction. The owners, TVO, expect to be covered for the cost escalation by the contract with the Franco-German

[260] As of April 2009, 52 or half of the operating US units had already received license extensions; additional ones have applied.

[261] As chapter II illustrates, the average age of the 121 units that have already been shut down is only 22 years. In France, the operator EDF has not yet convinced the Nuclear Safety Authority that its reactors could safely operate for 40 years or longer.

company, AREVA NP, although whether this contract will stick is now far from clear[262]. But most of the costs of late completion - buying the replacement power from a potentially tight Nordic wholesale electricity market - will fall on the owners.

Little new generation has been built since the Nordic market was created in the late 1990s and already, dry winters, which reduce the availability of hydro-power have led to short-term large increases (up to 6-fold) in the wholesale electricity price. So for the period 2009-12, when Olkiluoto-3 should have been producing 12TWh per year, the owners will have to buy that power from the wholesale market, assuming that amount of power is available. The economic studies on which Olkiluoto-3 were based assumed the generation cost would be €24/MWh. If the Nord Pool price was three times that, far from unusual in recent years, the extra cost of purchasing this power from the market, over three years would be on the order €2bn.

III.4.3. Reactors on which construction has stopped

Construction on a handful of reactors started in the 1980s but has been interrupted because of political or economic issues. These plants include Belene-1&2 (Bulgaria), Mochovce-3&4 (Slovakia), Cernavoda-3 (Romania), plants in Ukraine, Angra dos Reis (Brazil) and Atucha (Argentina). Restart of work is frequently reported to have occurred or to be imminent. Often, however, these reports often turned out to be false. Generally the problem is finance. Completing these plants may seem attractive to the owners who see the plants as cheap sources of power. Officially the construction sites at Belene and Mochovce have been recently reactivated.

However, experience with completing partially built plants on which work stopped for a significant time is poor, for example, at Mochovce-1&2, Rovno 4 and Khmelnitsky-2 (Ukraine) and Temelin-1&2 (Czech Republic). A particular concern is how much designs that may be more than 40 years old can be updated to meet current needs and requirements. Licensing procedures that provided the basis for the authorization of the construction of these plants over 20 years ago certainly do not reflect current state of the art either. However, because these plants are generally in countries where electricity liberalization has not been important yet (Russia and Ukraine) or where the generation market is not very competitive (Brazil), they may be able to obtain financing. Where competitive markets are on the horizon, obtaining finance will likely be much more difficult, preventing these plants being completed.

III.4.4. Future orders

The key elements for new orders to be placed are how well costs can be minimized and controlled; and how extensively the new reactors can be protected from the electricity wholesale market in case costs begin to rise.

Protection from the market

In the USA, nearly 30 separate subsidy programs are available to new reactors. In total, subsidies to new reactors in the USA are likely to exceed the private capital put at risk. In Europe, there are discussions about putting guarantees on the carbon price that nuclear plants would receive in the European Union emissions trading scheme – of course, if the price was guaranteed, it would not be a market.

Controlling costs

Loan guarantees are the most likely form of cost control that will be sought. These reduce finance costs by protecting the banks and vendors from default. Of equal importance, the guarantees enable plant owners to load up on far more debt than would otherwise be possible, brining down financing costs significantly.

The protection for utilities from the credit guarantees may not be complete, however. The credit rating of the utility may still suffer if a nuclear order is placed, as was illustrated by Eskom (South

[262] Nucleonics Week, "Target date for operating Olkiluoto-3 again delayed, this time until 2012", 23 October 2008.

Africa). Turnkey contracts would also be of great value but experience at Olkiluoto suggests they represent a risk the vendors cannot take. A turnkey contract may not offer protection against construction delays and the cost of 'replacement power' to replace the power the new plant was expected to provide may exceed the value of cost over-runs. Performance guarantees, such as are offered for combined cycle plants would also be useful but are highly unlikely to be offered due to the greater uncertainty on nuclear plant delivery times and cost.

The British government seems likely to offer companies building new nuclear plants a price for waste disposal that would be fixed on the day construction starts.[263] Although waste disposal costs are a relatively small element of the total cost of energy and these costs are not generally incurred for several decades, the guarantee is still useful to utilities in reducing long-tail risks to investors. However, the guarantee will carry little weight in discounted cash flow project appraisals.

It still remains to be seen whether in the USA and the UK, a package of measures can be established that offer enough assurance for utilities to build new nuclear plants but do not expose taxpayers and electricity consumers to a level of economic risk that is unacceptable. The politics of the decisions suggest that many of the incentives on offer to spur nuclear plant construction will result merely in shifting risks from investors to taxpayers, customers, or the population surrounding plants.

III.5. Nuclear Liability Issues

The nuclear liability and compensation arrangements currently in place are seriously inadequate. This has major negative implications for reactor safety, fails to ensure compensation of damage in the event of an accident, and creates distortion of competition in the electricity market.

There is a need to introduce new liability and compensation arrangements that reflect the actual potential costs of nuclear accidents, that would fully compensate damage caused in the event of a nuclear accident, and which would eliminate a significant subsidy to nuclear electricity generation. Yet attempts to significantly increase the minimum compensation required by international nuclear liability treaties by even a relatively modest amount have been efficiently resisted by the nuclear industry.

There are two basic international legal frameworks contributing to an international regime on nuclear liability: The IAEA's 1963 Convention on Civil Liability for Nuclear Damage (Vienna Convention) and the OECD's 1960 Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention), and the associated 'Brussels Supplementary Convention'[264] of 1963. The Vienna and Paris liability conventions are also linked by a Joint Protocol adopted in 1988.[265]

The Vienna and Paris Conventions had two primary goals: first, to create an economic environment where the nuclear industry could flourish; and, second, to ensure that clear procedures and some compensation would be available in the event of an accident. The first aim would be achieved by removing legal and financial uncertainties over potentially enormous liability claims that could arise in the event of an accident. From the industry's development, it was clear that nuclear power could only be exploited as an efficient and independent source of energy if a reasonable amount of financial protection were available for private investors who were placing their financial resources in an unknown and potentially high-risk sector.

While there are some differences in detail, the Vienna and Paris Conventions have some important features in common. In particular they:

- Allow limitations to be placed on the amount, duration and types of damage for which nuclear operators are liable;

---

263 Department of Business, Enterprise and Regulatory Reform (BERR), Press release, "Clean up fund is precondition for new nuclear – Hutton", 22 February 2008; http://www.nce.co.uk/clean-up-fund-is-precondition-for-new-nuclear-hutton/766426.article

264 Convention Supplementary to the Paris Convention of 29th July 1960 on Third Party Liability in the Field of Nuclear Energy.

265 The Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, September 1988. The Joint Protocol entered into force on 27 April 1992.

- Require insurance or other surety to be obtained by the operator;
- Channel liability exclusively to the operator of the nuclear installation;
- Impose strict liability on the nuclear operator, regardless of fault, but subject to exceptions;
- Grant exclusive jurisdiction to the courts of one country for any given incident, normally the country in whose territory the incident occurs.

The Chernobyl accident clearly revealed a number of deficiencies in the regimes. Compared with the damage caused by Chernobyl, it was obvious that the liability amounts were woefully low and many countries were not party to either Convention. In addition, not all of the damage – including some of the most serious damage - caused by Chernobyl was covered by the definition of damage applicable under either Convention. There were also problems with the periods of time during which claims for compensation could be brought, the claims procedures, and the limitations on which courts had jurisdiction to hear claims.

The 1988 Joint Protocol[266] was developed as an interim step intended primarily to address the lack of membership in the IAEA and OECD liability regimes. The Joint Protocol creates a 'bridge' between the two conventions, effectively expanding their geographical scope. However, the international community soon recognized that more fundamental reform was needed in order to attract broader adherence to the international nuclear liability conventions and to make them really effective. Work began on amendments to the Vienna Convention in 1990, followed later by revisions to the Paris Convention for the Brussels Supplementary Convention. Amending protocols to the Vienna, Paris and Brussels Conventions have been adopted,[267] as has the 1997 Convention on Supplementary Compensation (CSC) - a new instrument intended to establish a global regime of liability and compensation.

The revisions to the Vienna and Paris/Brussels Conventions do introduce a number of improvements. The liability and compensation amounts would be higher than before, with operator liability under the revised Paris Convention required to be at least €700 million and the total compensation available under the revised Brussels Supplementary Convention €1500 million. Nonetheless, the overall amounts remain worryingly low when compared with the costs of the Chernobyl accident, currently estimated to be in the order of hundreds of billions of Euros. Further, setting fixed compensation sums is not only arbitrary (in the absence of genuinely robust estimates of probable damage) but it is also unlikely to be valid over the longer term (unless they can be continually adjusted to take into account changes in the economic profile of accident consequences). Finally, even at the low levels covered under the Conventions, there are concerns about the strength of the guarantor parties and their ability or willingness to make good on financial pledges in a timely manner.

Although there are unifying features, the nuclear liability conventions do not provide one comprehensive and unified international legal regime for nuclear accidents. Furthermore, the goal to ensure broad participation in the new regimes has not been achieved. Less than half the world's nuclear reactors are covered by any of the existing international agreements.[268] At this point, only five countries have ratified the 1997 Vienna Convention. This was enough to bring the Protocol to amend the Vienna Convention into force in 2003, but the lack of wide adherence remains problematic.

There has also been a delay in the ratification of the revised Paris Convention and the revised Brussels Supplementary Convention. In order for the Protocol amending the Paris Convention to enter into force it must be ratified by *two-thirds* of the Contracting Parties. For EU Member States, this was supposed to have taken place by the end of 2006, but this still has not yet been done. For the Protocol amending the Brussels Convention, ratification by *all* Contracting Parties is required.

[266] The Joint Protocol entered into force in April 1992.

[267] The 1997 Protocol to Amend the 1963 Vienna Convention; the 2004 Protocol to Amend the 1960 Paris Convention; and the 2004 Protocol to amend the 1963 Brussels Supplementary Supplementary Convention.

[268] McRae has calculated that the nuclear power generating countries that operate outside the international compensation regimes account for more than half of worldwide installed capacity. See: Ben McRae, "Overview of the Convention on Supplementary Compensation", in: Reform of Civil Nuclear Liability, OECD, 2000, p.175.

Four countries have ratified the new Supplementary Compensation Convention, below the minimum needed for this to take effect.

Table 6: **Summary of Liability and Compensation Amounts for Different Conventions** (all figures rounded, in millions of euros)

Convention	Operator Liability + Installation State	Total Combined Contributions from Other States Party	Total Compensation Available
Paris, 1960	€6 to €18	-	**€6 to €18**
Brussels, 1963	Up to €202	€149	**€357**
Paris, 2004	At least €700	-	At least **€700**
Brussels, 2004	Up to €1200	€300	**€1500**
Vienna, 1963	€50	-	**€50**
Vienna,1997	Up to €357	-	**€357**
CSC*, 1997	At least €357	Depends	At least **€713**

*Convention on Supplementary Compensation

The United States has been covered by an entirely separate liability regime, the Price-Anderson Act, for the past fifty years (see section III.6.2.3 for more discussion). Like the Brussels and Paris Conventions, it establishes a minimum level of coverage for third party damages that each reactor owner must procure insurance for. It adds an additional, much larger, layer of coverage through retrospective payments by all reactors in the case of a large accident. While the pool is the largest in the world, it remains inadequate. On a present value basis, even storm events in the USA regularly result in higher levels of damage.

The capacity of the private nuclear insurance market is also a major factor in determining whether nuclear operators can obtain the necessary coverage to meet the amount and extent of their liability under the conventions. During the negotiations to revise the Vienna and Paris Conventions, representatives of the nuclear insurance industry stated that some of the proposed amendments would be problematic.[269] In particular, the nuclear insurance industry was concerned that there was:

- Insufficient private insurance market capacity to insure nuclear operators against raised liability amounts;
- An unwillingness of the market to extend the period after which the operator would no longer be liable;
- A difficulty in that private insurance could not cover all the categories included in the expanded definition of damage.

It remains unclear whether nuclear operators will be able to obtain private insurance coverage to cover their full liabilities under the revised Conventions. The gap between the liability risks the operators are required to assume under the revised convention and the coverage currently available from private insurers, is causing problems and delaying ratification of the revised liability conventions.

Another problem has to do with the new perception of the possibilities of terror attacks against nuclear installations. Under the Vienna Convention (both the original Convention and as amended in 1997) and the original Paris Convention, the operator of a nuclear installation is liable for damage due to acts of terrorism**.** After the events of September 11th 2001, the insurers reappraised the risks associated with acts of terror, concluding that the probability of a nuclear reactor becoming the target of such an attack was significantly higher than had been previously thought. Some insurers may be able to limit their coverage to operators for damage caused by a nuclear incident resulting from a terrorist act – requiring state intervention to insure this risk.

[269] Ibidem, p. 9. The nuclear insurance industry made its concerns known at an early stage in the discussion of amendments of the Paris Convention. See "Letter of the Comité Européen des Assurances", 8 December 2000.

The problem with private insurance can be seen to be - at least partly - a financial question. It is not that insurance is unavailable, it is just that "few [policies] can be purchased at reasonable cost or at least at costs that are competitive".[270] The UK Government has recognized that the increase in the liability amount and the cost of insurance for UK nuclear operators (present ones and any future ones), may mean that commercial cover cannot be secured for all aspects of the new operator liabilities. It will explore the alternative options available – including the possibility of providing cover from public funds. [271]

However, it is also – at least partly - a political decision. Simply because the private insurance industry is not able or willing to make cover available at the appropriate price to the industry, does not mean that the risks are not there.

From the perspective of potential victims there is a pressing need to ensure full and effective compensation for the full risks of nuclear accidents, and it is less of an issue what the specific modalities are. In accordance with the conventions, gaps in insurance coverage have to be covered by the operator to the extent that insurance or other financial security is not available or is insufficient to satisfy claims. From the perspective of the efficient functioning of the energy markets (for example, avoiding subsidies to nuclear power by failing to internalize the full costs of nuclear generation), whatever modalities are chosen must be reflected in the price of electricity from nuclear generation.

III.6. The Subsidy Issue

The problem is, of course, first, a new nuclear project is vastly expensive. We estimate two 1,500-megawatt units to cost on the order of $12 billion in today's numbers. I represent the biggest company in my industry, and that's bigger than my balance sheet. So we can't do it without the federal subsidy.

John Rowe
CEO, Exelon Corporation
April 2009[272]

III.6.1. Overview of subsidies to nuclear energy

In country after country, long frozen nuclear construction plans have been thawing. New plant announcements have been arriving with increasing frequency, and even countries such as Germany and Sweden that had foresworn their civilian nuclear sector have reopened debate[273]. The impetus for this shift has been twofold: the idea that nuclear power could bolster energy independence from unstable oil and gas producers; and most importantly claims that nuclear energy is the only large scale resource to provide energy without carbon. Without nuclear, the story goes, we will not be able to meet the twin challenges of preventing climate change while maintaining and further improving our quality of life.

Less visible than the pronouncements about our new nuclear commonweal, though always present in the background, has been a growing array of government programs to bolster, support, and subsidize these reactors. The subsidy programs are normally framed as 'temporary' and 'transitional' – needed just long enough to move the industry up the learning curve of a new reactor

---

[270] In Europe there are two mutual insurance arrangements, which supplement commercial insurance pools' cover for operators of nuclear plants. The European Mutual Assurance for the Nuclear Industry (EMANI) was founded in 1978 and European Liability Insurance for the Nuclear Industry (ELINI) created in 2002. ELINI plans to make €100m available as third party cover, and its 28 members had contributed half that as of late 2007 for a special capital fund. ELINI's members comprise most EU nuclear plant operators. EMANI's funds are also only about €500m. See UIC 2007: Civil Liability for Nuclear Damage, Uranium Information Centre, Issues Briefing Paper # 70, October 2007; http://www.uic.com.au/nip70.htm.

[271] HMG, "The Role of Nuclear Power", Consultation 2007.

[272] Panel Discussion, "Toward a Nuclear Power Renaissance? Fact or Fiction", 2009 Carnegie Endowment for International Peace International Non-Proliferation Conference, Washington, DC, 6 April 2009.

[273] However, it remains very unlikely that the 'debates' will lead to any policy shift in practice in the short and medium term.

type and a new set of regulatory oversight. Yet the reality is that nuclear power has already benefitted from more than a half-century of subsidies. A 1954 advertisement from the General Electric civilian reactor program notes this clearly:

> We already know the kinds of plants, which will be feasible, how they will operate, and we can estimate what their expenses will be. In five years – certainly within 10 – a number of them will be operating at about the same cost as those using coal. They will be privately financed, built without government subsidy.

The ad copy could have been written today.

It is certainly true that nuclear power can provide large scale, baseload energy resources with low direct carbon emissions. But just like all energy resources, its strengths are counterbalanced by a number of weaknesses. These include extremely high capital costs, long construction times, inability to follow load patterns, and a variety of safety and security challenges from highly radioactive waste storage to serving as cover for weapons proliferation. Some of these problems are unique to nuclear power, and quite difficult to address. But absent in the push for big new handouts for nuclear reactors is the basic idea on which markets normally operate – that the full cost of nuclear power, including private investment plus the public subsidy – should be more cost effective and lower risk than other ways to meet the same energy security and climate change challenges.

While even the private cost element of this picture is uncertain and continues to escalate, the public subsidy portion is generally missing entirely. Without it, nuclear as a solution cannot be properly compared to alternative solutions; nor can the potentially enormous cost to taxpayers be appropriately vetted.

There are actually two important costs to evaluate. There are financial costs, to be sure - costs that are likely to run into the many hundreds of billions of dollars worldwide. But the nuclear new build option entails very significant opportunity costs as well. No society has enough money to bankroll every technology. Investing a large share of available resources in subsidizing nuclear energy means that those funds are not around for other options.

It is important to evaluate what we get and what we are giving up by this course of action. Consider climate change. In a best-case scenario, large investments in nuclear buy greenhouse gas reductions that start in seven to 15 years. The net gains may be still further forward given that some new facilities are needed simply to offset the closure of aging plants. We give up smaller scale, more rapid mitigation approaches. And when these new reactors do come on line, we add large base-load plants with mostly public capital at risk. If they default, they will continue in service churning electricity at their very low marginal cost of production (the taxpayer having eaten the capital costs), freezing out energy efficiency and an array of alternative energy sources that may be less expensive overall, albeit with higher variable costs.

This chapter explores some common forms of subsidies around the world, followed by more specific examples of subsidies from the USA and the UK. These countries are included primarily due to a greater availability of information, not because they are the only nations subsidizing nuclear. To the contrary, subsidies to nuclear power are endemic throughout the world. In countries with limited budget transparency and government ownership of reactors and fuel chain facilities, there is simply less data available. One interesting aspect of the newest wave of reactor construction is how international they are becoming, both in terms of owners and major suppliers, and equally in the number of countries providing subsidies. Going forward, looking singly at home country subsidies may not be enough.

III.6.2. Common forms of support around the world

While there is some cross-country variation in nuclear subsidies, many of the measures are actually common throughout most of the world (see Table 7). These include subsidized access to credit; subsidies to capital equipment; below-cost provision of enrichment and regulatory oversight services; caps on liability resulting from an accident or attack; and socialization of costs and delivery risks associated with managing nuclear waste. Some countries make inadequate provision for other known end-of-life activities such as plant decommissioning. A few emerging subsidy schemes are also present in multiple countries. These include expanding purchase mandates for "green" energy to include nuclear and windfall grants of carbon credits at the inception of national carbon trading schemes.

Table 7: Common Subsidies to Nuclear Power Around the World

Policy	Overview
Subsidies to Capital Costs	
Subsidized access to credit -Direct government loans -Government guaranteed loans -Direct government investment in nuclear-related infrastructure	Policies dramatically reduce nuclear's cost of capital by enabling them to obtain debt at the government's cost of borrowing; and to use high levels of this inexpensive debt rather than much more expensive equity.
Rate-basing in-process plants -Work-in-process, allowance for funds used during construction	Allow recovery of plant investment prior to commencing operations. Shifts performance and investment risks from owners to ratepayers.
Subsidizing capital goods -Accelerated depreciation -Research and development -Investment tax or production tax credits -Capital write-offs transferred to taxpayer	Reduce after-tax cost of capital goods deployed in the nuclear sector. In the case of R&D, reduce the internal cost to develop new product lines or modify old ones.
Subsidies to Operating Costs	
Fuel and enrichment -Government-owned or subsidized enrichment facilities -Subsidized access to uranium ore	Socialize risks of building, operating, remediating fuel chain facilities. Reduces cost of fuel inputs to reactors.
Accident and attack risks -Caps on mandated liability coverage.	Reduces insurance costs for all participants of nuclear fuel chain. Shifts accident risks from investors to surrounding population and taxpayers.
Industry oversight -Government oversight of domestic industry. -International oversight through IAEA	If not fully funded by user fees, subsidies disadvantage less oversight-intensive competitors.
Emissions -Privileges under carbon constraints.	Windfall grants of carbon credits; can be immediately resold. Earmarked funds.
Waste Management, Plant Closure	
Nuclear waste management -Government-run long-term management of reactor waste. -Payments to existing reactors to store wastes on-site.	Converts very high risk, capital intensive fixed cost endeavor into something the reactors (and investors) no longer have to worry much about.
Plant decommissioning, remediation -Tax-advantaged accrual of decommissioning funds. -Government-provided decommissioning support.	Reduces break-even charges need for nuclear operations. For fuel chain facilities, resulted in very large public liabilities.
Market price support -Inclusion of nuclear in renewable energy portfolios or feed-in tariffs. -Transfer of capital costs to ratepayers via stranded cost rules or similar transfer of cost recovery of uneconomic investments.	Enables nuclear plants to earn higher revenues on power sales than they would be able to in a competitive market.

Some of the most important of these policies are discussed in more detail below.

III.6.2.1. Capital subsidies

Government programs to subsidize the cost of capital are probably the most common form of public subsidy, as well as the largest source of subsidy to the nuclear sector around the world. These programs include loan guarantees and rate-basing of in-process plants that reduce the cost of funds; as well as accelerated write-offs of plant and equipment and tax credits that help to reduce the effective cost of capital goods.

Capital subsidies either reduce the cost of funds or reduce the after-tax cost of capital equipment itself. Nuclear power is considered a high investment risk. Without subsidies, plant developers would be required to pay high-risk premiums to capital providers, both in the form of higher interest rates and higher returns on equity. They would also need to adopt a more resilient, though much higher cost, capital structure that is more heavily weighted to equity.

The introduction of loan guarantees dramatically reduces the cost of capital to plants in two ways. First, a government guarantee means lenders don't care how risky the nuclear plant itself is, since the financial strength of the guarantor drives their ultimate risk exposure. Thus, they are willing to lend funds based on the security of the guarantor. With large, national governments as guarantors, the previously high-risk debt becomes almost risk-free, and interest rates drop sharply. Second, the guarantee enables plant owners to use much more of this inexpensive debt to finance the plant – up to 80% in the case of the United States. This shift in capital structure is of great financial benefit to the firms. As noted by the Keystone Center in its 2007 report, "even very strong non-utility generators building plants in competitive wholesale markets now need 65% to 70% equity to access the bond market".[274] This implies a maximum debt level of only 30-35% - a value that has likely been scaled back even further since the credit market meltdown in late 2008.

The combination of lower risk debt and the ability to use much more of it greatly reduces the cost of financing a new nuclear plant, and with it the price of the resultant power. A recent evaluation by the US Congressional Research Service indicated that loan guarantees alone reduced the levelized costs of nuclear power by 20%.[275] Estimates by the private sector show even larger benefits. UniStar Nuclear Energy, a joint venture between Constellation Energy and EDF that hopes to build a series of reactors across the USA, estimates the loan guarantees will reduce their levelized costs by nearly 40%.[276]

Credit support is a common feature of most nuclear deals. The ongoing AREVA reactor project in Olkiluoto, Finland, for example, has received very low cost loans from government entities totaling €1.95 billion, and export credit assistance from both France (€610 million) and Sweden (€110 million) (see section III.3.1.4.). Japan has set up a specialized finance vehicle, the Japan Finance Corp, to provide credit guarantees on nuclear-related sales to developed countries.[277]

Efforts to move credit subsidies beyond developed economies and into the developing world are taking shape as well, irrespective of the complexity that proper oversight of a nuclear sector may pose for some of these governments. For example, Japan is considering a package "of soft loans from the Japan Bank for International Cooperation or insurance by Nippon Export and Investment Insurance, a state-sponsored export credit agency" to finance a reactor deal in Vietnam.[278]

Some of the larger multilateral development banks have implicit or explicit restrictions against lending to nuclear projects. Yet, these institutions form one of the larger pools of capital for investing in the developing world. The USA, France, and Japan are working on modifications to export credit terms in general so they are more attractive for nuclear projects. They have supported a study of the cost-effectiveness of nuclear power within the World Bank, and have pushed for an extension of the repayment period term for Export Credit Agency (ECA) nuclear support from 15 years (already three years longer than for other plants) to 30 years. Another change under consideration is greater flexibility to apply credit support to components supplied by a variety of countries (rather than just the one supporting a specific ECA).[279] If these shifts go through, a global

274 The Keystone Center, "Nuclear Power Joint Fact-Finding", Keystone Center, Keystone, 2007, p.43.
275 Stan Kaplan, "Power Plants: Characteristics and Costs, US Congressional Research Service", 13 November 2008, RL34746.
276 Joe Turnage, "New Nuclear Development: Part of the Strategy for a Lower Carbon Energy Future", presentation at the International Trade Administration Nuclear Energy Summit, 8 October 2008.
277 Nucleonics Week, 25 September 2008.
278 Kwok, 20 March 2009.
279 Daniel Horner and Ann MacLachlan, "US working with allies to change global rules on nuclear financing", Platts, 23 October 2008.

pool of government-subsidized credit will be able to be deployed to build reactor projects throughout the world.

III.6.2.2. Public spending on nuclear-related research and development (R&D)

Governments around the world have long supported nuclear power through substantial investments of public money into research and development related to the nuclear fuel chain. Between 1974 (when the International Energy Agency began collecting data on energy R&D) and 2007, nuclear captured nearly 55% of all public research dollars, equivalent to more than $236 billion (2007$) in support. This is more than six times the level of support to renewable energy – despite the fact that renewables actually comprise a fairly wide range of different technologies.

Recent years have seen some shift in support, with a smaller take for nuclear and a somewhat larger investment in efficiency, hydrogen, and renewables. Nonetheless, even after the adjustment, nuclear remains by far the largest beneficiary of government R&D funding, at more than 40% of total support. At the country level, R&D investments into nuclear have gone down as a share of energy R&D even in nuclear-focused countries such as France and Japan. Nonetheless, even after the decline, the technology captures 73% and 67% of total energy R&D spending respectively in those countries.

Table 8: Government Funded Energy R&D within IEA Countries (in millions of US$ $_{2007}$)

	1974-2007		1998-2007	
	Cumulative	**% share**	**Cumulative**	**% share**
Group 1: Energy Efficiency	38,442	8.9%	14,893	14.2%
Group II: Fossil Fuels	55,027	12.8%	11,114	10.6%
Group III: Renewable Energy Sources	37,333	8.7%	10,709	10.2%
Group IV: Nuclear Fission and Fusion	236,328	54.8%	43,667	41.5%
Group V: Hydrogen and Fuel Cells	2,824	0.7%	2,824	2.7%
Group VI: Other Power and Storage Technologies	15,717	3.6%	5,388	5.1%
Group VI: Total Other Technologies or Research	45,204	10.5%	16,599	15.8%
TOTAL ENERGY RD&D	430,875	100.0%	105,194	100.0%
Nuclear Share of Country Total				
Canada		39.0%		28.8%
France		81.4%		72.5%
Germany		67.0%		41.0%
Japan		72.7%		67.2%
Sweden		15.2%		6.7%
United Kingdom		69.0%		32.7%
United States		38.1%		13.2%

Source: International Energy Agency Energy RD&D Database, accessed 10 April 2009

III.6.2.3. Capping or shifting accident liability off of operator

Accident risks have been the Achilles heal of the nuclear industry since its inception. For most industries, even a large accident, while catastrophic to the immediately surrounding area, tends to be relatively well-contained geographically. The presence of high-level radioactive materials and wastes at nuclear facilities creates a different set of risks for the surrounding population, including the potential of rendering fairly large areas uninhabitable for decades or more.

In developed countries with good regulatory oversight, the risk of accident is deemed quite low. Nonetheless, the potential health and property damages of any medium size reactor accident could be enormous. The industry also faces systemic risks, noted by the Keystone Center analysis that

"Chernobyl's impact in slowing nuclear construction world-wide illustrates how reactor accidents anywhere can affect nuclear fleets everywhere."[280]

The scale of potential losses made commercial insurers steer clear of underwriting nuclear accident risks at the inception of the industry. Government intervention came early -- with the Price Anderson Act passed in the United States in 1957, and renewed ever since. This law set a maximum cap on liability for damages to people or property offsite from a nuclear accident. The level of this cap, even in the USA, is lower than insured damages often exceeded in storm events. Thus, the statutory cap on required insurance provides a subsidy, in the form of reduced premium costs, to nuclear operators. A similar situation exists in every country in the world with nuclear reactors. Subsidy magnitude is affected by a variety of factors, such as how low the cap is relative to likely damages in a major accident; how likely and quickly the covered amounts will be paid after an accident; whether the covered amounts are provided by the nuclear operator or directly or indirectly by a government entity, and whether there are risks associated with the fuel chain that are not covered at all by the various liability conventions.

There is tremendous variation across countries in the amount and quality of coverage available. Under the US system, the federal cap protects not only reactor owners, but contractors, transporters, and fuel chain operations as well. The US system has a primary tier of direct insurance provided by the operator; and a much larger second tier of 'retrospective' premiums collected from *every* reactor after an accident at *any* reactor that exceeds the primary coverage level. The total pool of coverage - the largest in the world - amounts to over $10 billion in nominal payments. However, much of the funding occurs over a six-year period, reducing the pool on a more appropriate present value basis to roughly $7.7 billion.[281]

With the exception of Germany, pooling is not used in other countries. Rather, a combination of operator and sovereign guarantees and insurance exist under a patchwork of international conventions and national laws. (see section III.5 for details). The specific conventions covering a particular nuclear nation vary widely. The caps under most of the conventions provide less than $500 million in aggregate coverage, with operator liability often lower. No liability regime now in effect outside the USA provides more than $2 billion in aggregate cover, despite the large populations and high valued real estate surrounding many of these plants.

III.6.2.4. Nationalization of waste management and site remediation risks

Nuclear power generates wastes that must be managed or safeguarded for hundreds or thousands of years. This creates a severe long-term liability risk for private firms - a risk that does not exist with other energy resources. Aside from liability exposure, there are also very significant technical challenges regarding the best way to store the wastes safely. Not surprisingly, these factors combined bring with them quite large financial risks.

National governments have stepped in with programs that effectively nationalize both the financial and liability risks of waste management. It is unlikely that the commercial industry could have developed at all without these programs. Nationalized waste management efforts have been supplemented with government responsibility for contaminated fuel chain sites such as uranium mines, enrichment and reprocessing facilities, even when the enterprises have been privatized.

---

[280] The Keystone Center, "Nuclear Power Joint Fact-Finding", Keystone Center, Keystone, 2007, p.58.

[281] Doug Koplow, " Nuclear Power as Taxpayer Patronage: A Case Study of Subsidies to Calvert Cliffs Unit 3," prepared for the Nonproliferation Policy Education Center, 2009.

Table 9: High Level Waste Management Responsibilities, Predominantly Government

Country	Disposal Site Operating?/Selected?	Earliest Site Open	Mgmt. Responsibility
Belgium	No/No	2035	Government
Canada	No/No	2025	Government
China	No/No	2050	Government
Finland	No/Yes	2020	Power companies
France	No/Narrowed	2025	Government*
Germany	No/Frozen	2025	Government
Japan	No/No	2030	Government
Netherlands	No/No	unknown	Government
Sweden	No/Narrowed	2020	Power companies
United Kingdom	No/No		Government
United States	No/Overturned	unknown	Government

Notes:
* Power companies pay for short and medium term management and storage and in theory for long-term disposal. However, responsibility is ultimately with the state waste management agency (ANDRA).

Sources:
Adapted from:
(1) World Nuclear Association, "Waste Management in the Nuclear Fuel Cycle," August 2008.
(2) Richard K. Lester, "Nuclear Waste Management," MIT OpenCourseWare for Managing Nuclear Technology, Course 22.812J, Spring 2004.

III.6.2.5. Shifting of bad debts, uneconomic facilities away from investors onto taxpayers or ratepayers.

In a competitive market, if costs of nuclear power, including debt service, rose too high, investors would lose money and plants might close. Historically, nuclear power has operated in a regulated environment. Above-market costs were shifted to ratepayers via higher power tariffs; or through plant cancellations, for which ratepayers remained liable. As markets were deregulated, these costs were packaged in other ways – 'stranded cost' surcharges in the United States. A 'fossil fuel levy' (FFL) was added to fossil plants in the United Kingdom in an effort to keep nuclear competitive. The sums were sizeable: the FFL was about 10% of all electricity bills, worth roughly £1 billion per year. Nuclear-related surcharges, write-offs, and stranded cost allocations (discussed below) were hundreds of billions of US dollars.

Efforts to recreate the regulatory conditions that protected nuclear investors twenty years ago are once again resurgent. Loan guarantees support this outcome, as do a growing number of US states that are allowing nuclear investors to collect from ratepayers while construction is still in process, and even if a plant is abandoned prior to completion.[282].

III.6.3. Subsidies to existing reactors in the USA

The types of subsidies to nuclear noted internationally have also been present within the United States. Government research and development support has existed for well over a half-century, spanning all elements of reactor design and the fuel chain. Between 1950 and 1989, for example, nuclear fission captured 49% of total government R&D spending; nuclear fusion another 13%.[283]

While the industry focuses on low operating costs it is easy to forget that even the existing reactor fleet required an immense amount of capital to construct, and that without capital subsidies, those

[282] Joe Turnage, "New Nuclear Development: Part of the Strategy for a Lower Carbon Energy Future", presentation at the International Trade Administration Nuclear Energy Summit, 8 October 2008.
[283] Doug Koplow, "Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts, Technical Appendix", Washington, DC: Alliance to Save Energy, 1993.

plants would not have been built. The most important historical subsidies were investment tax credits and special treatment of construction work in progress (CWIP). Investment tax credits allow a portion of capital spending to reduce taxes owed. On interest expensing and CWIP, plant developers were allowed to begin recovering interest and capital expenses on new construction well before the plant was completed. In effect, these rules coerce existing ratepayers into providing low cost financing to a plant that they might not ultimately even use; or that might not even be completed.

The costs of these write-offs were sizeable: more than $200 billion in cost overruns (2006 dollars) were paid by ratepayers, plus an additional $225 billion in "overcharges" to utility customers once the plants came online. An additional $50 billion (in today's dollars) were abandoned prior to completion, of which ratepayers and taxpayers bore a significant portion of the costs.[284]. Another wave of high-cost nuclear assets became visible as the US electricity market was deregulated, and every power plant had to find buyers for power at a market price. This led to 'stranded cost' deals, in which the portion of power plant capital that could not be recovered at competitive rates was separated from the plant, and treated as a separate liability to be recovered from all ratepayers. Nuclear-related stranded costs approached $100 billion in today's dollars as well.[285]

The existing reactors in the United States have also benefitted from a number of other subsidy programs. For example, all continue to benefit from caps on reactor accident liability; and nationalization of nuclear waste management in return for a small fee. They also received subsidized uranium enrichment services from the federal uranium enrichment enterprise, prior to its privatization in 1998. Finally, while US reactors do have segregated trust funds to cover post-operational closure and decommissioning of reactor sites (a better arrangement than in many other countries), these funds receive some favorable tax treatment through reduced tax rates on investment earnings. In addition, should there turn out to be shortfalls in accrued funds, it is likely that the original firm would no longer exist, and that they would become a taxpayer liability.

Although there is no comprehensive record of historical subsidies to nuclear power since inception, a review of a number of studies that have been done over the years demonstrates government's central role in the sector's market viability. Table 10 illustrates that subsidies were generally equal to one-third or more of the value of the power produced.[286] While such levels of support may not be surprising for very new industries with little installed base, to see subsidy levels so high over the course of four decades is quite striking. The subsidies undoubtedly served as a competitive barrier to other energy resources.

---

284 David Schlissel, Michael Mullett, and Robert Alvarez, "Nuclear Loan Guarantees: Another Taxpayer Bailout Ahead?", Union of Concerned Scientists, March 2009.

285 Christopher Seiple, "Stranded Investment: The Other Side of the Story," Public Utilities Fortnightly, 15 March 1997.

286 In fact, the actual subsidies were probably even higher because many of the studies did not do a full tally of all subsidies in effect at the time. In addition, the value of produced power in the earlier comparisons is overstated due to data limitations at the industrial retail rate, rather than the wholesale rates that would provide a more accurate metric of competitiveness.

Table 10: Subsidizing Plant Construction and Operation (in US$$_{2007}$)

Period of Analysis	Federal Subsidy in billion US$		Subsidy in cents/kWh		Average Subsidy as % of Industrial Price	Analysis	Notes
	Low	*High*	*Low*	*High*			
2008	-	-	5.0	8.3	113-189%	Koplow/Earth Track calculations - subsidies to a new reactor	Share of national average wholesale rates, 2002-06
1947-99	178.0	-	1.5	-	NA	Goldberg/Renewable Energy Portfolio Project (2000)[287]	Effect of Price-Anderson Act not estimated.
1968-90	122.3	-	2.3	-	33%	Komanoff/Greenpeace (1992)[288]	Effect of Price-Anderson Act not estimated.
1950-90	142.4	-	2.6	-	NA	Komanoff/Greenpeace (1992)[289]	
1989	7.6	16.2	1.4	3.1	32%	Koplow/Alliance to Save Energy (1993)[290]	
1985	26.8	-	7.0	-	83%	Heede, Morgan, Ridley/Center for Renewable Resources (1985)[291]	Effect of Price-Anderson Act not estimated.
1981	-	-	5.9	12.3	105%	Chapman et al./US EPA (1981) [292]	Tax expenditures only.
1950-79	-	-	4.1	6.0	NA	Bowring/Energy Information Administration (1980)[293]	Tax and credit subsidies not estimated.

Source: Koplow, 2009[294]

III.6.3.1. Subsidies to new-build reactors in the USA: Case Study of Calvert Cliffs-3

Calvert Cliffs-3 is a proposed new reactor to be co-located in Lusby, Maryland, with two existing reactors. The plant will be owned by UniStar Nuclear Energy (UNE), a joint venture between Constellation Energy, a large US utility, and EDF, a French utility mostly owned by the French government. The reactor provides a good case study for the manner in which subsidies affect nuclear economics in the United States.

---

[287] Goldberg/Renewable Energy Portfolio Project, “Federal Energy Subsidies: Not All Technologies Are Created Equal”; Marshall Goldberg for the Renewable Energy Policy Project, July 2000 Research Report No. 11.

[288] Charles Komanoff and Carla Roelofs, “Fiscal Fission: The Economic Failure of Nuclear Power”, Komanoff Energy Associates for Greenpeace, 1992.

[289] Ibidem.

[290] Doug Koplow, “Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts, Technical Appendix”, Washington, DC: Alliance to Save Energy, 1993.

[291] Morgan Heede et al./Center for Renewable Resources, “The Hidden Costs of Energy”; Rick Heede, Rick Morgan, and Scott Ridley; Center for Renewable Resources, 1985.

[292] Chapman et al./US EPA (1981); “Energy Production and Residential Heating: Taxation, Subsidies, and Comparative Costs”; Duane Chapman, Kathleen Cole, and Michael Slott of Cornell University for the Ohio River Basin Energy Study; U. S. Environmental Protection Agency Office of Research and Development, 1981.

[293] Bowring/Energy Information Administration, “Federal Subsidies to Nuclear Power: Reactor Design and the Fuel Cycle”; Pre-publication draft. Joseph Bowring, Energy Information Administration, March 1980.

[294] Doug Koplow, " Nuclear Power as Taxpayer Patronage: A Case Study of Subsidies to Calvert Cliffs Unit 3," prepared for the Nonproliferation Policy Education Center, 2009.

Public subsidies have always been a central plank of UniStar's new reactor development program, something the firm has been quite up-front about. Questioning before the California Energy Commission in June of 2007 is a good example:[295]

> *Associate Member Geesman:* "And just to revisit the cap[ital] question again. Your business model is premised on receiving the federal loan guarantee for each of your four projects. Is that correct?"
>
> *Dr. Turnage*: "That is correct."

Calvert Cliffs-3 will benefit from many subsidies implemented at the federal and even the county level to support new reactor construction. Constellation presentations on the venture over the past couple of years provide insights into how they estimate the subsidy value. However, additional adjustments are needed because the baseline costs for their models actually include some embedded subsidies as well.

Federal loan guarantees. As discussed above, loan guarantees are tremendously valuable to new nuclear reactors. UniStar is on a 'short-list' for accessing a pool of US federal guarantees of $18.5 billion.

Absent federal intervention, the risk profile of new plants suggest that debt providers would require a high share of equity in the plant. They would also require returns on both debt and equity that would be too high for the energy produced to compete in the marketplace.

The ability to get inexpensive debt, to finance most of the project with it, and to keep that debt for up to 30 years, generates significant subsidies to UniStar. Their own cost estimates peg the value of the guarantee at 3.7 cents per kWh on a levelized cost basis, a cost reduction of nearly 40%.[296] Based on their assumptions on operating factors and reactor size, this translates to nearly $500 million per year in savings *per reactor*. The authorizing statute allows the guarantees to stay out for a maximum of 30 years – which a rational owner will do since the cost of funds is so low. This translates to a public investment of nearly $13 billion to a *single nuclear reactor*, an astonishing amount of public support for a single private facility.

Production Tax Credits. The Energy Policy Act of 2005 introduced a 1.8 cent per kWh production tax credit (PTC) for new nuclear power plants. The nuclear PTC is capped at $125 million for a single plant and for a maximum of eight years of eligibility. There is also a national cap that may reduce the realized value for any single reactor. Nonetheless, this is a sizable subsidy for a new plant, and one that UniStar assumes it will get a piece of.

Accelerated depreciation. Normal accounting rules allow capital investments to be deducted from taxable income over the service life of the investment. Faster deductions shelter taxable income in the early years of an investment, generating a net gain to the firm. The larger the investment, and the more rapid the write-off relative to actual service life, the larger the subsidy will be. Nuclear reactors, which can last 40-60 years, can be written off from taxes entirely in only 15 years. This generates a reduction in levelized power costs of roughly 0.3 to 0.6 cents per kWh.

Accident liability. The Price-Anderson act provides liability protection for the life of a nuclear facility even if the Act expires while a plant is still operating. New reactors such as Calvert Cliffs-3, however, would not have been covered without more recent reauthorization of the Act, a law that when passed in 1957 was supposed to last only 10 years. Continued reauthorizations are predicated on the claim that private insurance cover still remains limited. Yet cover has grown for risks inside the plant wall: damage to plant and equipment from an accident, and coverage for interruption of power deliveries. In fact, if coverage on the existing reactors is an indication, Calvert Cliffs-3 will buy ten times as much cover for internal damages and interruptions than it will be required to buy

---

[295] Transcript to the Committee Workshop before the California Energy Resources Conservation and Development Corporation in the matter of "Preparation of the 2007 Integrated Energy Policy Report," 28 June 2007, Volume II.

[296] Joe Turnage, "New Nuclear Development: Part of the Strategy for a Lower Carbon Energy Future", presentation at the International Trade Administration Nuclear Energy Summit, 8 October 2008.

to protect the 7.6 million people in the surrounding area and all of their property in the case of an accident.[297]

Management of long-lived nuclear waste. Calvert Cliffs-3 will also benefit from risk shifting on the management of high-level radioactive waste. Poor risk sharing on this issue in the past has resulted in multi-billion dollar liabilities to the US taxpayer due to delays in the opening of a federal radioactive waste repository at Yucca Mountain in Nevada. These challenges are likely to remain; yet because of the subsidy, the technical and financial risks of waste management will not affect the decision on whether to build or operate Calvert Cliffs-3.

Table 11: Public subsidies to Calvert Cliffs-3 approach private capital at risk and exceed value of power produced

	Low	High	Notes
	Cents per kWh		
I. Private investment in Calvert Cliffs III			
Base case of Calvert Cliffs	5.7	5.7	Constellation estimate, Oct. 2008
II. Public investment in Calvert Cliffs III			
A. Selected EPACT subsidies			
Production tax credits	0.5	0.5	Constellation estimate assuming 50% access to PTCs
Loan Guarantees, 100% of debt	3.7	3.7	Constellation estimate, Oct. 2008
Industry total estimated cost	9.9	9.9	
B. Additional subsidies ignored in Constellation models			
Accelerated depreciation	0.3	0.6	15 yr 150% DB vs. service life.
Price-Anderson cap on reactors	0.5	2.5	Based on Heyes (2002)[298]; values uncertain.
Waste fund short-fall	-	0.2	Based on Rothwell (2005)[299].
Calvert Co. property tax abatement	0.0	0.0	$20m/year, but not visible on a per kWh basis.
Cost of capital value of delay insurance, first two reactors	0.0	0.8	High estimate based on Bradford (2007)[300].
Add-in missing subsidies	0.8	4.1	
III. Total cost of nuclear power			
Public subsidy	**5.0**	**8.3**	
Public/private share	**87%**	**145%**	
Subsidy/average wholesale rates, 2002-06	**113%**	**189%**	
Full cost of power	**10.7**	**14.0**	

Source: Koplow (2009)

[297] Doug Koplow, " Nuclear Power as Taxpayer Patronage: A Case Study of Subsidies to Calvert Cliffs Unit 3," prepared for the Nonproliferation Policy Education Center, 2009.

[298] Anthony Heyes 2002; "Determining the Price of Price-Anderson," Regulation, Winter 2002-2003; in The Keystone Center, "Nuclear Power Joint Fact-Finding", June 2007.

[299] Geoffrey Rothwell, E-mail correspondence with Doug Koplow, Earth Track, 20 October 2007.

[300] Peter Bradford, "New Nuclear Plants and Climate Change," Congressional Presentations, 20 April 2007.

Calvert County property tax abatement. In an effort to increase the chances of getting a new reactor at Calvert Cliffs, the Calvert County Board of Commissioners approved a 50% reduction in property taxes over the first 15 years of plant operations. This is expected to save the company $20 million per year. The company currently pays $15.5 million in annual property taxes.[301] While too small to even register on a per kWh basis, this is a large subsidy for a county-level government to offer. The property tax abatement to the new reactor is equivalent to roughly 7% of the County's 2009 budget of $296 million, and larger than their entire annual debt service.[302]

Subsidies to Calvert Cliffs 3 are tallied in Table 11. The results are striking: public investments in the plant approach or exceed private capital put at risk, a poor venture structure for achieving success. The public subsidies are larger than the value of the power produced, an indication of a "value subtracting" industry. In fact, based on Constellation's own cost models, the power from this plant is not competitive without subsidy.

III.6.4. Subsidies to the UK's Existing Nuclear Power Plants[303]

The UK's operating reactors can be split into three groups, those of the first generation British design known as Magnox, the second generation British-design known as the Advanced Gas-cooled Reactors (AGR) and a single plant using the Westinghouse Pressurized Water Reactor (PWR) design. The Magnox stations were completed between 1956 and 1971 and only the two most recent plants were still in operation in March 2009. Eight of the eleven Magnox stations were built as twin reactors by the Central Electricity Generating Board (CEGB), the nationalized electricity generation and transmission company that covered England and Wales. One station, also comprising twin reactors was built by the nationally-owned integrated electricity company that supplied the South part of Scotland, the South of Scotland Electricity Board (SSEB). Two further stations each comprised four reactors and were dual purpose plutonium/electricity production units owned and operated by British Nuclear Fuels Limited, the nationally-owned nuclear technology company.

The seven AGR stations each comprised twin reactors of about 600 MW and were ordered in two batches, five in 1965-69, of which one was owned by SSEB, and two in 1979, one of which was built by SSEB. The plants were originally given a design life of 30 years, but their life has been extended and the two oldest stations have now received regulatory approval in principle to run for 40 years. The lifetimes of all the stations are currently expected to be extended to 40 years but the owners do not make the case to the regulators until the plants are within three years of closure so only the two oldest stations are currently listed as having a 40-year life.

Construction of the PWR was started in 1987 by the CEGB, but in 1990, when this company was broken up and privatized, the plant passed to a new nationally-owned company, Nuclear Electric, which completed the plant in 1995.

III.6.4.1. The Period Up to 1990

It has become clear that none of these plants has ever been an economic source of power on a full-cost basis. Up to 1990, there was a common perception, encouraged by the nuclear industry and the utilities, that nuclear power represented a cheap source of power. Analyses purporting to show the full economic cost of nuclear power were published by the CEGB[304], but these were riddled with methodological errors[305] and the failed attempt to privatize the nuclear plants in 1990 demonstrated these analyses were largely worthless.

---

301 Jamie Smith Hopkins and Paul Adams, "Calvert County solicits reactor," Baltimore Sun, 9 August 2006.

302 Calvert County, "Budget Summary: FY2009 Commissioners Report", Maryland, 2009.

303 Based on Steve Thomas, "Nuclear Power in Britain Since Chernobyl: A Rollercoaster Ride", in Lutz Mez, Mycle Schneider & Steve Thomas, "International Perspectives on Energy Policy and the Role of Nuclear Power", Multi-Science Publishing, Brentwood, 2009.

304 For example, Central Electricity Generating Board, "Analysis of generation costs 1983", CEGB, London, 1983.

305 Gordon MacKerron, "Nuclear power under review", in John Surrey, "The British electricity experiment. Privatisation: the record, the issues, the lessons", Earthscan, London, 1996.

However, while the electricity system was operated by integrated, publicly-owned monopolies without explicit regulatory procedures, it was impossible to disentangle the nuclear costs from the other costs of the industry so while it is now clear that nuclear power was not an economic power source up to 1990, there were no explicit subsidies.

In 1987, the British government announced its intention to privatize and break-up the electricity companies and operate the system on competitive lines. It assumed that the nuclear plants would be saleable despite the fact that the Magnox plants were already near or at the end of their design lives (25 years). The program of 10 PWR orders (originally, one order per year was to be placed from 1981 onwards) announced by Margaret Thatcher in 1979 had shrunk to four, only one of which was ready to be placed. Implicitly, it was assumed the value of the existing plants would be determined by the market so the new owners would not have to recover all the costs involved in building them. It was acknowledged that new plants that had to repay in full their construction cost would probably not be economic but that the government could impose on the electricity retail companies an obligation to purchase a proportion, to be specified by the government, of their supplies from nuclear plants, the Non-Fossil Fuel Obligation (NFFO). As the old plants were retired, the retail companies would have to commission a generation company to build new nuclear capacity so they could fulfill their quota. This mechanism was expected to mean that building the four new PWRs would not be an inordinate economic risk to the company that was building them. The possibility of a consumer subsidy for nuclear power, the Fossil Fuel Levy (FFL), was mooted as a possibility but no indication of the scale of the subsidy was given nor how it would work.

The utilities did nothing in 1987/88 to disabuse the government of the belief that this new system could work. This is perhaps indicative that not only was the government, through the then Department of Energy unaware of how poor the economics of nuclear were, but also that few in the CEGB and SSEB were aware of how expensive the nuclear plants would turn out to be once their costs had been properly separated from other costs. By summer 1989, the scale of the additional costs was becoming clear and also that the NFFO was not feasible. In fact, it was the company that was expected to own the nuclear plants, which became National Power that appears to have been strongest in warning the government of the infeasibility of its plans.

In a series of hurried and unwieldy changes, the nuclear plants were withdrawn from the privatization. The CEGB's Magnox reactors and AGRs were placed in a new nationally-owned company, Nuclear Electric, while the SSEB's reactors were given to another new publicly owned company, Scottish Nuclear. The FFL was introduced for Nuclear Electric and set at a level that would allow Nuclear Electric to remain 'cash positive' so that it could continue to trade legally. The subsidy was collected as about 10% of all electricity bills and yielded about £1bn per year. The level of payments was set for the eight years that followed so that Nuclear Electric's income was assured – if the price they received for their power went down, the subsidy went up, and vice versa. Different arrangements applied to Scotland, which essentially required the privatized companies to buy all Scottish Nuclear's output at pre-determined prices. In the whole of the UK, the retail market for residential consumers was expected to remain a monopoly until 1998 so the retail companies were able to pass on any extra costs to residential consumers without fear that competitors, which did not have to buy nuclear power, would enter the market and undercut them.

The European Commission judged the FFL to be 'state aid', which under most circumstances is against European law, but the FFL was allowed provided it was phased out by 1998. A review of whether Sizewell-B, the PWR on which construction had been started in 1987, should be completed was launched and a review of government policy on nuclear power was to be carried out in 1994, when it was expected that Sizewell B would be in service. The review of Sizewell was completed in 1991 and it was argued that the costs already incurred were so large that cancelling the plant would not result in any savings.

Provisions to pay for nuclear decommissioning collected before privatization, given a value of £3.8bn in the accounts of the nationalized companies, were not segregated from the assets of the companies and were not passed on to Nuclear Electric and Scottish Nuclear, and were thus effectively lost.[306]

Overall, it is now clear that nuclear power was uneconomic throughout the period up to 1990 but there were no major explicit subsidies: additional costs were simply passed on to consumers.

III.6.4.2. The Period 1990-1996

The haste with which the privatization plans were changed and the FFL introduced meant these were ill thought-out. From 1990-96, about £6bn was collected from consumers under the FFL essentially as a nuclear subsidy. In theory, the FFL was payable to all technologies that did not use fossil fuels but, in practice, about 97% of the amount collected was paid to Nuclear Electric. Michael Heseltine, then the responsible government minister, told Parliament this was "to pay for the decommissioning of old and unsafe stations"[307]. This statement was not accurate. There were no restrictions on the way Nuclear Electric could spend the FFL and it was therefore used by Nuclear Electric as additional cash flow. A small amount was spent on decommissioning, nearly half was unspent, but the rest was spent by Nuclear Electric meeting its immediate costs. Given that Nuclear Electric's marginal expenditure was on the construction of the Sizewell B plant, which it built with no recourse to borrowing despite being effectively bankrupt, it must be concluded that a large amount of the FFL was effectively spent on building Sizewell B and must be seen as a consumer subsidy.

Sizewell B was completed in 1995 at a cost in excess of £3bn (in 1995 money)[308]. By the standards of the time, this was a huge price[309] although Nuclear Electric tried to explain the high cost as due to its bearing first of a kind costs. The unspent subsidy was mostly passed on to BNFL with a small amount (£227m) being passed on to the privatized nuclear generation company, British Energy, created in 1996 (see below).

The improved reliability of the AGRs meant that by 1995, Nuclear Electric was able to cover its operating costs by proceeds of sale of electricity and in its review of its nuclear policy, the government proposed the privatization of the AGRs and Sizewell-B and the removal of the nuclear subsidy. This was carried out in 1996 with the creation of British Energy to own the AGRs and Sizewell-B. The Magnox reactors clearly had to remain in public ownership and were placed in a new company, Magnox Electric, which was absorbed into BNFL in 1998. The FFL was removed in 1996, reducing electricity prices by 10%.

British Energy was sold for only about £1.7bn for the eight stations, about half the cost of just building Sizewell-B. No authoritative estimate of the cost of building the seven AGR stations has ever been given. However, their very troubled construction period – the worst station, Dungeness-B took 18-20 years of continuous construction before first power and then a further 4-6 years of testing before it was declared commercial – means that these plants must have been very expensive to build. If we assume their cost (in £1995) was £2bn each, only two thirds of the cost of building Sizewell-B, this means that assets that had cost consumers £17bn, were sold for only 10% of that value.

In fact, it was only possible to sell the stations for a positive sum because of manipulation of decommissioning liabilities. Decommissioning funds are normally set up to pay for all three stages of decommissioning – stage 1 is de-fuelling, stage 2 is removal of uncontaminated or lightly contaminated buildings and stage 3 is removal of all other parts. In undiscounted terms, stage 1 accounts for perhaps 10% of the cost of decommissioning, but if we discount the two later stages and we use the very long time frames assumed in the UK for the later stages (70 years or more before stage 3 is started), stage 1 accounts for nearly half the discounted estimated cost. Under the

[306] Stephen Thomas, "The organisation & the costs of the decommissioning nuclear plants in the UK", Economia delle fonti di energia e dell'ambiente, no. 2, 2008.
[307] M Heseltine, President of the Board of Trade, Hansard, 19 October 1992.
[308] Gordon MacKerron, "The Capital Costs of Sizewell C.", submitted to the Government's Nuclear Review as COLA 3, 1994.
[309] If we assume inflation has been 3% per year since 1995 and that the exchange rate is £1=US$1.50, that works out at a construction cost of nearly $6000/kW.

terms of the privatization, although a segregated decommissioning fund was set up, it only had to cover stages 2 and 3, with stage 1 expected to be paid out of cash-flow. As soon became clear, this was a reckless assumption because British Energy could not be assumed to have any available cash flow.

The government also found no case for providing the public subsidies that would have been necessary to allow the construction of the three further PWRs planned to follow Sizewell B. The additional output from the AGRs and the longer life of the Magnox units meant new capacity was not needed to retain the nuclear contribution to the generation mix at the existing level.

Overall, for the period 1990-96, consumers paid about £6bn to subsidize nuclear power, overtly to pay for decommissioning and waste management. In fact, only about £250m was actually spent on this, with about half the rest passed on to BNFL and British Energy to pay for decommissioning, while the rest was implicitly spent on building a new nuclear power station, which, within a year of its completion, was effectively given away.

III.6.4.3. The Period 1996-2002 – British Energy

By 1998, British Energy was apparently flourishing, its share price having doubled. In the USA, in partnership with a US utility, PECO (later this merged with another utility and became Exelon) in a joint venture created in 1997, Amergen, it bought existing nuclear plants. It followed this up with a deal to operate eight nuclear reactors in Ontario (Bruce Power). However, by 2000, the reality that British Energy's initial success had been built on an inflated wholesale electricity price sustained by an uncompetitive generation structure was becoming apparent. Improvements in output had dried up and operating cost reductions also seemed to have reached a limit. The intrinsic unreliability of the AGRs was acknowledged by British Energy.

In 2002, British Energy had to seek assistance from the British government, which, on 5 September that year, provided a credit facility of up to £410m, subsequently increased on 26 September to £650m. British Energy had been successfully reducing its operating costs, ironically reaching its lowest point almost in the year it collapsed. However, its profitability was determined by a wholesale electricity price that had been kept artificially high by a highly concentrated electricity market and when this started to fall from 2000 onwards, it was clearly going to get into serious trouble. On 28 November 2002, a rescue plan was agreed with the government, the main elements of which were:

- A renegotiation of the contracts with BNFL for new fuel and for the reprocessing of spent fuel;
- A reduction in the contributions British Energy had to make to the decommissioning fund; and
- The sale of British Energy's North American holdings in Bruce Power and Amergen.

III.6.4.4. The Period 2002 Onwards – British Energy

The government acknowledged that this rescue package was 'state aid' and an investigation was launched by the European Commission into whether it constituted unfair state aid.[310] The European Commission valued these measures at an undiscounted sum of £10bn, but decided to allow the rescue plan in September 2004.[311] British Energy was relaunched in January 2005, since when, the shares have increased in value from the re-launch price of £2.85 to a peak of over £7 in 2006.

The restructuring package consisted of seven measures that were agreed between British Energy, its major creditors (including BNFL), and the UK Government:

---

[310] State aid per se is not illegal under European Union law, but if it is considered to be distorting competition, it is.

[311] European Commission, "**Commission decision of 22 September 2004 on the State aid which the United Kingdom is planning to implement for British Energy plc", Official Journal of the European Union, European Commission,** *L 142 , 06/06/2005 pp 26-80;* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:142:0026:0080:EN:PDF .

A. measures linked to the funding of nuclear liabilities;
B. measures concerning the fuel chain agreed with BNFL;
C. standstill measures;
D. significant creditors restructuring package;
E. introduction of a new trading strategy;
F. asset disposals to help finance the restructuring;
G. local tax deferrals.

A. Measures linked to the funding of nuclear liabilities

These were the main measures and were subdivided into sub-categories

1. Historic fuel contracts. The British government assumed responsibility for the cost of these contracts for reprocessing spent fuel.
2. Uncontracted liabilities. The government agreed to meet these costs through a Nuclear Liabilities Fund (NLF). The liabilities included final disposal of spent fuel, plutonium, uranium and wastes arising from the reprocessing of AGR fuel, the storage and final disposal of spent PWR fuel, including the construction of a dry store at Sizewell-B, and the storage and disposal of operational wastes.
3. Decommissioning liabilities. The government undertook to pay any costs that could not be covered by the NLF.
4. Tax disregard. This represents the value of the tax that would be due if the previous three "assets" were taxable. The UK government introduced legislation to prevent them being taxed.

These measures (see Table 12) were offset because the value of the existing decommissioning fund, the Nuclear Decommissioning Fund (NDF), was transferred to the NLF; and British Energy was required to continue to make a small annual payment into the NLF of about £20m.

Table 12: Value of Measure A (£m)

	Net present value discounted at nominal 5.4%	**Undiscounted value**
Historic fuel contracts	2,377	3,067
Uncontracted liabilities	951	3,375
Decommissioning liabilities	1,115	5,062
Tax disregard	1,047	1,077
Payments by BE to the NLF	(2,007)	(2,510)
Total	3,483	10,071

Source: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:142:0026:0080:EN:PDF

Note: The discount rate of 5.4 % nominal rate recommended as the reference rate from 1 January 2003 in accordance with European Commission notice on the method for setting the reference and discount rates.

B. Measures concerning the fuel chain agreed with BNFL

As a part of the restructuring plan, BNFL (nationally-owned), which was British Energy's largest single creditor, has agreed to modify its fuel supply and spent fuel reprocessing contracts with British Energy (see Table 12). The value of these changes was estimated in two parts, from 2004-08 and from 2008 onwards and under three scenarios, 'upside' (lowest cost to taxpayers), 'downside' (highest cost to taxpayers) and 'bank' (the central assumption)). The British government claimed that giving precise estimates of the savings by British Energy after 2006 would be difficult, as the pre-restructuring fuel supply contracts were planned to end in 2006. The use of different discount rates for Measures A and Measures B mean that the discounted values are difficult to compare.

Table 13: Value of Measure B (£m)

	Upside	Bank	Downside
2004-08	46	72	103
Undiscounted	-87	559	1,113
Net present value discounted at real 3.5%	-289	174	589

Source: *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:142:0026:0080:EN:PDF*

Note: The real discount rate of 3.5% corresponds to the public sector discount rate.

C. Standstill Measures

As part of the restructuring plan, British Energy reached agreements (the Standstill Agreements) in relation to a standstill, subject to certain conditions, of payments due to BNFL and a number of significant financial creditors (see Table 14). This agreement applied to 2003 and 2004.

Table 14: Value of Measure B (£m)

	2003	2004	Total
Cash Savings	300	642	942

Source: *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:142:0026:0080:EN:PDF*

D. Significant creditors restructuring package

In addition to the Standstill Agreements, the restructuring plan provides for the claims of the significant creditors to be restructured and rescheduled. The liabilities of the significant creditors that were restructured totaled £1263m. The liabilities were restructured by issuing new bonds and shares in British Energy. No value of this package was given, presumably because the creditors were all private sector companies and the cost was not borne by the taxpayer.

E. Introduction of a new trading strategy

A new trading strategy for the output of the British Energy plants was introduced. Again, this seems to have involved no cost to the taxpayer.

F. Asset disposals to help finance the restructuring

The Bruce Power and Amergen assets were sold, but again with no cost implications for the taxpayer.

G. Local tax deferrals

Five local authorities agreed to defer without interest the payment of business rates owed to them by British Energy. In total, £4.3m in rates payments were postponed from November 2002 to February 2003. The rates were paid by British Energy in full in February 2003 and interest for late payment was paid in October 2003. So there appears to have been no cost to the taxpayer (or local authorities).

III.6.4.5. Total Value of State Aid

If we take the 'bank' case for Measures B, the total value of the state aid was over £11.5bn (see Table 15).

Table 15: Value of all measures (£m)

	Undiscounted value
Measures A	10,071
Measures B	559
Measures C	942
Total	11,572

In return for this state aid, the government was entitled to 65% of British Energy's net cash flow, the Cash Sweep, after tax, financing costs and the £20m annual payment to the NLF. This would be paid into the NLF, but could be converted at any time to shares. No payment was made for the financial year 2004/05 – the company was only re-launched in January 2005, but payments were made in the following two years (see Table 16). In 2007/08, the Cash Sweep was equivalent to £305m, but the NLF waived its right to £134m. No payment was made for the first half of 2008/09 and it is not clear if any payment will be made for the second half of 2008/09.

Table 16: Cash sweep payments to the NLF (£m)

	Payments
2004/05	0
2005/06	105
2007/08	171
Total	276

Source: British Energy Annual Report and Accounts, various

In May 2007, the government announced its intention to convert nearly half of its Cash Sweep entitlement to shares and sell them. This was done on 6 June 2007 and raised about £2.34bn, which was paid into the NLF. The Cash Sweep entitlement was reduced to 35.1%. In December 2008, EDF agreed to a bid of £12.5bn to take over the whole of British Energy, which involved buying the remaining 36% share entitlement of the British government. This raised £4.42bn, which was paid into the NLF.[312] Despite the takeover, the government retains all its liabilities for British Energy, including the obligation to meet any shortfall in the NLF.

A total of £7bn has been paid into the NLF as a result of the Cash Sweep arrangements, nearly matching the £8.4bn that the government forecast was the value of its Measures on decommissioning and historic fuel contracts. However, in the four years since its rescue, the liabilities that are to be met out of the NLF (uncontracted back end fuel costs and decommissioning) have increased in cost from £8.8bn (£5.2bn of which is for decommissioning) to £12.1bn (£9.4bn of which is for decommissioning) so the NLF is far from certain to have sufficient funds that the taxpayer will not have to bear some of the cost.

Even if we assume that there will be no cost to the taxpayer for uncontracted back end fuel costs and decommissioning, the estimated cost of the rescue of British Energy was still about £3.4bn.

The National Audit Office (NAO) was critical of the British government for not monitoring the scale of British Energy's liabilities. As the rescue proved, the taxpayer would inevitably have to pick up these large liabilities in the event of the failure of British Energy and the NAO argued that the government should have monitored these liabilities more carefully.[313]

III.6.4.6. The Period 1996 Onwards – BNFL

Most of the unspent proceeds of the FFL (about £2.7bn) were passed to the new owners of the Magnox stations, Magnox Electric. This was because the Magnox stations are expensive to decommission and were then near retirement so the need for funds was more urgent than for the British Energy stations. In 1998, Magnox Electric became a division of BNFL. The unspent proceeds were separately identified in BNFL's accounts as the Nuclear Liabilities Investment Portfolio (NLIP) and were invested in a way intended to ensure they would not lose value. By 2004, with additions from BNFL and interest, the fund had grown to a little over £4bn. However, the fund was an internal one, not rigorously separated from BNFL's business. In addition, BNFL was in increasingly deep financial trouble because it could not cover its assets and was allowed to continue to trade only through government assurances (the Secretary of State's Undertaking).

The government finally lost patience with BNFL in 2003 and decided to take away all BNFL's sites and give them to the then-to-be-established Nuclear Decommissioning Agency (NDA). The

[312] Press Association, "Nuclear sale raises £4.5bn for decommissioning fund", 19 January 2009.
[313] National Audit Office, "The restructuring of British Energy", National Audit Office, London, 2006, http://www.nao.org.uk/publications/0506/restructuring_of_british_energ.aspx#fn1 .

Treasury quietly absorbed the NLIP into its other income and this money was spent in the same was as all other government income.

III.6.5. The Future

When British Energy collapsed in 2002/03, its operating costs were £18.6/MWh up from £16.7 in 2001/02, but its average selling price was only £18.3/MWh. Since its relaunch in 2005, the company has generated large profits and is seen as being highly successful. However, this success seems to have everything to do with high electricity prices and little to do with the performance of the company. Its operating costs have continued to rise, reaching £30/MWh in 2007/08. Fortunately for British Energy, the electricity price has increased even faster and in 2007/08, it reached £40.7/MWh. However, in the first half of 2008/09, its operating cost had soared to £41.9/MWh. Fortunately, the selling price had remained high, at £47.2/MWh. However, if as seems likely, power prices fall sharply as demand declines and fossil fuel prices fall, British Energy could be trading at a loss again. In the longer term, the stations are now ageing rapidly and costs will continue to fall so the company may well fall into losses sooner or later. It remains to be seen whether the liabilities it leaves, if EDF is not prepared to meet them, will fall on taxpayers again.

Conclusions on UK Subsidies

Up to 1990, there were no overt subsidies for nuclear power. While it is clear the nuclear plants were far from economic, the additional costs, which are now impossible to estimate, were simply passed on to consumers. From 1990-96, there was an explicit consumer subsidy of about £1bn per year. About half of this was spent on a new nuclear plant, which quickly proved to be essentially worthless; and nearly all the rest was quietly expropriated by the Treasury in 2005 and used for general government current expenditure. Only £227m was retained and is available for the use the public was told it was for – decommissioning.

The privatization of British Energy was only possible by selling at a price that was only a small fraction of the cost of the assets and with too little attention paid to the liabilities that would fall on the public purse if the company failed. When this did happen in 2002, the government decided to intervene and not, as would have been normal policy, allow the company to close. The resulting rescue was estimated by the government to cost taxpayers more than £11bn. High electricity prices have meant that the government has been able to recoup some of these losses by selling its shares in the company, but the risk of British Energy failing again is clear and further costs could still fall on the taxpayer.IV. Overview by Region and Country[314]

IV.1. Africa

South Africa has two French (Framatome) built reactors. Construction started in the 1970s and they are both at the Koeberg site, east of Cape Town, which supply 5.2% (down from 6% in 2003) of the country's electricity. The reactors are the only operating nuclear power plants on the African continent.

The South African, state-owned, utility Eskom launched an effort in 1998 to develop the PBMR (Pebble Bed Modular Reactor), a helium-cooled graphite moderated reactor based on earlier German designs. Initially it was forecast that a demonstration plant would be built and commercial orders would be possible from 2004 onwards. A wholly-owned subsidiary company PBMR Ltd was set up in 2000 and a number of investors, including the UK state-owned BNFL and the US utility PECO Energy (later Exelon) as well as the Industrial Development Corporation, which is owned by the South African Government, and Eskom itself, promised to fund a feasibility phase. In December 2001 Exelon said that it was considering building a PBMR reactor in the USA in parallel

---

314 Unless otherwise mentioned, the figures on the numbers of reactors operating (by May 2009) and the nuclear share in the electricity generation (in 2008) are taken from the IAEA's Power Reactor Information System (PRIS) on-line data. The figures on the nuclear share of commercial primary energy production are taken from BP, "Statistical Review of World Energy", June 2009. The numbers of reactors under construction are essentially based on IAEA's PRIS as of 1st August 2009.

to those proposed in South Africa. However, following a change in management at Exelon, the company withdrew from the PBMR project entirely in April 2002.

All except Eskom failed to invest as much as promised, costs escalated dramatically and time-scales slipped, leaving Eskom and the South African government to pick up the costs. In 2008, operation of the demonstration plant was not expected before 2016. Its costs had increased by almost 10-fold from the early estimates and commercial orders were not expected before 2026. Serious technical issues also emerged[315] and in February 2009, Eskom, the only potential customer, abandoned plans to build the demonstration plant. In May 2009, PBMR Ltd was still deciding what to do, but its funds are due to run out in early 2010 and if no new investors emerge, the company will have to close.[316]

Delays with the PBMR led Eskom to consider buying large PWRs, short-listing the AREVA NP EPR and the Westinghouse AP-1000. It had a budget of R343bn (US$34bn) to build 16 GW of new coal and nuclear plant by 2017. In the longer term, it planned to build 20 GW of nuclear plant by 2025. But at US$5000/kW, its budget would provide less than 7 GW of new nuclear capacity. Eskom faces an additional challenge of a falling credit rating, reduced by Moody's August 2008 to Baa2. Finally in November 2008, Eskom admitted defeat and scrapped its tender because the scale of investment was too high. This was despite the willingness of Coface to offer export credit guarantees[317] and despite AREVA's claims that it could have arranged 85% of the finance.[318]

IV.2. Americas

Argentina operates two nuclear reactors that provide less than 6.2% (down from 9% in 2003) of the country's electricity. Argentina was one of the countries that embarked on an ambiguous nuclear program, officially for civil purposes but with a strong military lobby behind it. Nevertheless, the two nuclear plants were supplied by foreign reactor builders, Atucha-1, a heavy water reactor of a unique design which started operation in 1974, was supplied by Siemens and the Candu type reactor at Embalse by the Canadian AECL. Embalse was connected to the grid in 1983. Atucha-2, officially listed as "under construction" since 1981, was to be built by a joint Siemens-Argentinean company "that ceased in 1994 with the paralization of the project".[319] Nevertheless, in 2004 the IAEA estimated that the start-up of Atucha-2 was to be expected in 2005. At the end of 2007, the IAEA's expected start-up date had turned into a question mark that was replaced by 1 October 2010 as a new projected date for grid connection. By the middle of 2008 the plant was about 80% complete.

In July 2007 Argentina's Nucleoelectrica signed an agreement with Atomic Energy of Canada Ltd. (AECL) to enter into commercial negotiations over the potential delivery of a 740 MW Candu-6 reactor. 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 underway and that construction could start as early as within one year.[320] However, no siting decision, nor any call for tender has been reported to date.

The Presidents of Argentina and Brazil met in February 2008 and reportedly agreed to "develop a program of peaceful nuclear cooperation that will serve as example in this world".[321]

---

[315] Rainer Moormann, "A safety re-evaluation of the AVR pebble bed reactor operation and its consequences for future HTR concepts", Forschungszentrum Jülich, 2008. See http://juwel.fz-juelich.de:8080/dspace/handle/2128/3136, accessed 20 April 2009.
[316] Stephen Thomas, "PBMR: hot or not?", Nuclear Engineering International, April 2009.
[317] Nucleonics Week, "French export credit agency to insure loans for CGNPC, Eskom", 21August 2008.
[318] The Star, "Nuclear bid had funding – AREVA", 30 January 2009.
[319] At http://www-pub.iaea.org/MTCD/publications/PDF/cnpp2003/CNPP_Webpage/pages/..\countryprofiles\Argentina\Argentina2003.htm
[320] Market Wire, "Argentina to Reinforce Nuclear Energy by Adding 700 MW and Building Fourth Nuclear Plant", 7 May 2009.
[321] WNN, "Argentina and Brazil team up for nuclear", 25 February 2008. Both countries have a long way to go in order to make their programs exemplary. Their industrial as well as their non-proliferation record has been far from convincing.

Brazil operates two nuclear reactors that provide the country with 3.1% of its electricity (down from 4% in 2003). 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 1,300 MW reactors over a 15 year period. The outcome was a disaster. 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 abandoned in June 1991. Hopes of Eletronuclear, the owner of the plant, to relaunch construction received a severe damper in July 2008 when Environment Minister Carlos Minc announced 60 stiff "pre-license" conditions for the completion of the unit. The most difficult challenge will no doubt be to provide a "definite" solution for final disposal of high-level radioactive waste. Indeed, the completion of Angra-3 now "looks more doubtful".[322]

Canada was one of the early investors in nuclear power and began developing a new design of heavy water reactor in 1944. This set the development of the Canadian reactor program down a unique path, with the adoption of the Candu – CANadian Deuterium Uranium – reactor design. The key differences between the Candu and the more widely adopted light water reactors are that they are fuelled by natural uranium, can refuel without shutting down and are cooled and moderated by heavy water.

Officially, there are 18 reactors in operation, all of which are Candus providing 14.8% (up from 12.5% in 2003) of the country's electricity. Four additional units are listed by the IAEA as in "long term shutdown". Throughout their operational history the Canadian reactors have been plagued by technical problems that led to construction cost over-runs and reduced annual capacity factors. In August 1997 Ontario Hydro announced that it would temporarily shut down its oldest seven reactors to allow a significant overhaul to be undertaken. The four reactors at Pickering-A were shut down at the end of 1997 with the three remaining Bruce-A reactors closed on 31 March 1998 - unit 2 at Bruce A had already been closed in October 1995. At the time it was the largest single shutdown in the international history of nuclear power -- over 5,000 MW of nuclear capacity, one third of Canada's nuclear plants. The utility, Ontario Hydro, called for the "phased recovery" of its nuclear reactors starting with "extensive upgrades" to the operating stations - Pickering B, Bruce B, and Darlington - and then their return to service. There have been significant delays in restarting the reactors and as of May 2009 only four of the eight reactors had returned to operation; two more are scheduled to come back online later in 2009 or early 2010. The two remaining Bruce-A3 and -A4, according to Bruce Power "one of North America's most complex engineering projects", are slated to be back online by 2013.[323]

In March 2009, Bruce Power announced that it is looking at the Whitemud site close to Lac Cardinal in Alberta for a nuclear plant of up to 4,000MW. The company had selected another site a year earlier but abandoned it following massive opposition. Bruce Power predicts a 10-year site preparation and construction phase, so that the units would start up well after 2020. No decision has been taken at this point.

On 16 June 2008 the Canadian government announced Darlington in Ontario as the site for a two-unit new build project and on 20 May 2009 information leaked that the Ontario government had chosen AECL as the leading bidder over AREVA and Westinghouse to start building the first new nuclear plants in Canada in 25 years. Two new reactors were projected to start operating by 2018.

[322] WNN, "The completion of Brazil's Angra-3 reactor looks more doubtful after the country's environment minister set 60 tough conditions for the project", 24 July 2008.

[323] Bruce Power, "Bruce A Restart & Refurbishment project expanded", 29 August 2007; http://www.brucepower.com/pagecontentU12.aspx?navuid=5002&dtuid=83558 accessed 22 May 2009.

However, the provincial government reportedly conditioned any go-ahead on financial guarantees by the federal government to cover the financial risks involved.[324]

In early July 2009, the Ontario government shelved the entire plan and Premier McGuinty stated: "We didn't factor in the single greatest global economic recession in the past 80 years."[325] So 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.

New Brunswick is investigating the option of adding a second nuclear reactor at its Point Lepreau site; but meanwhile a $1.4 billion refurbishment project on the first unit is running at least three months late and could extend well into 2010. The unit has been down since April 2008.

Any new-build plan in Canada risks running into massive difficulties. There is substantial local opposition against projects, in particular in Alberta and Saskatchewan. The industry would have to cope with extensive refurbishment and new-build activities at the same time. As in other countries, the Canadian nuclear industry faces a severe shortage in skilled workers. The President of the Canadian Nuclear Safety Commission (CNSC) has stated that CNSC is "facing many of same issues as the rest of the nuclear industry", including a 10% annual turnover and 23% of the workforce eligible to retire in the next five years.[326] New build would also involve a new design of Candu, ACR-1000, which, unlike the earlier plants, would use light water as coolant. This would have to undergo a thorough regulatory review and its costs are therefore, as yet, impossible to estimate.

AECL has, with the support of the Canadian Export Credit Agency, undertaken an aggressive marketing campaign to sell reactors abroad and to date 12 units have been exported to South Korea (4), Romania (2), India (2), China (2), Pakistan (1), Argentina (1). The export market remains a crucial component of the AECL's reactors development program. In September 2004, a Memorandum of Understanding was signed with the National Nuclear Safety Administration of China. This MoU will in part facilitate the development of AECL's Advanced Candu Reactors.

Canada is the world's largest producer of uranium and in 2008 produced about 21% of the global total.

The development of nuclear power in **Mexico** began in the 1960s with site investigations and a call for tenders was announced in 1969. In 1976 General Electric began the construction of the Laguna Verde power plant, with a proposal to build two 650 MW reactors. The first unit went into commercial operation in 1990 and the second in April 1995. In 2008, nuclear power produced 4% (down from 5.2% in 2003) of the country's electricity. An uprating project that is currently underway is hoped to raise installed capacity of both units by about 20%. There are some vague proposals but no concrete plans to build new reactors.

The **United States** has more operating nuclear power plants than any other country in the world, with 104 commercial reactors providing 19.7% of the electricity (roughly stable since 2003). Although there are a large number of operating reactors in the USA, the number of cancelled projects – 138 units – is even larger. It is now 36 years since a new order that has not subsequently been cancelled (October 1973) has been placed. In 2007 for the first time in three decades, utilities requested a license to build a nuclear plant. NRG/Exelon announced plans to build two reactors at the South Texas site that already operates two Westinghouse pressurized water reactors.

The last reactor to be completed was Watts Bar 1, in 1996 and the construction licenses on a further four (Watts Bar-2, Bellefonte-1 and -2, and WNP-1) was recently extended, although there is no active construction on these sites. In October 2007 TVA announced that it had chosen the Bechtel group to complete the two-thirds built, 1,200 MW Watts Bar-2 reactor for $2.5 billion.

[324] The Globe and Mail, "AECL favoured to build Ontario reactors: sources", 20 May 2009.
[325] The Star, "Economy let us delay nuclear plan, premier says", 7 July 2009.
[326] Michael Binder, President, Canadian Nuclear Safety Commission, "Moving Forward", Presentation, 4 June 2008.

Construction had been originally started in 1972, but was frozen in 1985 and abandoned in 1994. Construction has restarted and is now expected to take until 2012 to finish the reactor. Watts Bar 1 was one of the most expensive units of the US nuclear program and its completion took 23 years.

Despite the failure so far to build more reactors, the nuclear power industry remains highly successful in two main areas, increased output from existing reactors and plant life extensions. Due to changes in the operating regimes and increased attention to reactor performance, the energy availability of US reactors has increased significantly from 56% in the 1980s to 78.3% in 2007. As a result, along with new capacity coming on line and reactor uprates, the output from US reactors has tripled over this period. The lack of new reactor orders means that around 30% of the country's reactors will have operated for at least 40 years by 2015. Originally it was envisaged that US reactors would operate for 40 years; however, projects are being developed and implemented to allow reactors to operate for up to 60 years. As of July 2009, 54 US nuclear plants had been granted a life extension license by the Nuclear Regulatory Commission, 16 applications are under review and around 21 have submitted letters of intent covering a period up to 2017[327].

The election of George W. Bush in 2000 was expected to herald a new era of support for nuclear power. The administration's National Energy Policy set a target of two new reactors to be built by 2010, but this objective will not be met. To reduce uncertainties regarding new construction a two-stage license process has been developed. This will enable 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.

As of July 2009, the US Nuclear Regulatory Commission had received 17 applications for a total of 26 units.[328] These applications cover five different reactor designs, 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 AP-1000. Only one design – the ABWR, which is referenced only in the application for South Texas units 3 and 4 – has been certified by the NRC, but this certification runs out in 2012 and major modifications are likely to be needed for it to be re-certified.

Delays to the generic approval process have meant that the sequence of approval has been inverted with utilities likely to be granted COLs before generic approval of the design of reactor to be built has been granted.

As of July 2009, the NRC had granted three Early Site Permits (ESP)[329] and received one additional application[330] that is currently under review. ESPs are independent of the construction/operating license.[331] None of the applicants has received an ESP *and* a certified design at this stage.

The July 2005 US 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% of debt (not including equity) or $18.5 billion for the first 6 GW, additional support in case of significant construction delays for up to six reactors and the extension of limited liability (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 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

[327] http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html ; accessed 22 May 2009
[328] http://www.nrc.gov/reactors/new-reactors/col.html ; accessed 22 May 2009
[329] Clinton (Exelon), Grand Gulf (SERI), North Anna (Dominion).
[330] Vogtle (Southern).
[331] At http://www.nrc.gov/reactors/new-reactors/esp.html ; accessed 22 May 2009.

80% of the debt to 80% of the total cost. In May 2009 Friends of the Earth filed an appeal with the South Carolina Supreme Court over the state regulator's approval of the Summer reactor project.[332]

The nuclear industry has suffered a series of other drawbacks in the USA recently:

- Entergy asked the NRC to suspend reviews specific to the ESBWR projects for Grand Gulf and River Bend "after unsuccessful attempts to come to mutually acceptable business terms" with GE Hitachi.[333] Grand Gulf was one of only three NRC approved Early Site Permits. A few days later Dominion pulled the plug on the ESBWR for its North Anna project. In both cases some of the contracts for major components had already been signed and have now to be cancelled.[334]
- Ameren announced that it would withdraw its EPR project at Callaway, Missouri, since the current legislation "will not give us the financial and regulatory certainty we need to complete this project".[335]
- Exelon in March 2009 dropped the ESBWR for its Victoria project in Texas and chose the ABWR instead. However, two months later, Exelon CEO John Rowe stated that his company would "delay or cancel" the project entirely, because it was not amongst the projects selected by the DOE for loan guarantees.[336]
- Progress Florida announced that its Levy County project would be delayed by a minimum of 20 months. The NRC will not accept groundwork until a pending COL request is decided upon.[337]
- The Minnesota Senate voted by a majority of 50 to 16 to maintain the State's ban on nuclear power.
- President Obama has made a number of key appointments that are certainly not the first choice of nuclear proponents. Steven Chu, an energy efficiency and renewable energy expert, now heads the DOE. Carol Browner was appointed the President's Special Assistant for Energy and Climate Change[338] and Gregory Jaczko was named chairman of the NRC. Before joining the NRC as a commissioner in 2005, Jaczko was a science advisor to Senate Majority Leader Harry Reid from Nevada. Reid has been fighting the Yucca Mountain final disposal option for high-level waste for many years.
- The attempt to introduce a $50 billion nuclear share in the US government's Stimulus Package was defeated by Congress. The fiscal year 2009 federal budget severely cut funding for nuclear programs and de facto ended funding for Yucca Mountain.

IV.3. Asia

China operates 11 reactors with a cumulated installed 8,438 MWe that generated 2.1% of the country's electricity in 2008. According to the IAEA's PRIS database there are an additional 16 reactors under construction (although other sources suggest that this is on the high side). However, these two figures highlight the contradiction that is the Chinese nuclear program. Firstly, nuclear energy's 2% contribution to the electricity supply translates into 0.8% of the country's overall primary energy supply and is amongst the lowest percentage contributions in the world

[332] Platts, "Group goes to court over Summer reactor plans", 22 May 2009.
[333] Entergy, "Entergy Temporarily Suspends Reactor License Applications", Press Release, 9 January 2009.
[334] WNN, "Double Blow to ESBWR from Entergy and Dominion", 12 January 2009.
[335] Ameren, "AmerenUE Requests Sponsors to Withdraw Missouri Clean and Renewable Energy Construction Bills in General Assembly", Press Release, 23 April 2009 ; http://ameren.mediaroom.com/index.php?s=43&item=634.
[336] Platts, "Exelon to 'delay or cancel' plans for new reactors, CEO says", 15 May 2009.
[337] Platts, "US NRC move to delay Florida units at least 20 months: Progress", 1 May 2009.
[338] Fortune Magazine reports from a session of 'Fortune's Brainstorm' on nuclear power: "While Energy Secretary Steven Chu might be open to new nukes, said one participant, speaking not for attribution, Carol Browner, President Obama's special assistant for climate, decidedly is not. And Browner, this participant added, is calling the shots." Fortune Magazine, "A nuclear power renaissance? Maybe not.", 22 April 2009.

(with India and Pakistan). On the other hand, China has more reactors under construction than any other country in the world, with almost one third of the global total.

China's energy demand is growing at apace, averaging between 5-10% per year over the past decade and is heavily reliant on coal, which provides nearly 70% of the country's energy. For security of supply reasons and environmental concerns China has an active and ambitious plan to increase energy efficiency (a 20% increase between 2005 and 2010) and to diversify energy sources. This is perceived as particularly important given the predicted increase in energy demand. Most notable has been the current and proposed expansion of the wind sector, which by 2007 had reached 5 GW installed capacity, a target that the National Development and Reform Committee (NDRC) had set for 2010. The 2020 target of 30 GW is now expected to be met by 2012. Industry observers expected this target to be met easily, with some predicting that the installed capacity might reach 100 GW by this date[339].

Plans for the nuclear sector also entail major expansion. The current plan envisages nuclear power will increase from the current level of 8.4 GW to 40 GW by 2020. This would require the completion of all of the 16 reactors under construction (15.2 GW) plus a further 15 or so over the next 11 years. Various government departments have suggested that this target should be increased, including a call from the NDRC in May 2007 for 160 GW of nuclear by 2030 and a June 2008 projection from the China Electric Council for 60 GW by 2020 while the State National Energy Administration was reported to be proposing a target of 70 GW by 2020. However, even such an ambitious target would only enable nuclear energy's contribution to the primary energy supply in 2020 to reach 3%.

While it is clear that the engineering skills and infrastructure and the energy demand as well as the 'command and control' political system in China has made possible the completion of projects on a scale that may well be unachievable in other parts of the world, the nuclear sector in China has not been without its problems. In particular, China has played, and continues to play, a careful balancing act, needing the state of the art nuclear technologies from abroad and striving for self-sufficiency for manufacturing.

The eleven reactors in operation in China have been built with a mixture of foreign and indigenous resources. The Daya Bay and Lingao plants were constructed using French light water reactor designs. Those at Qinshan, phase 3, are Candu 6 pressurized heavy water reactors, while those at Tianwan, phase 1, are of the AES-91 design supplied by Russia. The other reactors have been built using domestic design and resources, although key components, such as pressure vessels, have been imported in some instances (such as at Qinshan, phase 1).

The desire to obtain new reactor designs is also being pursued for the next generation of reactors. In late 2004 the State Council approved plans for the construction of up to eight new units at Sanmen and Yangjiang. Three bids were received from Westinghouse (US), AREVA (France) and Atomstroyexport (Russia). Bids were said to be assessed on the level of technology, the degree to which it is proven, price, local content, and technology transfer.[340]

The last two points are crucial. China has masterfully negotiated contracts in the past. The French lost a significant amount of money in the first reactor deliveries at Daya Bay, Guandong: "We did not lose the shirt but cuff-links" in the deal, the EDF President stated at the time. "Yes, and golden ones!" the Director General added during the press conference in 1985 when the deal was announced. EDF managed the construction of the two units together with Chinese engineers. At the time, the project was meant to be a door-opener for a whole series of reactors to be delivered. In reality, AREVA exported just two more units to China over the following 20-year period.

The contracts were not allocated to foreign bidders in 2005 as planned. Westinghouse won the battle against AREVA for four units of Generation III design and signed a contract in February 2007. Although the specific terms were not disclosed, the contract was said to be worth around $5.3 billion. Construction was expected to start in 2009 with power production in August 2013.

339 Junfeng Li, "China's Wind Power Development Exceeds Expectations", OPINION, World Watch Institute, 2 June 2008.

340 At http://www.uic.com.au/nip68.htm .

One of the key factors in the contract was that it contained not only technology transfer for the reactor but for the back end services.

However, not to be outdone, on 26 November 2007 AREVA announced the signing of a "record contract, worth 8 billion euros (…) unprecedented in the world nuclear market". AREVA will build together with the CGNPC (China Guangdong Nuclear Power Corp.) two EPRs in Taishan in Guangdong province and will provide "all the materials and services required to operate them".[341] In October 2008 AREVA and the China Guangdong Nuclear Power Holding Co. Ltd. (CGNPC) announced a joint venture with a 45%/55% split between the two companies to enable the development of EPRs and other light water reactors in China and abroad.

Co-operation agreements have been signed with other reactor suppliers, including with AECL of Canada (in September 2005), while the Korean Doosan Heavy Industry has supplied a pressure vessel for the Qinshan reactor and is expected to supply pressure vessels for the AP1000. A memorandum of understanding has also been signed for co-operation on the pebble bed reactor with South African bodies.

In addition to the agreements for reactor development there are a number of partnership agreements for the supply of uranium. These have included deals with companies from Australia, Canada, Kazakhstan and France.

India operates 17 reactors with a total capacity of 3,779 MW that provide just 2% of its electricity (down from 3.3% in 2003). Total power generating capacity in India is about 130 GW – 10% more than France – for a country with 20 times the population of France. Less than 3% of the installed capacity is nuclear.

India lists six units as under construction (two less than in 2004) with a total of only 2.9 GW. The current operating reactors are also mainly of a smaller capacity, ranging from 90 to 200 MW, and most experienced construction delays resulting in building times stretching over 10 to 14 years and operational targets seldom achieved. In 1985 India's goal was 10 GW of operating nuclear capacity installed by the year 2000—requiring a tenfold increase from the 1985 base. In reality, installed capacity rose to only 2.2 GW and its actual (operating) capacity by no more than 1.5 GW.

In 2006 the chairman of the Nuclear Power Corporation of India (NPCI) told reporters that 62 reactors with a combined capacity of 40 GW would be operating by 2025.[342] There is no evidence of how the country would enable an annual increase of 1,850 MW every year between 2008 and 2025.

India was the first country to clearly use designated "civil" facilities for military purposes. Its 1974 nuclear weapons test triggered the end of most of the official foreign nuclear cooperation and invaluable Canadian assistance in particular. The test series in 1998 came as a shock to the international community and triggered a new phase of instability in the region including a following test series by Pakistan. Nevertheless, in July 2005, the Bush administration decided to lift the nuclear trade sanctions against India and in a joint statement with the Indian Prime Minister the ground was laid for a far reaching cooperation agreement.[343] The agreement was signed into law on 8 October 2008 in spite of severe criticism in particular in the USA but also in many other countries and in India itself.[344] The IAEA safeguards agreement with India was approved in August 2008 and the Nuclear Suppliers Group (NSG)[345] granted an exception to its own rules on 6 September 2008. India is a non-signatory of the Non-Proliferation Treaty, has developed and maintains a nuclear weapons program, refuses full-scope safeguards on all of its nuclear facilities

[341] AREVA, Press Release, 26 November 2007.
[342] India e-news, 23 May 2006.
[343] For a detailed discussion of the implications of the agreement, see Zia Mian, et al., "Fissile Materials in South Asia: The Implications of the U.S.-India Nuclear Deal", IPFM, September 2006.
[344] See previous footnote and for example Daryl Kimbal, "Fixing a flawed nuclear deal", Arms Control Today, September 2007, http://www.armscontrol.org/act/2007_09/focus.asp .
[345] A 45-country group regulating international commerce in order to prevent the proliferation of nuclear weapons.

and is still permitted to receive nuclear assistance and to carry out nuclear commerce with other nations.

"Nuclear trade restrictions on India were lifted last year and delegation after delegation of foreign firms has visited since then," *World Nuclear News* reports.[346]

The French government, which did not have to seek approval from Parliament, signed a nuclear cooperation agreement with India a few days before the US-Indo deal was inked. The French nuclear industry immediately offered its services. In March 2009 Nuclear Power Corporation of India Ltd (NPCIL) and AREVA signed a memorandum of understanding to develop a project with two EPRs for a site in Jaitapur. Apparently 15 banks, including 10 French ones, have offered loans for the project.[347] Other builders including GE Hitachi, AECL and the Russian industry are also in negotiations over the potential supply of nuclear power plants.

Considering its poor past industrial record, it remains to be seen whether the Indian nuclear sector will be up to its own expectations in the future. Foreign assistance could make a difference to some extent. However, a setback was the decision by the Australian government to maintain its embargo over uranium sales, despite the Nuclear Suppliers Group (NSG) waiver, unless India signs the Non-Proliferation Treaty.

Japan operates 53 reactors that in 2008 provided 24.9% of the country's electricity. In 2002 nuclear energy had produced almost 35% of Japan's electricity. Two units at Hamaoka were officially shut down definitively on 22 December 2008.[348] They had not produced any power since 2001 and 2004 respectively. However, they were never listed in the IAEA's "long term shut down" category and were taken off the operating reactors' list only in January 2009.

A massive falsification scandal starting in August 2002 led to the shut down of all of Tokyo Electric Power Company's 17 nuclear reactors.[349] Later the scandal widened to other nuclear utilities. No wonder that the nuclear electricity generation in the country dropped by over a quarter between 2002 and 2003 and the average load factor of the Japanese nuclear plants crashed to less than 60%. The falsification of quality-control data re-surfaced in April 2009 when Hitachi detected that inspection records for heat-welded pipes had been manipulated and launched an investigation.[350]

On 16 July 2007 a severe earthquake measuring 6.8 on the Richter scale hit the region that houses TEPCO's Kashiwasaki-kariwa plant. The plant with seven units is the largest single nuclear power station in the world. The reactors were shut down and have remained closed since for damage verification and repairs. Since the seismic acceleration of the quake detected at one of the reactors was at least 2.5 times as high as the design basis of the nuclear facilities, it is unclear under what conditions the units can restart. When on 11 October 2007 the first vessel head was taken off unit seven for inspection, one control rod was stuck in the core and could not be moved. This means that a key safety feature was not properly working. The discovery is likely to lead to additional delays in the operation of the units. The capacity factor for the financial year ending 31 March 2009 was again only 60%.

In February 2009 the Nuclear Safety Commission granted permission to restart unit seven, considered to be the least damaged on the site. On 5 March 2009 for the eighth time since operator TEPCO prepared for restart and Niigata Prefecture requested additional assurances for safety, a fire broke out on the Kashiwasaki site. By 8 May 2009 the local authorities gave in to "intense pressure from TEPCO and the central government" and authorized restart of unit seven against significant protests.[351] The fate of the other Kashiwasaki units remains uncertain.

---

[346] WNN, "Money no object for Indian reactor plans", 25 March 2009.
[347] Ibidem.
[348] Chubu Electric, Press Release, 22 December 2008.
[349] See also http://cnic.jp/english/newsletter/nit92/nit92articles/nit92coverup.html.
[350] WNN, "Data falsification prompts component checks", 14 April 2009.
[351] CNIC, "Kashiwazaki-Kariwa-7 Restart", 8 May 2009; http://cnic.jp/english/topics/safety/earthquake/kk7restart8may09.html.

Officially two reactors are listed as under construction, down from three in 2003. The Monju reactor is still considered to be in "long term shutdown". Further construction plans are vague and have been scaled back several times. Construction starts at Ohma, Fukushima and Higashidori have been delayed again by at least one year. Toshiba, which owns Westinghouse, has filed a record $3.6 billion deficit for the last financial year and has reduced planned investment by 42% for the current financial year.[352]

The plutonium separation plant in Rokkasho-mura started active testing in March 2006. The reprocessing facility with a nominal annual throughput of 800 t experienced its first technical problems less than a month later (a leak in the cleaning tank for hulls and nozzles). The accidents and scandals of the last years have significantly delayed introduction of plutonium in MOX (uranium-plutonium mixed oxide) fuel. So far, no MOX fuel has been used, and Japan has a significant stock of plutonium, about 47 t, of which about 38 t are in France and the UK. A shipment of MOX fuel fabricated in France and containing about 1.7 t of plutonium reached Japan on 18 May 2009. The construction of Japan's own MOX fuel fabrication facility, which is many years behind schedule, is now supposed to start in November 2009. Additional seismic protection has driven up the cost estimate again by 46% to, currently, $2 billion.[353]

Pakistan[354] operates two reactors that provide 1.9% of the country's electricity (down from 2.4% in 2003). One additional unit, supplied by China, is under construction. As in the Indian case, Pakistan has used designated civil nuclear facilities for military purposes. In addition, the country has developed a complex system to access components for its weapons program illegally on the international black market, including from various European sources.[355] Immediately following India's series of nuclear weapons tests in 1998, Pakistan also exploded several nuclear devices. International nuclear assistance has been practically impossible, given the fact that Pakistan, like India, has not signed the Non-Proliferation Treaty (NPT) and does not accept full-scope safeguards (international inspections of *all* nuclear activities in the country). The Pakistani nuclear program will therefore most likely maintain its predominantly military character. The most recent crisis over the security of Pakistan's nuclear weapons in view of the positioning of militant Talibans close to Pakistan's capital is unlikely to help Pakistan waive basic NSG standard rules for international assistance and commerce as in the case of India.

On the Korean Peninsula, the **Republic of South Korea** (ROK) operates 20 reactors that provide 35.6% of the country's electricity (down from 40% in 2003). In addition five reactors are listed as under construction, and work on a further two units will commence in 2009. For a long time, South Korea, besides China, has been considered the main future market for nuclear power expansion. While the early program was implemented without much public debate, a major controversy over the future of the nuclear program – and in particular about the destiny of the radioactive waste – hit expansion plans in the 1990s and brought them virtually to a halt. The current government has reinvigorated nuclear projects and announced in December 2008 its plan to complete 12 more units by 2022 and thus raise installed nuclear capacity from the current 34% to 48% of total installed capacity.[356]

The **Democratic People's Republic of Korea** (DPRK) does not have any nuclear power reactors operating. A 1994 international agreement (KEDO) provided for the construction of two power reactors with financial and technical assistance from the USA, the EU and a number of other countries. In return the DPRK was to have abandoned all nuclear weapons related research and development activity. In 2002 the USA accused the DPRK of violating the agreement. Although

[352] AFP, "Toshiba to raise $5bln: reports", 18 April 2009
[353] Bloomberg, "Seismic Work on Japan Spent-Nuclear fuel Plant Boosts Costs 46%", 16 April 2009.
[354] For details on Pakistan's energy and nuclear program, see Zia Mian, Abdul H. Nayyar, "Pakistan and the Energy Challenge", in Lutz Mez, Mycle Schneider & Steve Thomas (eds), "International Perspectives on Energy Policy and the Role of Nuclear Power", Multi-Science Publishing, Brentwood, 2009.
[355] See Mycle Schneider, "Nucléaire : Paris, plaque tournante du trafic pakistanais", Politis, Paris, 1989.
[356] Bloomberg, "South Korea to Spend $28 Billion on New Power Plants", 28 December 2008.

the US accusation turned out to be overstretched, the DPRK decided to quit the NPT and openly prepared for the reactivation of nuclear weapons-related activities. As a consequence, the reactor building project was frozen. On 7 October 2006, the country exploded a nuclear device to demonstrate its nuclear weapons capability. After an intensive round of disarmament talks, the country on 13 February 2007 signed the "North Korea - Denuclearization Action Plan" and agreed to "shut down and seal for the purpose of eventual abandonment the Yongbyon nuclear facility, including the reprocessing facility and invite back IAEA personnel to conduct all necessary monitoring and verifications" as agreed between IAEA and the DPRK.[357] Beginning in 2008 several activities concerning the potential reactivation of its nuclear weapons and ballistic missile related activities raised severe doubts about the DPRK's willingness to go down the disarmament route, and in May 2009, it exploded another test weapon. In any case, there is no discussion any more over the completion of the two power reactors that were under construction under previous international agreements.

Taiwan operates six reactors that provide 19% of the country's electricity (down from 21.5% in 2003). Two 1350 MWe Advanced Boiling Water Reactors are listed under construction at Lungmen, near Taipei. They were scheduled for start-up in 2006-2007, but this has been delayed to no earlier than 2011-2012. The most recent operating unit started up in 1985. All of the power plants are US-delivered. For the two plants under construction, initial bids to supply the units on a turnkey basis were rejected, and contracts were awarded to General Electric for the nuclear islands, Mitsubishi for the turbines and others for the remaining equipment. Construction began in 1999. "When the two reactors were one third complete a new cabinet cancelled the project but work resumed the following year after legal appeal and a government resolution in favour".[358] In March 2009 state utility Taipower told the parliament that it would need additional funding of US$ 1.1-1.5 billion to finish the two units five years late by 2012. The additional funding would bring the total cost of the two units to US$ 7.8-8.1 billion.[359]

IV.4. Europe

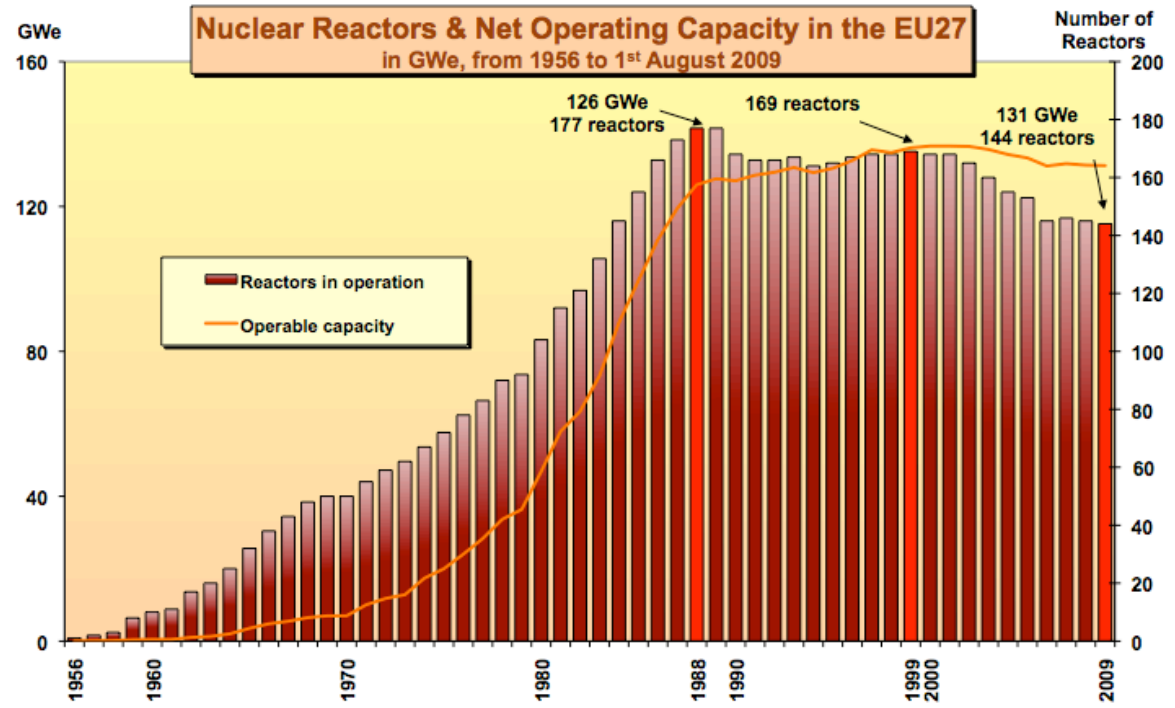
On 1st August 2009, 15 of the 27 countries in the enlarged European Union (EU27) operated 144 reactors, about one third of the units in the world, down from 177 reactors in 1989.

The vast majority of the facilities, 124 (down from 132 in 2003), are located in eight of the western EU15 countries and only 20 are in the seven new Member States with nuclear power. In other words, almost nine out of ten operating EU27 nuclear reactors are in the West. Nevertheless, especially when it comes to safety issues, a large part of the public and political attention seems to be directed towards the East.

In 2008, nuclear power produced 28% (down from 31% in 2003) of the commercial electricity in the EU. Moreover, almost half (47%) of the nuclear electricity in the EU27 was generated by one country only: France.

357 At http://www.fmprc.gov.cn/eng/zxxx/t297463.htm .
358 At http://www.world-nuclear.org/info/inf115_taiwan.html .
359 WNN, "Taipower: More money to complete Lungmen", 12 March 2009.

Graph 16



© Mycle Schneider Consulting *Source: IAEA-PRIS, MSC, August 2009*

IV.4.1. Nuclear Power in Western Europe

Especially in Western Europe, the public generally overestimates the significance of electricity in the overall energy picture and the role of nuclear power in particular. The share of electricity in the commercial primary energy consumption in the EU15 corresponds to only about one fifth.

The 124 operating nuclear power reactors in the EU15 as of 1st August 2009 – that is 33 units less than in 1988-89 when the number of operating units peaked – provide:

- less than one third of the commercial electricity production;
- about 12% of commercial primary energy consumption;
- less than 6% of final energy consumption.

Two reactors are currently under construction in the EU15, one in Finland and one in France. No building site had been opened in the EU15 since the French Civaux-2 unit got underway in 1991. Apart from the French exception, until the recent reactor project in Finland, no new reactor order had been placed in Western Europe since 1980 – that is one order outside France in 29 years.

The following chapter gives a short overview per country (in alphabetical order).

Belgium operates seven reactors and has with 53.8% (down from 55.5% in 2003) one of the highest nuclear shares in its power mix in the world. In 2002, Belgium passed nuclear phase-out legislation that required the shut-down of the nuclear power plants after 40 years of operation and therefore, according to their start-up date, the plants will be shut-down between 2014 and 2025.

Although the legislation was passed under a government that included a coalition with the Green Party, the governments that followed, which did not include any green ministers, have not overturned the phase-out law.

Finland currently operates four units that supply 29.7% (up from 27% in 2003) of its electricity. In December 2003, Finland became the first country to order a new nuclear reactor in Western Europe in 15 years. The utility TVO signed a turn-key contract with the Franco-German consortium

Framatome-ANP, now AREVA NP (66% AREVA, 34% Siemens) to supply a 1600 MW EPR (European Pressurized water Reactor). Construction started in August 2005. Three and a half years later the project is over three years behind schedule and at least 55% over budget, the loss for the provider being estimated at €1.7 billion (see chapter III. for further economic analysis). It remains unclear who will cover the additional cost.

In an unusually critical report the Finnish Safety Authority (STUK) pinned down a number of reasons for the delays:

> The time and resources needed for the detailed design of the OL3 unit was clearly underestimated, when the overall schedule was agreed upon (...). An additional problem arose from the fact that the supplier was not sufficiently familiar with the Finnish practises at the beginning of the project. (…) The major problems involve project management (...). The power plant vendor has selected subcontractors with no prior experience in nuclear power plant construction to implement the project. These subcontractors have not received sufficient guidance and supervision to ensure smooth progress of their work (...). As another example, the group monitored manufacturing of the reactor containment steel liner. The function of the steel liner is to ensure the leak-tightness of the containment and thus prevent any leaks of radioactive substances into the environment even in case of reactor damage. The selection and supervision of the liner manufacturer was left to the subcontractor who designed the liner and supplied it to FANP [AREVA NP]. The manufacturer had no earlier experience on manufacturing equipment for nuclear power plants. Requirements concerning quality and construction supervision were a surprise to the manufacturer (...).[360]

Almost three years later, nothing seems to be solved. In December 2008, the Director General of STUK, Jukka Laaksonen, sent a letter to the CEO of AREVA expressing "great concern" about "Olkiluoto-3 NPP automation". He stated:

> The construction of Olkiluoto 3 plant seems to proceed generally well but I cannot see real progress being made in the design of the control and protection systems. Without a proper design that meets the basic principles of nuclear safety, and is consistently and transparently derived from the concept presented as an annex to the construction license application, I see no possibility to approve these important systems for installation. This would mean that the construction will come to a halt and it is not possible to start commissioning tests.[361]

This is not the latest episode in a long series of events around the construction of OL3 (see Annex 4 for a chronology). In May 2009 STUK ordered the halt of welding work in France on primary circuit piping because for the second time faults have been discovered. STUK section head Martti Vilpas commented: "Things cannot continue like this".[362]

The repeated construction delays of OL3 are not only a blow to power planning by the utility and the some 60 large customers that are involved in the project consortium, but also for the Finnish government. OL3 was part of the Finnish government's strategy to achieve its target of 0% increase of 1990 emissions under the Kyoto Protocol. In 2006 Finland was 13% higher than in 1990. The lack of an operational OL3 will force Finland to use expensive flexible Kyoto mechanisms in order to compensate for emissions in the country.

The trouble with the OL3 project has not prevented TVO from filing an application, in April 2008, for a decision-in-principle on OL4, a 1-1.8 GW reactor that should start construction in 2012 and

---

[360] STUK, Press Release, 12 July 2006, http://www.stuk.fi/stuk/tiedotteet/2006/en_GB/news_419/ ; STUK, "Management of Safety Requirements in Subcontracting During the Olkiluoto-3 Nuclear Power Plant Construction Phase", Investigation Report 1/06, translation dated 1 September 2006. For full report see http://www.stuk.fi/stuk/tiedotteet/2006/en_GB/news_419/_files/76545710906084186/default/investigation_report.pdf .

[361] Letter dated 9 December 2008, leaked to Finnish television in May 2009 and made available by Greenpeace at http://weblog.greenpeace.org/nuclear-reaction/2009/05/problems_with_olkiluoto_reacto.html .

[362] Helsingin Sanomat, "TVO: Welding problems will not cause further delays to completion of Olkiluoto III", 13 May 2009.

enter operation "in the late 2010s".[363] In parallel Fortum Power is planning a similar project as Loviisa-3. Fennovoima Oy in January 2009 submitted an application to the Ministry of Employment and the Economy for a decision-in-principle on the construction of a new plant at one of the following locations: Pyhäjoki, Ruotsinpyhtää or Simo. The EIA procedure concerning that project ended in February 2009. However, none of these projects has been decided upon politically, nor have they developed to the level of a call for tender and the likelihood of their implementation is difficult to assess at this point.

Finland is planning a final spent fuel repository also at the Olkiluoto site. In March 2009 the operator Posiva Oy submitted an application for a decision in principle to license an increase in the final disposal capacity from 6,000 tons to 12,000 tons in order to accommodate not only fuel from Olkiluoto-4 but also from Loviisa-3.[364]

France is the worldwide exception in the nuclear sector. Thirty-five years ago, the French Government launched the world's largest public nuclear power program as a response to the so-called oil crisis in 1973. However, less than 12% of France's oil consumption in 1973 was used for power generation. Three decades later, France has reduced overall fossil fuel consumption (oil, gas, coal) by less than 10% and the oil consumption in the transport sector has increased far more than the annual consumption substituted by nuclear energy in the electricity sector. Per capita oil consumption in France is higher than in Germany, Italy, the UK or in the EU27 on average.[365]

In 2008, the 59 French reactors[366] produced 76.2% of the electricity (down from 77.7% in 2003), although only about 55% of its installed electricity generating capacity is nuclear. Entirely unnoticed by the French public, the oldest French reactor was definitively taken off the grid in March 2009. Neither the operators EDF and CEA nor the government thought it was necessary to inform anybody of the fact that the last operating breeder reactor, once the technology of the future, was disconnected from the grid. A number of experiments are scheduled yet, before its final shutdown in November 2009.[367]

In other words, France has a huge overcapacity that led to dumping electricity on neighboring countries and stimulated the development of highly inefficient thermal-applications electricity. A historical winter peak-load of 92 GW is to be compared with an installed capacity of over 120 GW. Even a comfortable 20% reserve leaves a theoretical overcapacity, which is the equivalent of 20 of the 34 units of 900 MW. No wonder that the equivalent of about 10 reactors operate for export and France still remains the only country in the world that operates over 40 units on load-following mode.

On the other hand, the electricity seasonal peak-load has exploded since the middle of the 1980s, mainly due to the widespread introduction of electric space and water heating. Roughly a quarter of French households heat with electricity, the most wasteful form of heat generation (because it results in the loss of most of the primary energy in the transformation, transport and distribution process). The difference between the lowest load day in summer and the highest load day in winter is now over 60 GW. That is a very inefficient load curve, since significant capacities have to be made available for very short periods of time in winter. This type of consumption is not covered by nuclear power but either by fossil fuel plants or by expensive peak-load power imports. In 2008, France imported 19 TWh peak power from Germany for an unknown but probably high price. As a

[363] TVO, "Construction of a Nuclear Power Plant Unit at Olkiluoto – General Description – OL4", August 2008.

[364] Ministry of Employment and the Economy, "Application to the MEE for a desion-in-principle on expanding the spent nuclear fuel final disposal facility", Press Release, 13 March 2009.

[365] For a detailed analysis of the French energy sector see Mycle Schneider, "Nuclear Power in France – Beyond the Myth", commissioned by the Greens-EFA Group in the European Parliament, Brussels, December 2008; http://www.greens-efa.org/cms/topics/rubrik/6/6659.energy@en.htm .

[366] Essentially pressurized water reactors, 34 x 900 MW, 20 x 1300 MW and 4 x 1400 MW plus one 35-year-old 250 MW fast breeder reactor (Phénix, Marcoule) planned to be shut down later in 2009.

[367] ASN-Division Marseille, "L'Autorité de sûreté nucléaire et l'état de la sûreté nucléaire et de la radioprotection en Languedoc-Roussillon en 2008", undated.

consequence, the national utility EDF (Electricité de France) decided to reactivate 2,600 MW of very old oil-fired power plants – the oldest one had originally been started up in 1968 – in order to cope with the peak load phenomenon.

Today, per capita electricity consumption in France is over 25% higher than in Italy (which phased out nuclear energy after the Chernobyl accident in 1986) and 15% higher than the EU27 average. French per capita primary energy consumption is also significantly higher than, for example, in Germany.

Considering the existing overcapacities and the average age of about 25 years of its nuclear power plants, France does not need to build any new units for a long time. Other factors equally play in that direction:

- The energy establishment has admitted privately for years that the country has gone too far with its nuclear share in the overall power mix and that in the future, the nuclear contribution should not exceed some 60% of the power production.
- It is inconceivable that France will build new reactors with the sole aim of exporting power. That would be far too expensive especially in a liberalized energy market.
- EDF is intending to operate its reactors now for at least 40 years.
- AREVA is in the course of starting up a centrifuge enrichment plant at Tricastin that replaces the old gaseous diffusion plant. That will save the power generation equivalent to the output of three 900 MW reactors.
- Many plants that will be shut down should not be replaced but made redundant.

Therefore it will be many years, if not decades, before capacity constraints require new base load power plants in France. If the French government and EDF have decided to go ahead with the construction of a new unit, then this is because the nuclear industry faces a serious problem of maintaining competence in the field (see chapter II).

In December 2007 EDF started construction of Flamanville-3. The FL3 construction site encountered problems of quality control on basic concrete and steel issues similar to those at the OL3 project that started two and a half years earlier. After repeated incidents in May 2008 the French Safety Authority (ASN) stopped the concreting on the site for several weeks. By the end of September 2008, ASN still considered the organization "perfectible". ASN inspectors had discovered that the documentation on welding "does not allow the justification of conformity with the referential".[368]

At the end of October 2008 the nuclear safety authorities identified quality control problems at the builder AREVA. The Italian AREVA sub-contractor Società delle Fucine had not applied the obligatory fabrication procedures. In May 2009 ASN rejected two out of three Società delle Fucine pressurizer forgings, which now have to be remanufactured.

Finally, the problems are not only linked to the reactor project itself. The existing high power lines would not be sufficient to export the electricity from the new plant. An additional line is in the planning process and has encountered massive local opposition.

The two companies EDF and AREVA are in fierce competition to bring the first EPR online. EDF did not appreciate AREVA's offering the Olkiluoto project as a turnkey facility, because for all previous reactor projects EDF was responsible for overall construction oversight and AREVA's role remained limited to manufacturing. In an unprecedented move, EDF felt obliged to put out a press release claiming that the Flamanville project is still on schedule, thus providing a firm rebuttal of a statement by AREVA CEO Anne Lauvergeon who had stated in a radio interview that the project would be one year behind schedule.[369] ASN sources claimed in May 2009 that Flamanville and Olkiluoto were merely several months apart.

[368] ASN, Letter to Director of Flamanville-3 construction project, 30 September 2008.
[369] EDF, Press Release, 12 November 2008.

France also operates a large number of other nuclear facilities including uranium conversion and enrichment, fuel fabrication and plutonium facilities. France and the UK are the only countries in the EU that separate plutonium from spent fuel, a procedure called reprocessing. France's two La Hague facilities are licensed to process 1,700 t of fuel per year. However, all the significant foreign clients have finished their contracts and have turned away from plutonium separation. The La Hague operator AREVA NC therefore entirely depends on the domestic client EDF for future business. In late 2008 both companies signed a long-term agreement for reprocessing and fabrication of MOX fuel until 2040.

Germany operates 17 reactors that, according to the IAEA, provide 28.3% of the electricity in the country. However, the IAEA apparently takes into account only public electricity generation. German official sources indicate a nuclear share in the gross national power generation of only 23.3%, in decline since 1997 when the nuclear share stood at 30%.[370]

In 2002 the Parliament voted a nuclear phase out law that stipulates that the nuclear power plants in the country have to be shut down after an average lifetime of about 32 years. However, the utilities had a total "nuclear electricity generating budget" of 2,623 billion kWh (corresponding to the annual world nuclear power production) and can transfer remaining kWh from one reactor to another unit. Two units have already been shut down under the phase-out law (Stade, Obrigheim). A third unit (Mülheim-Kärlich) that had been under long-term shutdown since 1988 has been closed for good. The construction of new nuclear plants and spent fuel reprocessing (beyond quantities of fuel shipped to reprocessing plants until 30 June 2005) is prohibited.

After a significant crisis in the nuclear utility sector following a number of incidents at the Brunsbüttel and Krümmel plants in June 2007, three top managers of the operator Vattenfall were sacked and the units underwent extensive reviews and upgrading. While Brunsbüttel was still off line as of July 2009, the attempt to restart Krümmel in early July 2009 failed due to new incidents.

Two other units have been shut down (Biblis A and B) since the beginning of 2007 "for maintenance". While Biblis-B restarted on 1 December 2007, Biblis-A remained shut down until February 2008. It is speculated that the operator RWE has been prolonging the outage in order to push the planned final shutdown date of unit A beyond the next federal elections, scheduled for September 2009, in the hope that a pro-nuclear government will overrule current phase-out legislation.

The previously mentioned incident in July 2009 and further events at the Krümmel plant near Hamburg triggered not only safety concerns but also anger about the operator Vattenfall amongst the population and politicians of all backgrounds. Although the technical problems (short-circuit in transformer, fuel cladding failure) did not directly put into jeopardy the control of the reactor, the impression that the operator simply does not master the facility in spite of the replacement of the manager, has grown. An opinion poll showed that almost three quarters of the people polled were in favor of the immediate closure of *all* older German nuclear power plants.[371]

The current "grand coalition" government between Christian Democrats and Social Democrats has confirmed the phase-out legislation. While the Social Democrats have repeatedly reconfirmed their commitment to the nuclear phase-out, the Christian Democrats are in favor of lifetime extension of existing reactors but they are also opposed to the construction of new nuclear plants.[372] According to the phase-out legislation and under current planning, the remaining 17 units will be shut down between 2010 and 2022. Within the next legislative period, which ends in 2013, seven reactors will have to close.

---

370 AG Energiebilanzen, "Energieverbrauch in Deutschland im Jahr 2008", 20 February 2009.

371 According to an Emnid-Poll commissioned by "Bild am Sonntag" 72 % of the people polled were in favor of the immediate shutdown of older nuclear power plants; Bild am Sonntag, 12 July 2009.

372 CDU Secretary General has reconfirmed that position in February 2009; see CDU, "Wir wollen die Laufzeiten verlängern", 25 February 2009, www.cdu.de/archiv/2370_25720.htm ; accessed 24 May 2009.

While the nuclear lobby has not abandoned hopes of overturning the phase-out decision, no utility would be willing to order a new plant. However, German utilities have demonstrated interest in investing in foreign projects, for example in France, the UK and Eastern Europe.

In a generally hostile public environment, nuclear power has no future in Germany. An April 2009 opinion survey commissioned by the Federal Environment Ministry showed that 35% wish to accelerate the nuclear phase-out (+6% since 2005) while 31% agree to the current plan and 12% want nuclear power to be abandoned at a slower pace. Only 18% (same as in 2005) think that Germany should not abandon nuclear power.[373]

The **Netherlands** operates a single, 36 year old 480 MW plant that provides 3.8% of the country's power. The original political decision to close down the reactor by 2004 was successfully overturned in the courts by the operator. In June 2006 an agreement was reached between the operator and government that would allow operation of the reactor up to 2033 under certain conditions. "It would be maintained to the highest safety standards, and the stakeholders, Delta and Essent, agreed to donate EUR250 million towards sustainable energy projects. The government added another EUR250 million, in the process avoiding the compensation claim it would have faced had it continued towards early shutdown."[374]

In early 2004, the 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. EPZ pays the French EDF instead to get rid of it.

Spain operates eight reactors that provide 18.3% (down from 23.6% in 2003) of the electricity in the country. Beyond the de-facto moratorium that has been in place for many years, the current Spanish Premier Jose Luis Zapatero made the nuclear phase out a part of his key government goals. Zapatero announced at his swearing-in ceremony in April 2004 that his government would "gradually abandon" nuclear energy while increasing funding for renewable energy in an effort to reduce greenhouse gas emissions, in accordance with the Kyoto protocol. The first unit (José Cabrera) was shut down at the end of 2006. Zapatero has confirmed the nuclear phase-out goal since his reelection in 2008 and Industry Minister Miguel Sebastian stated: "There will be no new nuclear plants."[375] However, the Spanish Nuclear Safety Council (CSN) is currently reviewing potential lifetime extensions for existing facilities. The licenses of seven units will run out within Zapatero's current term. On 5 July 2009 the Spanish government extended the operating license of the Garoña plant until 2013, while the safety authorities had approved an extension up to 2019.

The current government intends to put energy conservation first. "Saving 20 percent would be the equivalent of doubling the number of nuclear power plants. It seems easier and cheaper to me," Miguel Sebastian said. "Furthermore, it (saving) is immediate, whereas nuclear plants take 15 years. There is no controversy, no waste or security problems, nothing," he added.[376] In addition, in recent years Spain has turned into the world's second largest operator of solar power capacity[377] and the third largest of wind power.

Sweden operates 10 reactors that provide 42% (down from 50% in 2003) of the electricity. Sweden has one of the highest per capita power consumptions in the world. The main origin of this high consumption level is the widespread, very inefficient thermal uses of electricity. Electric space heating and domestic hot water use represent about a quarter of the country's power consumption.

[373] FORSA, "Meinungen zum Ausstieg aus der Atomkraft", 23 April 2009.
[374] At http://www.world-nuclear.org/info/inf107.html .
[375] Reuters, "Spain insists on energy saving, not nuclear plants", 21 January 2009.
[376] Ibidem.
[377] Spain has connected to the grid 2,600 MW in 2008 alone, which is equivalent to the total installed grid connected photovoltaic capacity added that year in the rest of the world; see REN21, "Renewables Global Status Report – 2009 Update", Paris, 2009.

Sweden decided in a 1980 referendum to phase out nuclear power by 2010. The referendum was a somewhat strange initiative since it took place when only six out of a program of 12 reactors were operating; the other six were still under construction. It was therefore a "program limitation" rather than a "phase-out" referendum. Following the Chernobyl accident, Sweden pledged to phase out two units by 1995-6, but this early phase out was abandoned in early 1991. The country 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: start the phase-out earlier but give up the 2010 deadline. Therefore 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 conservative coalition government parties signed an agreement on energy and climate policy that defines some ambitious renewable energy and energy efficiency targets. The agreement calls for the Nuclear Phase-Out Act to be scrapped and the prohibition on the construction of new nuclear power plants to be lifted. However, the implementation of the agreement implies fulfilling a number of significant conditions[378]:

- The coalition parties only have a small 178/171 majority in parliament but need to change legislation in order to allow new nuclear construction. The opposition parties, Social Democrats, Green Party and Left Party remain firmly opposed to nuclear power and the 2010 elections could bring the pro-nuclear coalition parties back to square one.
- New plants can only be built once an existing plant is shut down. The maximum number of operating units thus shall not exceed ten as currently.
- "Central government support for nuclear power, in the form of direct or indirect subsidies, cannot be assumed."
- The liability limits will be raised so that "reactor owners must take greater responsibility for the risks of nuclear power".
- Ambitious targets for 2020 include 50% renewables in the primary energy balance, the increase of efficiency by 20% and the annual generation of 30 TWh wind power. That leaves very little or no space for new nuclear power.

The **United Kingdom** operates 19 reactors (4 less than in 2003) that provide 13.4% (down from 22% in 2003) of the country's electricity. The first generation plants, the Magnox reactors, of which there were 11 stations have mostly been retired and the last two stations will close in the next year or two. The seven second-generation stations, the Advanced Gas-cooled Reactors (AGR) are also near or at the end of their design life, although the owners now hope to extend their life to 40 years so that the plants would be retired in the period 2016-2029. 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 the safety case can be made. The newest plant is a Westinghouse PWR, completed in 1995.

The UK nuclear industry has gone through troublesome decades. Ever since Margaret Thatcher failed in the first attempt at privatization in the late 1980s when the nuclear kWh turned out to be twice as expensive as the market price for electricity, nuclear utilities and fuel industries have moved between scandal and virtual bankruptcy. In September 2004, the European Commission accepted that a UK Government €11 billion restructuring package (for example, it took over the decommissioning liability) to stop the privately owned nuclear generator British Energy from going into liquidation was state aid but did not distort markets. 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 into the physical 'assets' which were passed to a new agency, the Nuclear Decommissioning Authority (NDA), while the capabilities were privatized, for example, the reactor design and fuel manufacture division (mainly based on the Westinghouse nuclear division acquired in 1998) was re-privatized as Westinghouse and sold to Toshiba. The European Commission again accepted that this was state aid (the liabilities of the technology

[378] Regeringskansliet, "A sustainable energy and climate policy for the environment, competitiveness and long-term stability", 5 February 2009.

divisions were being taken over by government) but this did not distort competition. The NDA is now responsible for decommissioning all Britain's civil nuclear facilities except those owned by British Energy, a liability estimated in 2007/08 to be in excess of £63bn (compared to £51bn a year earlier).[379] The NDA inherited negligible funds for this task, relying partly, and increasingly, on grants from the Treasury and partly on income from the facilities still in operation, including the two Magnox stations, the THORP reprocessing and the SMP plutonium fuel manufacturing plants. However, both of the latter facilities have been plagued by a number of very serious technical problems that kept their operation significantly below expectations. A leak discovered at one of the accountancy tanks at the THORP facility in April 2005 that had gone unnoticed for about eight months resulted in a spill on the floor of a building of over 80 m^3 of dissolved fuel containing some 22 tons of uranium and 200 kg of plutonium. After two and a half years the plant has only reprocessed a test batch of 33 tons and a significant part of the plant remains closed. Another leak detected at one of the evaporators in May 2009 could lead to the long-term or even permanent closure of the plant.[380]

The Sellafield MOX Plant or SMP has fared even worse. Since the plant opened in 2002, the plant has produced a total of only 6.3t of mixed-oxide fuel. Its original annual production rate was reported to be 120t.[381]

In 2004 the nuclear lobby in the UK launched a major initiative, widely reflected in the media, in order to keep the nuclear option open. However, key government ministers rebutted the claims in an unusually clear manner. "Building nuclear power stations would risk landing future generations with 'difficult' legacies", then Environment Secretary, Margaret Beckett, stated.[382]

However, in 2006, Tony Blair stated that "nuclear power is back on the agenda with a vengeance",[383] and the current Brown government seems to be willing to support the nuclear option. After Greenpeace's legal challenge successfully undermined a first public consultation procedure over the future of nuclear power in the UK, a second consultation ended on 10 October 2007. However, it was considered equally inappropriate by a number of environmental and consumer organizations, and Greenpeace filed an official complaint over the conduct of the process with the Market Research Standards Board (MRSB), following its withdrawal along with other NGOs from the consultation a month earlier.[384] The government is being accused in particular of having made up its mind prior to the consultation process, essentially turning it into a farce, and of distributing factually erroneous information.

A confidential draft memo on energy policy for the Prime Minister by the Secretary of State for Business, Enterprise and Regulatory Reform curiously identified renewable energies as a threat to the development of nuclear power through the weakening of the European emissions trading scheme: "[Meeting the 20% renewables target] crucially undermines the scheme's credibility ... and reduces the incentives to invest in other low carbon technologies like nuclear power", say the papers.[385]

In March 2006 the UK Government's Sustainable Development Commission issued its report on nuclear energy and came up with the following conclusion[386]:

---

[379] At http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=21824 .

[380] CORE, "THORP – Living on a knife-edge. Future hopes evaporating fast", 18 May 2009.

[381] Nuclear Engineering International, "Official figures show scale of Sellafield MOX Plant losses", May 2009.

[382] The Observer, 19 September 2004.

[383] When Tony Blair announced the new nuclear program in the UK in May 2006, he stated: "These facts put the replacement of nuclear power stations, a big push on renewables and a step change on energy efficiency, engaging both business and consumers, back on the agenda with a vengeance." See "Blair Presses the Nuclear Button," The Guardian, 17 May 2006; http://www.guardian.co.uk/environment/2006/may/17/energy.business .

[384] At http://www.greenconsumerguide.com/index.php?news=3545 .

[385] The Guardian, 23 October 2007.

[386] Sustainable Development Commission, "Is Nuclear the Answer?", London, March 2006.

> The majority of members of the Commission believe that, given sufficient drive and support, a nonnuclear strategy could and should be sufficient to deliver all the carbon savings we shall need up to 2050 and beyond, and to ensure secure access to reliable sources of energy.
>
> The relatively small contribution that a new nuclear power programme would make to addressing these challenges (even if we were to double our existing nuclear capacity, this would give an 8% cut on total emissions from 1990 levels by 2035, and would contribute next to nothing before 2020) simply doesn't justify the substantial disbenefits and costs that would be entailed in such a programme.

Two years later the Brown government started to organize the new build programme. In April 2009 the NDA auctioned off the first pieces of land earmarked for the construction of new reactors. French utility EDF[387] and German companies E.ON and RWE were amongst the buyers. By May 2009 EDF[388] had issued prequalification questionnaires to a number of firms for preparatory and civil works contracts.[389] While EDF would propose the EPR model, RWE is in negotiations with Westinghouse over the construction of up to three AP1000 in North Wales starting in 2013. Westinghouse estimates that between 70% and 80% of the work and services for AP1000 construction could by provided by the UK supply chain.[390] Considering the dramatic situation of nuclear and general engineering education in the UK (see chapter II.), this seems very optimistic.

Between the middle of April and the middle of May 2009 the UK population was invited to submit comments on the pre-selection of 11 proposed sites for potential new nuclear reactors (five of which belong to EDF Energy).[391] The Government's National Policy Statement (NPS) on those proposed sites is scheduled for autumn 2009.

Public opinion remains split in the UK and while, in a 2007 European Commission sponsored poll, 36% were in favour of increasing the share of nuclear energy in the EU 57% were in favour of decreasing the role of nuclear power.[392] Meanwhile, an action group has been set up to fight plans to build a new plant at Layriggs Farm in Kirksanton. A private vote carried out by campaigners found that 90% of villagers said they would leave Kirksanton if the nuclear power station were built.[393]

A key plank of the government's nuclear policy was its commitment that new nuclear power plants would not need or be given subsidies, a claim that the utilities did not initially dispute. However, as estimated costs escalate, EDF was the first utility to break ranks suggesting that a minimum carbon price would be required and also that targets for renewables would have to be reduced to allow nuclear plants to stay on base-load.[394]

The only Non-EU Western European country that operates nuclear power plants is **Switzerland**. It operates five reactors that cover 39.2% of the country's electricity consumption. In 2001 the resentment against nuclear power was at an all time high with 75% of the Swiss people responding "no" to the question "is nuclear power acceptable?"[395] In 2003 a majority of people rejected nevertheless two far-reaching motions against the further use of nuclear power. Switzerland is the only nuclear country that repeatedly undertakes referenda over the future of nuclear power. While

[387] As early as 2006 EDF hired a powerful ally, Andrew Brown, the Prime Minister's younger brother, who, as of May 2009, acts as press officer for EDF Energy.

[388] Platt's David Stellfox in a February 2009, Washington DC presentation, put it this way: "How to resurrect a flagging nuclear industry quickly – give it to the French!"

[389] Contract Journal, "Ten firms in race for £700m nuclear civils packages", 20 May 2009.

[390] WNN, "Westinghouse gets set for UK construction", 5 September 2008.

[391] Not all contenders stayed in the race. When land prices went through the roof, a group comprising Iberdrola SA, GDF Suez SA and Scottish & Southern Energy Plc dropped out of the bidding process; see Bloomberg, "Iberdrola Group Pulls Out of UK Nuclear Bidding, FT Reports", 28 April 2009.

[392] Gallup, "Attitudes on issues related to EU Energy Policy", European Commission, DG TREN, April 2007.

[393] North-West Evening Mail, "Nuclear Row – Residents will quit village", 26 March 2009.

[394] Financial Times, "EDF calls for support for nuclear industry", 25 May 2009.

[395] Conrad U. Brunner, "Democratic Decision-Making in Switzerland: Referenda for a Nuclear Phase-Out, in "Rethinking Nuclear Energy after September 11, 2001", Global Health Watch, IPPNW, September 2004.

the phase-out option never gained a sufficient majority, the referenda have maintained an effective moratorium on any new project over long periods of time. Currently, the nuclear operators have initiated a debate over the potential replacement of the country's aging nuclear power plants. However, there are no short-term prospects for any new nuclear plants in Switzerland. Long-term observer Conrad Brunner notes that utilities that in spring 2008 have introduced proposals for new nuclear power plants are "in for a long fight because neither the site decision is clear (…) nor the economy of nuclear energy in the light of the Finnish example is clear".[396]

IV.4.2. Nuclear Power in Central and Eastern Europe

In **Bulgaria** in 2008 nuclear power provided 32.9% of the country's electricity. This is 10% down from the 2006 level as of December of that year. To fulfill the conditions for entry into the EU, the second two blocks of the Kozloduy power plant were closed. This follows the closure of the first two units at the end of 2002. The agreement for the closure of the four VVER 440-230 designed reactors, along with deals for similar vintage reactors in Lithuania and Slovakia, was made in 1999. Bulgaria received €550 million from the EU as compensation for the closure. Two VVER 1000 reactors remain in operation at the Kozloduy site. In 2003 the Government announced its intention to restart construction at the Belene site in Northern Bulgaria. Construction of a reactor began in 1985 but following the political changes in 1989 construction was suspended and formally stopped in 1992, in part due to concerns about the geological stability of the site. In 2004 a call for tender for the completion of the 2000 MW of nuclear capacity was made and seven firms initially expressed an interest. However, all but two proposals, those involving the original VVER design, one led by Skoda and one by Atomstroyexport (ASE) of Russia, were withdrawn. In October 2006 the ASE consortium, involving the French nuclear constructor AREVA and Bulgarian firms, was awarded the €4 billion contract.

Controversy remains over the completion of the Environmental Impact Assessment (EIA), which it is claimed does not contain adequate information on the seismic conditions, nor does it address the possibility of beyond design base accidents or give details of the potential impacts of decommissioning[397]. Furthermore, following a legal action by environmental groups the authors of the original EIA confirmed, in court, that it was flawed and that it would require a new EIA once a design and builder were appointed[398]. In February 2007 the Bulgarian authorities informed the European Commission – as they are required to do under the Euratom Treaty – of the construction plans.

A Belene construction consortium has been established in which the State utility **Natsionalna Elektricheska Kompania** (NEK) will retain overall control, with 51%, with the remaining shares having been put to tender. In late 2008 German utility RWE was announced as the strategic investor with a requirement to put up €1.275 billion as well as provide an €300 million loan in advance. This led to the formation of the Belene Power Company in December 2008 as a joint venture. However, press reports suggest that RWE is unwilling to inject funds into the project prior to its completion, leading to a request for additional finance for the project from Russia[399].

The new Bulgarian government that was voted into office in July 2009 might scrap the Belene project altogether. Deputy Prime Minister Simeon Djankov, a former chief economist at the World Bank who is also the new finance minister, declared that "there is an 80 percent chance that the Belene project will be stopped".[400]

---

[396] Conrad Brunner, "Switzerland – What's Left from the Glaciers in the Alps", in Lutz Mez, Mycle Schneider & Steve Thomas (eds), "International Perspectives on Energy Policy and the Role of Nuclear Power", Multi-Science Publishing, Brentwood, 2009.

[397] Jan Haverkamp, "Comments on the non-technical summary of the EIA report of the Investment Proposal of the Belene Nuclear Power Plant", Greenpeace, June 2004.

[398] Answers of the EIA team on question 29 by NGOs and citizens during the hearings on the Framework of the EIA for Belene, 2004.

[399] Novinite, "Russia to Temporarily Finance Bulgaria Nuclear Plant Belene", 24 March 2009; http://www.novinite.com/view_news.php?id=102206 .

[400] Bloomberg, "Bulgaria May Cancel Nuclear-Plant Project, Sell Utility Shares", 31 July 2009.

The **Czech Republic** has six Russian designed reactors in operation at two sites, Dukovany and Temelin. The former houses four VVER 440-213 reactors, while the latter two VVER 1000-320 units. Between them they produce 32.5% of the country's electricity. The State utility CEZ has become a major importer and exporter of electricity and in 2007 it had a net export of around 16 TWh (physical exchange), with significant exports to Austria, Germany and Slovakia[401]. This represents about two thirds of the nuclear generated electricity.

The Temelin nuclear power plant was the focus of considerable controversy since a decision was taken to restart construction in the mid 1990s after construction was halted in 1989. The two reactors were eventually started in 2000 and 2002, with the financial assistance of the US Export-Import Bank and instrument and control technology supplied by Westinghouse. The involvement of Westinghouse at a relatively late stage of construction caused additional technical problems, leading to delays and cost over-runs. The International Energy Agency has suggested that "despite low operating costs, amortizing Temelin's costs (total cost: CZK99 billion [$€_{2001}$ 3.1 billion], plus CZK10 billion [$€_{2001}$ 313 million] of unamortized interest) will create a significant financial burden for CEZ".[402]

Even after the reactors began operating the controversy did not stop, as technical problems, especially those relating to the uniquely large turbines, have caused a number of unplanned outages. The turbine problems as well as additional difficulties over the deformation of the fuel elements have resulted in lower lifetime plant availability. In 2007, unit 1 had a capacity factor of 64% and unit 2, 74%, compared to a global average of 82%.

In July 2008 CEZ announced a plan to build two more reactors at Temelin, with construction to start in 2013 and commissioning the first unit in 2020. However, planning is vague at best, at this point. The Czech government is split on the nuclear question, the industry minister favoring nuclear power and the Green Party chairman and minister of the environment opposing nuclear power.

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%. It is envisaged by the operators that the power plant will continue operating until 2025.

There is one nuclear power plant operating in **Hungary** at Paks, which houses four VVER 440-213 reactors providing 37.2% of the country's electricity. The reactors started commercial operation in the early 1980s and have been the subject of engineering works to make possible their operation for up to 50 years accompanied by a 20% increase in capacity. In April 2003 the second reactor at the site experienced the country's worst ever nuclear accident, rated on the International Nuclear Event Scale (INES) as a "serious incident", which resulted in the evacuation of the main reactor hall and the venting of radioactivity into the outside environment. It later transpired that the accident was caused by inadequate cooling of the fuel rods during cleaning in a special container, leading to their overheating and the damage of the majority of the 30 fuel elements. The reactor was out of operation for 18 months.

In 1998 the operator of Paks proposed building additional nuclear capacity, but this was rejected by the national utility MVM. However, in March 2009 the Parliament approved the Government proposal for the construction of additional reactors that would double the capacity of Paks. No industrial plans or projections are known at this point and financing remains a key issue.

The Ignalina nuclear power plant in **Lithuania** is the only RBMK design still in operation outside Russia. Given the impact that the Chernobyl accident had across Western Europe, it is remarkable that a similar design of reactor has been allowed to operate within the European Union. As part of

---

[401] UCTE 2007: Physical electricity exchange of UCTE countries, http://www.ucte.org/_library/statsexchange/e_exchanges_2007.pdf .

[402] International Energy Agency, 'Energy Policies in IEA Countries, Country Review - Czech Republic', IEA 2001.

the accession agreement the remaining unit has to close by the end of 2009. The first unit was closed in 2004. The justification for the long phase-out was the country's dependency on the stations. Even after the closure of unit one in 2004, the power station was still responsible for over 72.9% of the country's electricity in 2008. This is because the power station is far too large for the country's relatively small demand, as prior to the political changes in 1992 it provided electricity mainly to Russia. The dependency on one reactor for such a large percentage of electricity would be highly risky from a security of supply perspective. In reality the country always had a very large, up to over 250%, overcapacity. Therefore the replacement of the Ignalina plant has always been more a political than a technical issue.

In February 2007 the Governments of the three **Baltic States** and **Poland** agreed in principle to build a new nuclear power plant at Ignalina. A parliamentary bill was passed in Lithuania in July 2007 calling for its 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. The latest, published in January 2009, calls for the construction of only one reactor, under the management of a Lithuanian government-controlled company LEO Lt. In March 2009 the Lithuanian President Valdas Adamkus stated that work on the new plant would get underway before the end of 2009 and possibly as early as the autumn. "By May we will have a business plan. By the fall we can probably start work on digging the ground", Adamkus said.[403] In 2007 the Lithuanian government formed a national company LEO LT to finance the project together with the other Baltic States and Poland. However, energy minister Arvydas Sekmokas stated: "I doubt LEO LT is capable of building the plant. None of the four countries involved have expertise to do so; therefore we need to get the strategic investor."[404] Considering the fact that by the end of May 2009 neither a strategic investor nor a call for tender had been announced and that financing issues have remained entirely in the dark, the start of the project in the short term is highly unlikely.

The Cernavoda nuclear power plant in **Romania** hosts the only Candu (Canadian designed) reactors in Europe. In 2008 they provided 17.5% of the electricity in the country. The power plant was started under the regime of Nicolae Ceausescu and initially was to house five units. Construction was started 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. Eventually this was completed in 1996 at an estimated cost of around US$2.2 billion and nearly a decade late. The second unit, also completed with foreign financial assistance, a $140 million Canadian loan and a €223 million Euratom loan, was connected to the grid in August 2007 - after 27 years of construction. Plans are being actively developed to complete two additional units at the power plant. Bids have been solicited to create an independent power producer between the utility, SNN, which will complete and provide operation and maintenance, and a private investor. In 2008, following protracted negotiations, the government decided that SNN would take 51% equity and provide funding of €1 billion in loans and loan guarantees. Other funds would be internal and from partial privatizing of SNN in 2011. In November 2008 an investment agreement was signed between SNN and ENEL (Italy), CEZ (Czech Republic), GDF Suez (France), RWE Power (Germany) each holding 9.15%, Iberdrola (Spain) and ArcelorMittal Galati (Romania) both having 6.2%. Initially, commissioning of unit 3 was due in October 2014 and unit 4 in mid 2015. However, this has now been revised and the first unit is not expected to be completed until 2016 at the earliest.

The state utility Slovenske Elektrarne (SE) operates all the nuclear power plants in **Slovakia** at two sites: Bohunice, which houses two VVER 440 units, and Mochovce, which operates two similar reactors. There were two other reactors at Bohunice but these were the older VVER 440 230 design and were closed in 2006 and 2008 as part of the EU accession partnership agreement. The

[403] Earth Times, "Lithuanian president says work on nuclear plant to begin 2009", 27 March 2009.
[404] Reuters, "Lithuania to seek strategic investor for n-plant", 12 March 2009

remaining units were subject to engineering works to extend their operating lives to 40 years, which would enable the station to operate until 2025.

The Mochovce units were completed in 1998 and 1999. They were to have been the first reactors to receive funding from the European Bank for Reconstruction and Development (EBRD) in 1995. However in the week before a, expected to be, positive decision by the Bank's board of directors, the Slovakian authorities withdrew the loan application. It was said that the withdrawal was due to the financial conditions and overall price of the project (€1.2 billion). At the time the Slovak Government said it would be completed at a lower cost using solely Russian and Slovak engineering. The reactors were officially 90% and 75% complete and the new completion cost was said to be on the order of €800 million. However, when finally completed the cost was estimated to be around double that amount.

In October 2004 the Italian utility ENEL acquired 66% of SE. As part of its bid ENEL proposed to invest nearly €2 billion in new generating capacity, including the completion of the third and fourth blocks of Mochovce. In February 2007, SE announced that it was proceeding with the completion of these units and that ENEL had agreed to invest €1.8 billion. Although the European Commission gave its permission for construction to restart in July 2008, it noted that the reactor did not have a "full containment" structure which is used in the most recent construction of nuclear power plants planned or under way in Europe and they requested that the investor and national authorities implement additional features to withstand an impact from a small aircraft[405].

Despite pressure from the Slovak Government it took until June 2009 to reactivate construction. The two units are now scheduled for completion in 2012 and 2013 respectively.

The Krsko nuclear power plant in **Slovenia** is the world's first reactor to be jointly owned by two countries – Croatia and Slovenia. The reactor is a 700 MW Westinghouse PWR and was ordered by the former Yugoslavia and provided 41.7% of Slovenia's electricity in 2008. It was connected to the grid in 1981 and is due to operate until 2021. The output is shared between the two countries. Discussions remain ongoing for the potential construction of a second reactor at the site without any short-term perspective.

IV.5. Russia and the Former Soviet Union

Armenia has one remaining reactor (Armenia-2) at the Medzamor nuclear power plant, which is situated within 30 km of the capital Yerevan. In 2008 it generated 39.4% of the country's power. The reactor is of early Soviet design, a VVER 440-230, and has raised considerable safety concerns. In 1995 a US Department of Energy document stated: "In the event of a serious accident, however, the reactor's lack of a containment and proximity to Yerevan could wreak havoc with the lives of millions[406]". Due to its proximity to the capital a referendum was held in 1988, which resulted in an agreement to close the then two operating VVER 440-230 reactors. In December 1988 Armenia suffered a major earthquake which killed around 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. This led to significant power shortages and in 1993 the Government decided to re-open Unit 2, the younger of the two units. The reactor is due to close in 2016. In September 2007 the Minister of Energy called for a new reactor to be built at Medzamor, with an anticipated construction cost of $2 billion and a construction time of four and a half years. More recently, in February 2009, the Government announced a tender to build a 1000 MW unit with an expected cost of around $5 billion.

[405] European Commission, "Commission issues its opinion on units 3 and 4 of the Slovak Nuclear Power Plant of Mochovce", IP/08/1143, 15 July 2008.
[406] DOE, "Most Dangerous Reactors - A worldwide compendium of reactor Risk", US Department of Energy, Office on Energy Intelligence, May 1995.

Kazakhstan had just one fast breeder reactor in operation at Aktau, the BN 350, which, in 1973, was the world's first commercial fast breeder reactor. It was closed down in 1999, having been used to generate power, heat and for desalination. There are a wide range of proposals for the further use of nuclear power, ranging from further breeder reactors, to larger light water reactors, to up to 20 smaller reactors deployed in towns across the country. The plans seem to mainly involve Russian or Japanese technology but have not turned into concrete projects.

However, Kazakhstan's main contribution to the global nuclear industry is its uranium production, as it has 15% of the world's reserves. Uranium production has increased rapidly in the last decade, from 795 tons in 1997 to 6,637 tons in 2007, with plans for 30 000 tons by 2018. In order to meet these objectives various co-operation agreements have been signed with companies and government agencies from amongst others, Canada, China, France, Japan and Russia. These agreements are not restricted to uranium supply but also involve enrichment and fuel fabrication.

There are 31 operating reactors in **Russia** with a total installed capacity of 21.7 GW. In 2008 the nuclear fleet generated 152 TWh, providing 16.9% of the country's electricity. The following reactors are in operation: 15 of the early design, four first generation VVER 440-230 and 11 RBMK reactors; four small (11 MW) BWRs used for cogeneration in Siberia; one fast breeder; and 11 second generation light water reactors (2 VVER 440-213 and 9 VVER 1000s). The average age of the reactors in operation is 27 years and only two have been completed in the last 10 years. The last reactor was completed in 2004 at Kalinin.

There are nine reactors officially under construction, of which three were started over 20 years ago (Volgodonsk 2 [1983]; Kursk 5 [1985] and Kalinin 4 [1986]). The other reactors include one fast breeder at Beloyask and two small PWRs (32 MW) – to be placed on barges. Two of the latest VVER 1200 reactors (the AEA 2006) are being built at Novovoronezh and Leningrad – where construction started in October 2008.

Over the years the Government has announced a number of plans for the expansion of the nuclear sector. For example the plan in 2000 was that by 2010 over 200 TWh of nuclear electricity would be generated. In October 2006 a US$55 billion nuclear energy development program was adopted. Nearly half of this proposed program, $26 billion, was to come from the Federal budget, with the rest coming from the industry. In September 2007 the Government announced plans for the construction of an additional 8 VVER 1200 by 2016 with further reactors to be built after this, leading to a doubling of installed capacity by 2020. It is anticipated that the construction of 2 GW per year of new reactors will start after 2009. However, the recent global economic situation is particularly affecting the Russian economy, due to the low price of oil and gas, and may once again lead to the delay or cancellation of a number of nuclear projects.

In addition to expansion plans, the Russian industry is proposing to extend the operating lives of existing reactors. In particular the RBMK reactors are now expected to operate for around 45 years.

Russia is constructing more reactors for export than it is for its domestic market, with sales of the latest design of the VVER 1000, the AES 91 and AES 92, in Bulgaria, China and India. A number of other reactor designs are being developed, including smaller 300 MW BWRs.

Russia has developed the whole nuclear fuel chain. Russian uranium resources are around 10% of the world's reasonably assured resources plus inferred resources according to the Nuclear Energy Agency, with the largest mines close to the Chinese/Mongolian border. Exploration expenditure has nearly doubled in two years to about US$ 52 million in 2008. Plans are also being proposed to develop mining reserves in a number of countries, through the formation of the Uranium Mining Company (UGRK) in conjunction with Kazakhstan, Uzbekistan and Mongolia. In September 2007 a deal was also signed with the Australian Government to import up to $1 billion worth of uranium per year. Joint ventures are also being developed for mining projects in Russia, such as with Japan's Mitsui & Co, and in February 2009 Rosnedra published a list of deposits to be offered for tender in 2009.

For many decades Russia has been involved in the supply of fresh fuel and the return of spent fuel to and from countries in Central and Eastern Europe. This practice has now largely ceased. Despite the intention to increase the reprocessing of nuclear fuel, only the VVER 440 fuel is reprocessed, with the VVER 1000 and RBMK fuel stored. The construction of the RT-2 plant at Krasnoyarsk, proposed for reprocessing of VVER 1000 fuel, was stopped. Furthermore, the RT-1 reprocessing lines at Mayak for the VVER 440 fuel are now operating at only one third capacity due to the loss of foreign contracts.

Ukraine has fifteen reactors in operation providing 47.4% of the country's electricity in 2008. The accident at Chernobyl in 1986 not only did huge damage to the country's economy, environment and public health, but it also stopped the development of nuclear power. This situation was further exacerbated when there was another accident at the Chernobyl station, in unit 2 in 1991. Since then the two remaining units at Chernobyl have been closed and the station is now awaiting decommissioning.

Since 1986 three reactors have been completed, Zaporozhe 6, Khmelnitsky 2 and Rovno 4. The latter two units were initially planned to be completed using financing from the EBRD and Euratom, but the project was withdrawn at the last moment by the Ukrainian Government claiming that the costs and conditions for the loans were too high. The reactors were completed using Ukrainian and Russian resources, but both reactors were later the recipients of much smaller loans from both the EBRD and Euratom for 'post completion' upgrades.

In 2006 the Government approved a strategy that would lead to the doubling of nuclear installed capacity by 2030. This would require both the replacement of existing units (between 9 to 11 reactors totaling 10.5 GW) and a further 11 reactors for expanding capacity. The strategy envisages initially the completion of the third and four units at Khmelnitsky with work commencing in 2010. Despite their apparent completion status (75% and 28%) the reactors are not expected to be completed until 2016 and 2017. The majority (85%) of the funding for the completion project is expected to come from a Russian loan. Despite this an international tender was announced, but in the end only Atomstroyexport and Korea HNP submitted tenders. The contract is due to be signed in 2009.

The identification of the other projects in the expansion plan and the ordering of new construction are expected to start in 2010.

Ukraine has some uranium reserves and is undertaking mining activities, in particular at Zholtye Vody in the Dnepropetrovsk region. These activities provide about one third of the Ukrainian uranium needs. As of 1 January 2007 uranium resources, recovered at mining cost less than 40 USD/kgU. Further sites are under active exploration and development using domestic resources, although plans exist to boost these activities using foreign investment with an objective of production doubling to about 1500 t/year by 2013.

Annex 1: Status of Nuclear Power in the World (1st August 2009)

Countries	Nuclear Reactors[407]				Power[408]	Energy[409]
	Operate	Average Age	Under Construction[410]	Planned[411]	Share of Electricity[412]	Share of Commercial Primary Energy
Argentina	2	31	1	1	6%(=)	2%
Armenia	1	30	0	0	39%(–)	?%
Belgium	7	29	0	0	54%(=)	14%
Brazil	2	18	0	1	3%(=)	1%
Bulgaria	2	20	2	0	33%(=)	18%
Canada	18	26	0	3	15%(=)	6%
China	11	8	16	29	2%(=)	<1%
Czech Republic	6	18	0	0	32%(+)	14%
Finland	4	30	1	0	30%(=)	20%
France	58	24	1	1	76%(=)	39%
Germany	17	28	0	0	28%(=)[413]	11%
Hungary	4	24	0	0	37%(=)	14%
India	17	18	6	10	2%(=)	<1%
Iran	0	0	1	2	0%(=)	0%
Japan	53	24	2	13	25%(–)	11%
Lithuania	1	22	0	0	73%(+)	26%
Mexico	2	18	0	0	4%(=)	1%
Netherlands	1	36	0	0	4%(=)	1%
Pakistan	2	24	1	2	2%(=)	<1%
Romania	2	8	0	2	18%(+)	7%
Russia	31	27	9	7	17%(=)	5%
Slovakia	4	19	2	0	56%(+)	21%
Slovenia	1	28	0	0	42%(=)	?%
South Africa	2	25	0	3	5%(=)	2%
South Korea	20	17	5	7	36%(=)	14%
Spain	8	26	0	0	18%(=)	9%
Sweden	10	31	0	0	42%(–)	31%
Switzerland	5	34	0	0	39%(=)	21%
Taiwan	6	28	2	0	19%(=)	8%
Ukraine	15	21	2	0	47%(=)	16%
United Kingdom	19	28	0	0	13%(–)	6%
USA	104	30	1	11	20%(=)	8%
EU27	**144**	**25**	**6**	**3**	**28%(=)**	**12%**
Total	**435**	**25**	**52**	**93**	**ca. 14%**	**5.5%**

[407] According to IAEA PRIS August 2009, http://www.iaea.org/programmes/a2/index.html unless noted otherwise.
[408] In 2008, based on IAEA PRIS, May 2009.
[409] In 2008, according to BP, "Statistical Review of World Energy", June 2009.
[410] As of May 2009.
[411] Adapted from WNA; the WNA lists an addition 13 planned units in potential newcomer countries; see http://www.world-nuclear.org/info/reactors.html accessed on 28 May 2009.
[412] A +/-/= in brackets refer to change in 2008 versus the level in 2007; a change of less than 1% is considered =.
[413] German statistics (AG Energiebilanzen) give the share in the gross national power generation as only 23.3%.

Annex 2: Nuclear Reactors in the World Listed as "Under Construction" (1st August 2009)

Country	Units	MWe (net)	Construction Start	Planned Grid Connection
Argentina	1	692	1981/07/14	2010/10/01[414]
Bulgaria	2	1906		
...Belene-1		*953*	1987/01/01	2014[415]
...Belene-2		*953*	1987/03/31	2015[416]
China	16	15220		
...Fangjiashan-1		*1000*	2008/12/26	2013[417]
...Fangjiashan-2		*1000*	2009/07/17	2014[418]
...Fuqing-1		*1000*	2008/11/21	2013/10[419]
...Fuqing-2		*1000*	2009/06/17	2014/08[420]
...Hongyanhe-1		*1000*	2007/08/18	2012/10[421]
...Hongyanhe-2		*1000*	2008/03/28	2013[422]
...Hongyanhe-3		*1000*	2009/03/07	2014[423]
...Lingao-3		*1000*	2005/12/15	2010/08/31
...Lingao-4		*1000*	2006/06/15	2011/08[424]
...Ningde-1		*1000*	2008/02/18	2012[425]
...Ningde-2		*1000*	2008/11/12	2013[426]
...Qinshan-II-3		*610*	2006/03/28	2010/12/28
...Qinshan-II-4		*610*	2007/01/28	2011/09/28
...Sanmen-1		*1000*	2009/04/19	2013[427]
...Yangjiang-1		*1000*	2008/12/16	2013[428]
...Yangjiang-2		*1000*	2009/06/04	2014[429]
Finland	1	1600	2005/08/12	2012/06[430] (completion)
France	1	1600	2007/12/03	2012/05/01[431]
India	6	2910		
...Kaiga-4		*202*	2002/05/10	2009/11/30[432]
...Kudankulam-1		*917*	2002/03/31	2009/07/31[433]
...Kudankulam-2		*917*	2002/07/04	2010/04/30[434]
...PFBR		*470*	2004/10/23	2011[435]
...Rajasthan-5		*202*	2002/09/18	2009[436]
...Rajasthan-6		*202*	2003/01/20	2009/06/30[437]

Notes pertaining to Annex 2

414 Delayed multiple times. Most recent date published after January 2008.
415 Delayed multiple times, no IAEA start-up date, this estimate from: http://world-nuclear.org/info/inf87.html .
416 Delayed multiple times, no IAEA start-up date, this estimate from: http://world-nuclear.org/info/inf87.html .
417 No IAEA start-up date, this estimate from: http://www.world-nuclear.com/info/inf63.html .
418 No IAEA start-up date, this estimate from: http://www.world-nuclear.com/info/inf63.html .
419 No IAEA start-up date, this estimate from: http://www.world-nuclear.com/info/inf63.html .
420 No IAEA start-up date, this estimate from: http://www.world-nuclear.com/info/inf63.html .
421 No IAEA start-up date, this estimate from: http://www.world-nuclear.com/info/inf63.html .
422 No IAEA start-up date, this estimate derived from: http://www.world-nuclear.com/info/inf63.html .
423 No IAEA start-up date, this estimate derived from: http://www.world-nuclear.com/info/inf63.html .
424 No IAEA start-up date, this estimate from: http://www.world-nuclear.com/info/inf63.html .
425 No IAEA start-up date, this estimate derived from http://www.world-nuclear.com/info/inf63.html .
426 No IAEA start-up date, this estimate derived from http://www.world-nuclear.com/info/inf63.html .
427 No IAEA start-up date. Westinghouse planned grid connection. Source: Westinghouse, Press Release, 19 April 2009.
428 No IAEA start-up date, this estimate for commercial operation from http://www.world-nuclear.com/info/inf63.html .
429 No IAEA start-up date, this estimate derived from: http://www.world-nuclear.com/info/inf63.html .
430 After several revisions of the original planned commissioning in 2009, the date refers to the "completion" of the plant. Source: TVO, Press Release, 13 January 2009.
431 Delayed by 9 months, according to press reports. AREVA's CEO Anne Lauvergeon has claimed on public radio that the unit is one year behind schedule. EDF claims the project is on schedule.
432 Delayed again from planned start-up at 2007/07/31. Date delayed again in early 2009.
433 Delayed again from previous planned start-up in December 2007. Date delayed again in early 2009.
434 Delayed again from previous planned start-up in December 2008. Date delayed again in early 2009.
435 Delayed several times; no IAEA start-up date; this estimate for commercial operation from http://www.world-nuclear.org/info/inf53.html .
436 Delayed again from planned start-up at 2007/12/31, new date 2009/09/30 withdrawn in July 2009; no new IAEA date; retained date for modeling purposes only.
437 Delayed again from planned start-up at 2007/06/30. June 2009 date still on IAEA-list on 5 August 2009. Retained 2009 as start-up date for modeling purposes.

Country	Units	MWe (net)	Construction Start	Planned Grid Connection
Iran	1	915	1975/05/01	2009/09/01[438]
Japan	2	2191		
...Shimane		*1325*	2007/10/12[439]	2011/12/01
...Tomari		*866*	2004/11/18	2009/12/10[440]
Pakistan	1	300	2005/12/28	2011/05/31
Russia	9	6894		
...BN-800		*750*	1985[441]	2014 (commercial operation)[442]
...Kalinin-4		*950*	1986/08/01	2011[443]
...Kursk-5		*925*	1985/12/01	?[444]
...Leningrad-2-1		*1085*	2008/10/25	2013/10[445]
...Novovoronezh-2-1		*1085*	2008/06/24	2012/12/31 (commercial operation)[446]
...Novovoronezh-2-2		*1085*	2008/07/12	2014 (commercial operation)[447]
...Lomonosov-1		*32*	2007/04/15	2012/12/31 (commercial operation)[448]
...Lomonosov-2		*32*	2007/04/15	2012/12/31 (commercial operation)[449]
...Volgodonsk		*950*	1983/05/01	2010 (commercial operation)[450]
Slovakia	2	810		
...Mochovce-3		*405*	1985/01/01[451]	2012/09[453]
...Mochovce-4		*405*	1985/01/01[452]	2013[454]
South-Korea	5	5180		
...Shin-Kori-1		*960*	2006/06/16	2010/08/01
...Shin-Kori-2		*960*	2007/06/05	2011/08/01
...Shin-Kori-3		*1340*	2008/10/31	2013/09/30 (commercial operation)[455]
...Shin-Wolsong-1		*960*	2007/11/20	2011/05/28
...Shin-Wolsong-2		*960*	2008/09/23	2012/05/28
Taiwan	2	2600		
...Lungmen-1		*1300*	1999/03/31	2011[456]
...Lungmen-2		*1300*	1999/08/30	2010[457]
Ukraine	2	1900		
...Khmelnitski-3		*950*	1986/03/01	2015/01/01[458]
...Khmelnitski-4		*950*	1987/02/01	2016/01/01[459]
USA	1	1165	1972/12/01	2012/08/01
Total	52	45883		

 Sources: IAEA PRIS, May-August 2009, unless otherwise noted

438 Delayed again from planned start-up at 2007/11/01 as of January 2008.
439 This unit was added to the IAEA list only in October 2008.
440 Delayed slightly from planned start-up at 2009/12/01 as of January 2008.
441 The IAEA Power Reactor Information System (PRIS) curiously provides a new 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 start-up date "1985". In subsequent editions of the CEA's annual publication *ELECNUC, Nuclear Power Plants in the World*, the BN-800 had disappeared.
442 Delayed numerous times; no IAEA start-up date; this estimate from http://www.world-nuclear.com/info/inf29.html .
443 Delayed from planned start-up at 2010/12/31 as of end of 2007, no new IAEA date. This estimate from http://www.world-nuclear.org/info/inf45.html .
444 Delayed from planned start-up at 2010/12/31 as of end of 2007; no new IAEA date. Kursk-5 is based on an upgraded RBMK design and its completion seems highly uncertain. We have arbitrarily envisaged, for modeling purposes only, that it starts in 2012.
445 No IAEA start-up date; this estimate for commercial operation from http://www.world-nuclear.org/info/inf45.html .
446 Commercial operation date introduced in early 2009.
447 No IAEA start-up date; this estimate for commercial operation from: http://www.world-nuclear.org/info/inf45.html
448 Commercial operation originally planned for 2010 at Severod. Since, moved to Lomonosov and delayed by two years.
449 Commercial operation originally planned for 2010 at Severod. Since, moved to Lomonosov and delayed by two years.
450 Delayed from planned start-up at 2008/12/31 as of end of 2007, no new IAEA date. This estimate from http://www.world-nuclear.org/info/inf45.html .
451 On 11 June 2009 construction officially resumed.
452 On 11 June 2009 construction officially resumed.
453 Delayed numerous times. No official start-up date; this estimate from: http://www.world-nuclear.org/info/inf91.html .
454 Delayed numerous times. No official start-up date; this estimate from: http://www.world-nuclear.org/info/inf91.html.
455 Commercial operation date introduced in early 2009.

Annex 3: Potential Nuclear Newcomer Countries, Research Reactors and Grid Size

Country	Research Reactor*	Grid Size (in MW)**
Albania	No	1,700
Algeria	Yes	6,500
Australia	Yes	50,000
Azerbaijan	No	5,200
Bangladesh	Yes	4,700
Belarus	Yes	8,000
Bosnia	No	4,300
Chile	Yes	13,500
Croatia	No	3,900
Egypt	Yes	20,500
Estonia	No	2,300
Georgia	Yes	4,400
Ghana	Yes	1,500
Indonesia	Yes	24,300
Israel	Yes	10,000
Ireland	No	6,200
Italy	Yes	82,000
Jordan	No	2,100
Kuwait	No	11,000
Latvia	Yes	2,200
Libya	Yes	5,400
Malaysia	Yes	23,300
Mongolia	No	800
Morocco	Yes	5,000
Namibia	No	300
New Zealand	No	8,900
Nigeria	No	6,000
Norway	Yes	28,000
Philippines	Yes	15,600
Poland	Yes	31,000
Portugal	Yes	14,000
Thailand	Yes	26,000
Tunisia	No	3,300
Turkey	Yes	41,000
Uganda	No	300
United Arab Emirates	No	15,700
Venezuela	Yes	22,200
Vietnam	Yes	12,400

Notes:
* Based on IAEA, Research Reactor Database, May 2009.
**Mainly as of 2006, as of 2007 if available, rounded, based on US-DOE-EIA, "World Total Electricity Installed Capacity", 8 December 2008.

[456] Delayed several times from original start-up date of mid-2006. No IAEA start-up date; this estimate for commercial operation from: http://www.world-nuclear.org/info/inf115_taiwan.html
[457] Delayed several times from original start-up date of mid-2007.
[458] Delayed numerous times.
[459] Delayed numerous times.

Annex 4: Timetable of Events at Olkiluoto-3 *(according to Nucleonics Week)*

Date	Event
12/03	Turnkey contract €3bn signed by TVO with AREVA NP & Siemens. Target construction time 48 months. Contract includes cost of nuclear and non-nuclear islands and related construction, financing costs, some waste management costs and the first fuel core.[460]
4/04	STUK: 'We are getting the documents late. They (AREVA) aren't reserving enough time for our review and they don't have all the information required by our guides.'[461]
1/05	STUK approves construction of Olkiluoto-3.[462]
2/05	Finnish government gives construction license.[463]
9/05	Ceremony for laying of 'cornerstone'[464]
10/05	Pouring of base slab delayed by concerns about strength of concrete. Manufacturing of reactor pressure vessel and steam generators "a few weeks" behind the original schedule[465]
2/06	Problems with qualifying pressure vessel welds and delays in detailed engineering design put construction more than six months behind schedule[466]
3/06	STUK opened an investigation into manufacturing and construction problems[467]
5/06	Despite measures including two shifts on site and three shifts at AREVA's component manufacturing plant, work is eight to nine months behind schedule.[468]
7/06	TVO acknowledges delay now 1 year. STUK investigation: An extremely tight budget and timetable, supplier inexperience, poor subcontractor control and regulators' difficulty in assessing information have caused confusion and quality control problems that have delayed the 0lkiluoto-3 project[469]
10/06	AREVA takes provision of ca €300m for Olkiluoto project[470] 3 out of 4 'hot legs' not made to specification. [471] Project manager replaced [472]
12/06	Delay estimated at 18 months[473]
1/07	AREVA NP: 'AREVA-Siemens cannot accept 100 % compensation responsibility, because the project is one of vast co-operation. The building site is joint so we absolutely deny 100 % compensation principle' TVO: 'I don't believe that AREVA says this. The site is in the contractor's hands at the moment. Of course, in the end, TVO is responsible of what happens at the site. But the realization of the project is AREVA's responsibility'[474]
5/07	TVO and AREVA agree design not complete enough when contract signed. STUK: 'a complete design would be the ideal. But I don't think there's a vendor in the world who would do that before knowing they would get a contract. That's real life.'[475]
8/07	Problems meeting requirements to withstand an airplane crash mean delay 2 years[476]
9/07	Steel containment liner repaired in 12 places to fix deformations and weld problems[477] AREVA acknowledges further financial provisions for losses but does not quantify them. Independent estimate €500-700m[478]

[460] Nucleonics Week, "Finnish regulators anticipate challenging schedule for EPR", 1 January 2004, p. 21.
[461] Nucleonics Week, "Problems in getting information could delay review of Olkiluoto-3", 1 April 2004, p. 4.
[462] Nucleonics Week, "STUK okays Olkiluoto-3, sets limit on initial fuel burnup", 27 January 2005, p. 1.
[463] Nucleonics Week, "Finnish government issues license for construction of Olkiluoto-3", 24 February 2005, p. 1.
[464] Nucleonics Week, "Multinational ceremony marks Olkiluoto-3's cornerstone", 17 September 2005, p. 15.
[465] Nucleonics Week, "Olkiluoto-3 base slab pour delay not expected to impact end date", 20 October 2005, p. 4.
[466] Nucleonics Week, "Construction of Olkiluoto-3 behind schedule", 2 February 2006, p. 1
[467] Nucleonics Week, "STUK begins investigating construction delay at Olkiluoto-3", 2 March 2006, p. 8.
[468] Nucleonics Week, "Olkiluoto-3 containment liner set in place, but project still lags", 2 March 2006, p. 8.
[469] Nucleonics Week, "Host of problems caused delays at Olkiluoto-3, regulators say", 13 July 2006, p. 1.
[470] Nucleonics Week, "Olkiluoto-3 delays lower AREVA nuclear profits by Eur 300 million", 5 October 2006, p. 4.
[471] Nucleonics Week, "Problems found with Olkiluoto-3 hot legs", 19 October 2006, p. 1.
[472] Nucleonics Week, "AREVA puts star engineer in charge of Olkiluoto-3 project", 2 November 2006.
[473] Nucleonics Week, "Olkiluoto-3 commercial date slips to late 2010 at earliest", 7 December 2006, p. 1.
[474] Finnish Broadcasting Company TV news, 30 January 2007.
[475] Nucleonics Week, "Lack of complete design blamed for problems with Olkiluoto-3", 17 May 2007, p. 4.
[476] Nucleonics Week ,"AREVA: Plane crash requirements to delay Olkiluoto-3 construction", 16 August, 2007, p.1.
[477] Nucleonics Week, "Regulator requires repairs to welds on Olkiluoto-3 containment liner", 20 September 2007, p.1.

Date	Event
6/08	TVO site manager replaced[479]
10/08	Delay now estimated at 3 years[480] Manufacturer of containment liner failed to obey an order to stop welding after a STUK-TVO inspection discovered that an incorrect welding procedure was being used.[481] AREVA initiates arbitration proceedings in Arbitration Institute of the Stockholm Chamber of Commerce over 'a technical issue'[482]
12/08	AREVA announces further loss provisions. Independent estimates €1.3bn[483]
12/08	Letter from STUK Director General top CEO AREVA: 'I cannot see real progress being made in the design of the control and protection systems.' 'This would mean that the construction will come to a halt and it is not possible to start commissioning tests.' 'The attitude or lack of professional knowledge of some persons who speak in the expert meetings on behalf of that organization prevent to make progress in resolving the concerns.'[484]
1/09	Delay acknowledged being 3.5 years.[485] Siemens announces withdrawal from AREVA NP.[486] AREVA-Siemens file a second arbitration proceeding against TVO.[487] AREVA asking for €1bn in compensation. TVO counterclaiming for €2.4bn for 'gross negligence'[488] TVO expects arbitration to take several years[489]
3/09	AREVA admits cost over-run now €1.7bn[490]
5/09	STUK orders AREVA to stop welding of primary coolant pipes of the reactor.

[478] Nucleonics Week, "AREVA, TVO at odds over resolution of Olkiluoto-3 cost overruns", 6 September 2007, p. 9.
[479] Nucleonics Week, "Second top TVO executive leaving Olkiluoto-3", 26 June 2008, p. 1.
[480] Nucleonics Week, "Target date for operating Olkiluoto-3 again delayed, this time until 2012", 23 October 2008.
[481] Nucleonics Week, "STUK finds more problems with Olkiluoto-3 liner, forgings", 13 November 2008, p. 3.
[482] Nucleonics Week, "TVO CEO sees improved workflow, potential for problems at Olkiluoto-3", 20 November 2008, p. 11.
[483] Nucleonics Week, "Olkiluoto costs weigh on AREVA 2008 profits; TVO rejects blame", 25 December 2008, p. 9.
[484] Letter from Jukka Laaksonen to Anne Lauvergeon, 9 December 2008.
[485] Nucleonics Week, "TVO: Olkiluoto-3 operation delayed to June 2012", 15 January 2009, p. 1.
[486] Nucleonics Week, "Siemens' departure seen putting AREVA under financial stress", 29 January 2009, p. 14.
[487] Nucleonics Week, "TVO: Olkiluoto-3 operation delayed to June 2012", 15 January 2009, p. 1.
[488] Nucleonics Week, "AREVA reveals 47% cost overrun on contract for Olkiluoto-3", 5 March 2009, p. 1.
[489] Nucleonics Week, "Olkiluoto-3 arbitration could last 'several years,' TVO says", 19 March 2009, p. 9.
[490] Nucleonics Week, "AREVA reveals 47% cost overrun on contract for Olkiluoto-3", 5 March 2009, p. 1.