"such an illuminating report"
Sam Geall
Deputy Editor,
China Dialogue,
London, UK

"must reading for any observer of nuclear energy"
Henry Sokolski
Executive Director,
Nonproliferation Policy
Education Center (NPEC),
Washington, USA

"the quality of your information is impeccable"
Alain Michel
Former nuclear industry official,
Publisher, *Le Hêtre Pourpre*
Namur, Belgium

THE WORLD NUCLEAR INDUSTRY STATUS REPORT 2007

(Updated to 31 December 2007)

by

Mycle Schneider, Paris

with contributions from

Antony Froggatt, London

Independent Consultants

Brussels, London, Paris, January 2008

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The Greens | European Free Alliance
in the European Parliament

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For questions and comments please contact:

Michel Raquet
Energy Adviser
Greens / EFA
European Parliament
PHS 06C69
Rue Wiertzstraat
B-1047 Brussels
Phone: +32.2.284.23.58
E-mail: mraquet@europarl.eu.int
Web: www.greens-efa.org

To contact the authors:

Mycle Schneider Consulting
45, Allée des deux cèdres
91210 Draveil (Paris)
France
Skype: mycleschneider
Phone: +33-1-69 83 23 79
Fax: +33-1-69 40 98 75
E-mail: mycle@orange.fr

Antony Froggatt
53a Nevill Road
N16 8SW London
UK

Phone: +44-207-923 04 12
Fax: +44-207-923 73 83
E-mail: a.froggatt@btinternet.com

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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 neighbouring states. He has worked extensively on EU energy issues for European Governments, the European Commission and Parliament, environmental NGOs, commercial bodies and the media. He has given evidence to inquiries and hearings in the Parliaments of, Austria, Germany and the EU. He is a part time senior research fellow at the Royal Institute of International Affairs – Chatham House in London.
He 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 programmes across the region.
Prior to working freelance Antony worked for nine years as a nuclear campaigner and co-ordinator for Greenpeace International.

Introduction and General Overview

Fifty three years ago, in September 1954, the head of the U.S. Atomic Energy Commission stated that nuclear energy would become "too cheap to meter": The cost to produce energy by nuclear power plants would be so low that the investment into electricity meters would not be justified. By coincidence the U.S. prophecy came within three months of the announcement of the world's first nuclear power plant being connected to the grid in… the then Soviet Union. In June 2004, the international nuclear industry celebrated the anniversary of the grid connection at the site of the world's first power reactor in Obninsk, Russia, with a conference entitled "50 Years of Nuclear Power – The Next 50 Years". This report aims to provide a solid basis for analysis into the prospects for the nuclear power industry.

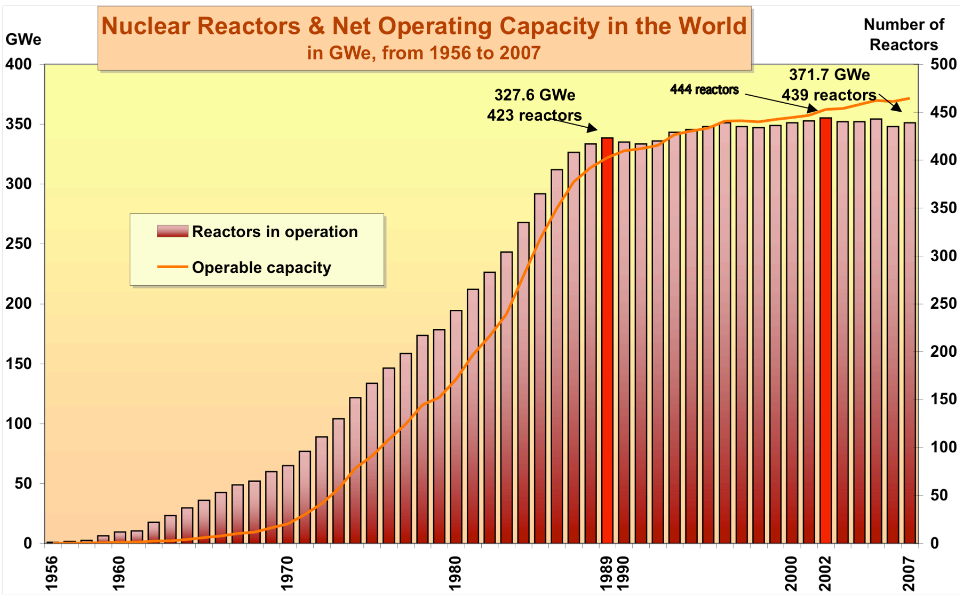
Fifteen years ago, the Worldwatch Institute in Washington, WISE-Paris and Greenpeace International published the *World Nuclear Industry Status Report 1992*, this was then subsequently updated in 2004 by two of the original authors. The present publication provides an entirely updated and slightly modified version of the 2004 report.

The *World Nuclear Status Report 1992* concluded:

> *"The nuclear power industry is being squeezed out of the global energy marketplace (…). Many of the remaining plants under construction are nearing completion so that in the next few years worldwide nuclear expansion will slow to a trickle. It now appears that in the year 2000 the world will have at most 360,000 megawatts of nuclear capacity, only ten per cent above the current figure. This contrasts with the 4,450,000 megawatts forecast for the year 2000 by the International Atomic Energy Agency (IAEA) in 1974."*

In reality, the combined installed nuclear capacity of the 436 units operating in the world in the year 2000 was less than 352,000 MW or 352 GW[1]. The analysis in the 1992 Report proved correct. At the end of 2007, there are 339 units operating in the world – that is one less than at the moment of the release of the 2004 version of the World Nuclear Industry Status Report and five units less than at the historical peak in 2002 – which total 371.7 GW of capacity.

Graph 1



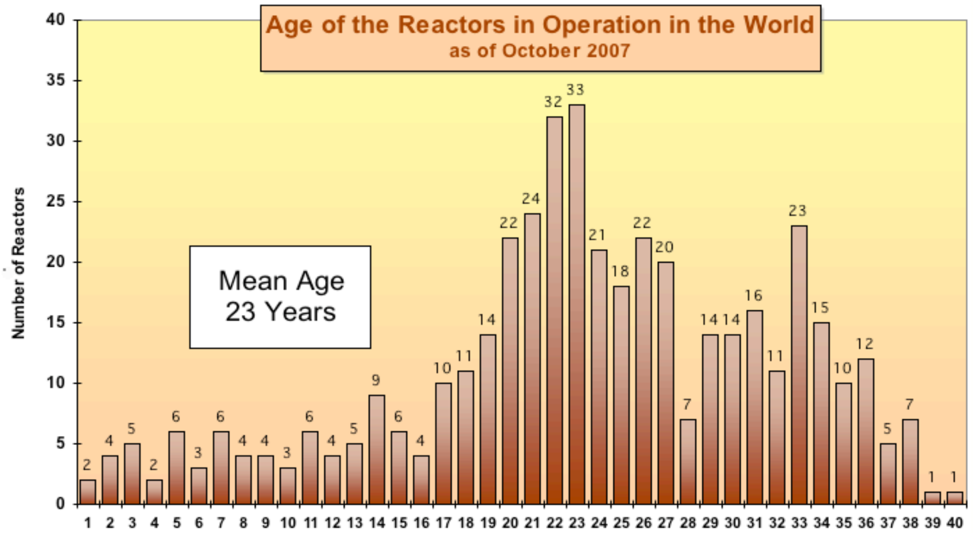
© Mycle Schneider Consulting *Source: IAEA, PRIS, 2007[2], MSC*

[1] 1 GW = 1,000 MW = about 1 large nuclear power reactor

[2] International Atomic Energy Agency (IAEA), Power Reactor Information System (PRIS), see http://www.iaea.org/programmes/a2/index.html

The installed capacity has increased faster than the number of operating reactors because units that are being shut down are usually smaller than the new ones coming on-line and because of uprating of capacity in many existing plants. According to the World Nuclear Association (WNA), in the USA the Nuclear Regulatory Commission (NRC) has approved 110 uprates since 1977, a few of them "extended uprates" of up to 20%. As a result an additional 4.7 GW were added to the nuclear capacity in the USA alone.[3] A similar trend of uprates and extending the lives of existing reactors can be seen in Europe. However, in the absence of significant new build, the average age of operating nuclear power plants in the world has been increasing steadily and stands now at 23 years, up two years from the Status Report 2004 (see Graph 2).

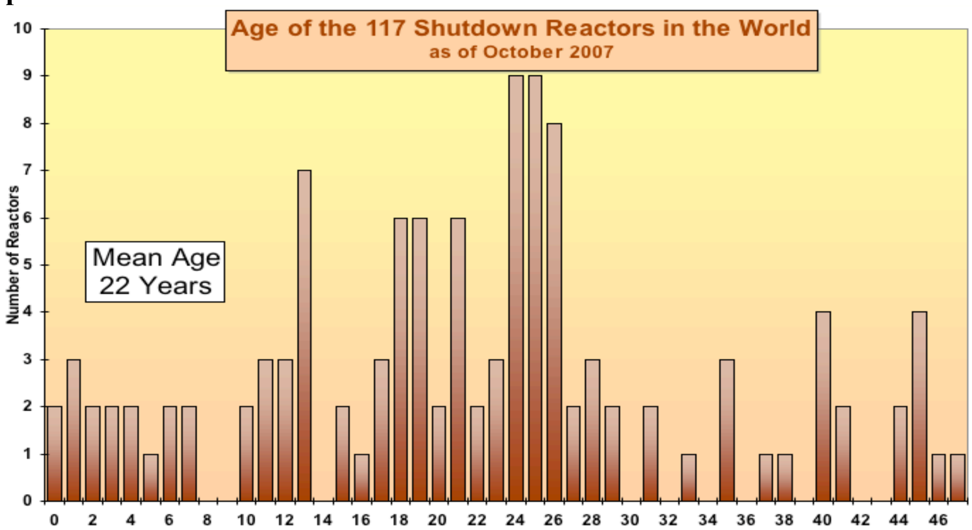
Graph 2



© Mycle Schneider Consulting *Source: IAEA, PRIS, 2007, MSC*

A total of 117 reactors have been permanently shut down, with an average age of about 22 years, the figure is up one year from the situation in 2004 (see Graph 3). Since the 2004 edition of the Status Report ten reactors have been shut down - eight in 2006 - and nine have been started up.

Graph 3



© Mycle Schneider Consulting *Source: IAEA, PRIS, 2007, MSC*

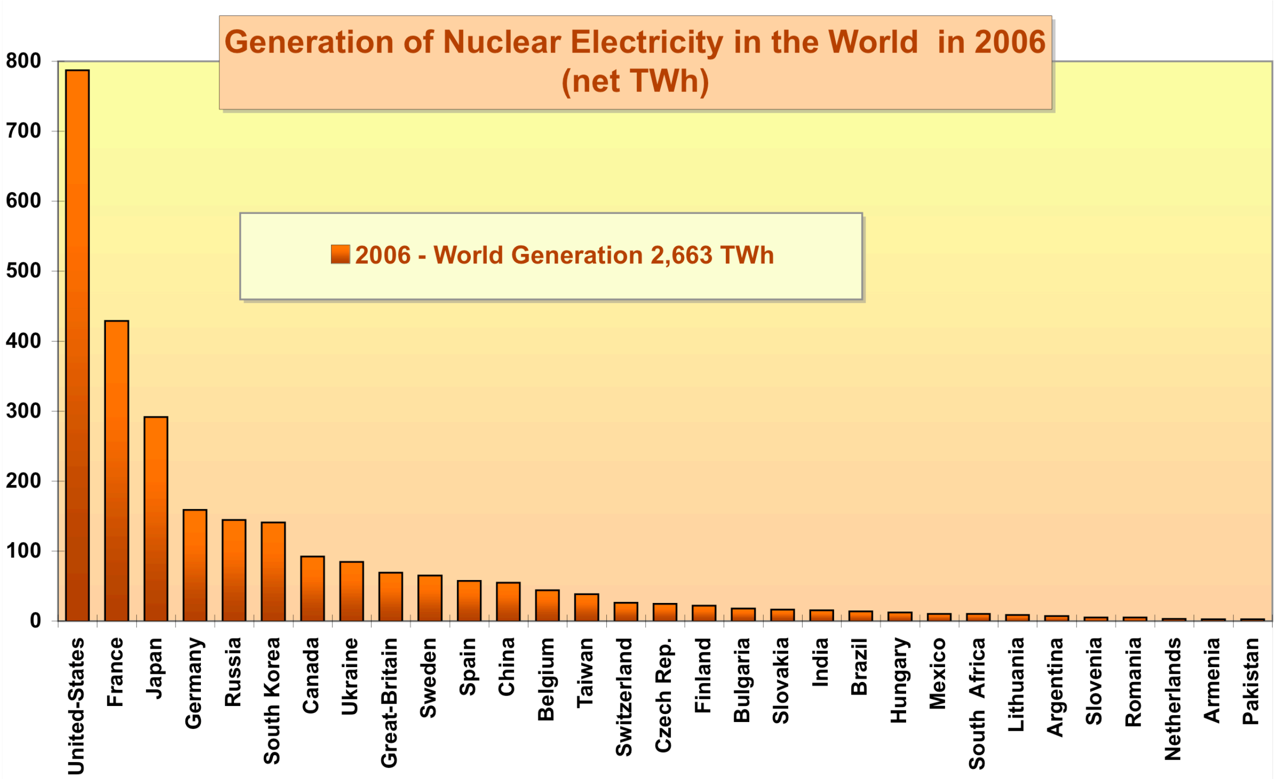
[3] http://www.world-nuclear.org/info/Copy%20of%20inf17.html

The capacity of the global fleet increased annually between the years 2000 and 2004 by about 3 GW, much of it through uprating and dropped to 2 GW per year between 2004 and 2007. This figure should be compared to the global net increase in all electricity generating capacity of about 135 GW *per year*[4]. Wind power alone recorded an average annual increase of 13.3 GW between 2004 and 2006, more than 6.5 times the nuclear additions. This leaves nuclear power with a global share of roughly 1.5% of the annual increase.

The slightly increased output from nuclear energy will not be sufficient, at least over the short and medium term, to maintain its current 16% share in the world commercial power production and the 6% in the commercial primary energy – which is less than the contribution of hydropower alone – or about 2% to 3% final energy consumption.[5]

The use of nuclear energy is limited to a small number of countries in the world. Only 31 countries, or 16% of the 191 United Nations Member States, operate nuclear power plants (see Graph 4). The big six - USA, France, Japan, Germany, Russia, South-Korea – half of which are nuclear weapon states, produce almost three quarters of the nuclear electricity in the world. Half of the world's nuclear countries are located in Western and Central Europe and count for over one third of the world's nuclear production. The historical peak of 294 operating reactors in Western Europe and North America had been reached as early as 1989. In fact, the decline of the nuclear industry, unnoticed by the public, started many years ago.

Graph 4



© WISE- *Paris* / Mycle Schneider Consulting *Source: IAEA, PRIS, 2007*

The international nuclear industry continues to forecast 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

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[4] This is the average annual net addition between 2003 and 2010 as estimated by the OECD's International Energy Agency in its International Energy Outlook 2006.

[5] Final energy is the amount of energy available to the consumer, which is the primary energy input minus the transformation and transport/distribution losses. In the case of electricity, typically about three quarters and at least about half of the primary energy is lost on the way to the consumer.

nuclear power back on the agenda for projected new capacity in both Europe and North America," says the WNA.[6]

The nuclear industry is not alone to proclaim its "renaissance". Over the last three years, several international assessments of the possible future of nuclear power in the world have been adjusted to more optimistic prospects for the horizon of 2030. The OECD International Energy Agency's World Energy Outlook 2007[7] presents a "reference scenario", an "alternative policy scenario" and a "450 stabilisation case" that include respectively 415 GW, 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. Under the reference scenario the share of nuclear power in the world commercial primary energy supply would drop from 6% to 5% in 2030.

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."[8]

A recent report commissioned by the InterAademy Council, a research body that federates national academies of science, stated in a similar way: "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" and 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".[9]

The U.S. Department of Energy, in its latest edition of the International Energy Outlook (IEO), forecasts 438 GW of nuclear by 2030, "in contrast to projections of declines in nuclear power capacity in past IEOs".[10]

The International Atomic Energy Agency (IAEA) has revised its forecasts several times over the last years and anticipates 447 GW in its "low" scenario and on 679 GW in its "high" scenario by 2030.[11] 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[12] and 729 GW[13] of nuclear power plants by 2030.[14]

The above mentioned scenarios "forecast" an installed nuclear capacity by 2030 of anything between 415 GW and 833 GW, respectively an increase of less than 13% to 125% over the current installed 371 GW. In fact, even the lower figure corresponds to a significant challenge considering the current age structure of operating units. 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.

For the immediate future new build remains essentially restricted to Asia. Of the 34 units listed by the IAEA as under construction in 13 countries (as of 31 December 2007) – eight more than by the end of 2004, but about 20 less than in the late 1990s – all but five are located in Asia or Eastern Europe. Twelve of these units

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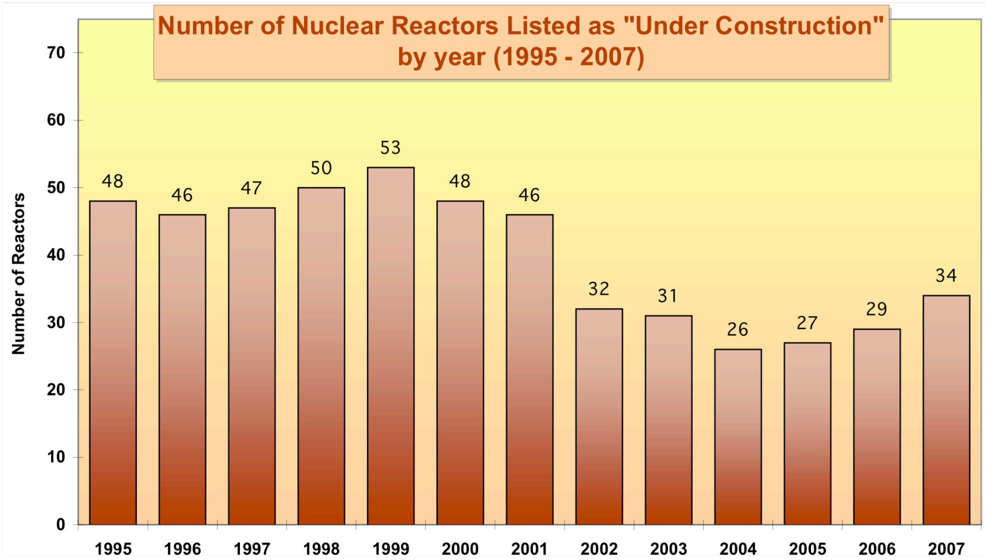
[6] http://www.world-nuclear.org/info/inf104.html
[7] OECD-IEA, "World Energy Outlook 2007", 7 November 2007
[8] OECD-IEA, "World Energy Outlook 2006", 7 November 2006
[9] InterAcademy Council, "Lighting the Way", October 2007
[10] US Department of Energy, Energy Information Administration, "International Energy Outlook 2006", June 2006, see www.eia.doe.gov/oiaf/ieo/index.html
[11] IAEA, Press Release, 23 October 2007, http://www.iaea.org/NewsCenter/PressReleases/2007/prn200719.html
[12] addition of 180 GW over the 2004 installed nuclear capacity of 366 GW
[13] This corresponds to practically the double of the currently installed nuclear capacity. The 729 GW figure rather than approximately 730 GW suggest a level of precision that is as far from reality as the figure itself.
[14] 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

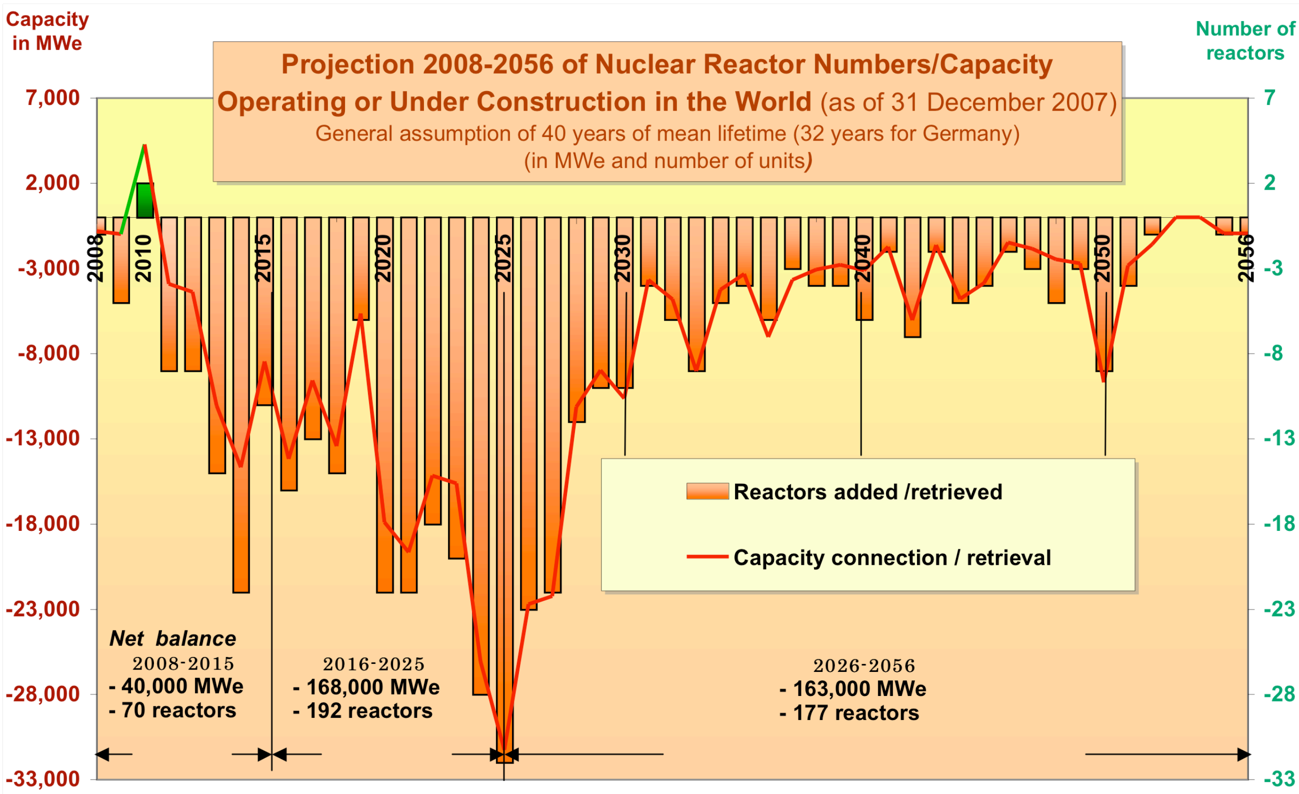
have been formally under construction for 20 years or more. The longest building time so far has been achieved by the U.S. Watts Bar-2 reactor that just resumed construction that had originally started in 1972 and by the Iranian Busheer-1 project that began in May 1975 and continues to accumulate delays. The Russian fast breeder reactor project BN-800 that started in 1985 and Watts Bar-2 have now been re-included in the current official statistics. (See Appendix-1 for details on reactors under construction).

Graph 5



© Mycle Schneider Consulting…… *Source: CEA 1997 - 2006, IAEA 2007, MSC 2007*

Graph 6



© Mycle Schneider Consulting *Source: IAEA, PRIS, 2007, MSC*

In order to evaluate the status of the world nuclear industry, it is helpful to estimate the number of units that would have to be replaced over the coming decades just to maintain the current number of operating plants. We have considered an average lifetime of 40 years per reactor, with the exception of the remaining 17 German nuclear plants that, according to German legislation, will be shut down after an average operational lifetime of about 32 years. Considering that the average age of reactors closed to date is 22 years, a 40 year lifetime expectancy might seem optimistic, but at the same time it seems possible given the progress that has been achieved on the current generation of plants compared to the previous one.

Graph 6 illustrates the results. The calculation includes 24 reactors with an official start-up date of the 34 units listed as under construction by the IAEA as of the end of 2007, all but one of which would be in operation by 2015. In total, 93 units will reach the age of 40 between January 2008 and 2015 or are scheduled to be shut down for other reasons. In other words, in addition to the 23 units under construction with published start-up dates in that time period 70 units or close to 40,000 MW (40 GW) would have to come online until 2015 in order to maintain the current level of equipment. Even taking into account the 10 units officially under construction without scheduled start-up date, 60 reactors would still have to be planned, built and started up over the next eight years to maintain the current number of units operating. This seems virtually impossible given the long lead times for nuclear power projects. Furthermore, in the following decade - up to 2025 - a total of 192 new units or more than 168,000 MW (168 GW) would be needed just to maintain the status quo.

According to the same logic, between 2007 and 2030 a total of 339 reactors would have to be replaced in order to maintain the same number of plants operating than today. The IAEA, in its low scenario, has considered the closure of 145 units and the building of 178 new units by 2030.[15] This would require 193 units extending their lifetime beyond 40 years.

Developments in Asia and particularly in China won't fundamentally change the global picture. The news media *China Daily* recently stated: "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."[16] The average construction time of the 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 at the latest in 2015. Only about 10% of the additional 31 GW are currently under construction with five units totalling 3.2 GW that started over the last three years. Building frequency would have to more than triple in order to meet the ambitious goal. A prospect that seems highly unlikely[17] although not entirely impossible. 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."[18] The industry organisation WNA is particularly optimistic as it states: "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."[19]

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[15] Alan McDonald, H.H. Rogner, "Nuclear Power: Energy Security and Supply Assurances", paper presented at the WNA Annual Symposium, 5 September 2007. The paper suggests with 692 MW a different "high scenario" than in a press release a month later (op.cit). It assumes the closure of 82 units and the building of 357 new reactors.
[16] http://www.chinadaily.com.cn/china/2007-10/16/content_6177053.htm
[17] A certain number of units currently in the planning stage are of designs that have never been built elsewhere.
[18] Bradford, et al. "Nuclear Power Joint Fact-Finding", Keystone Center, June 2007
[19] http://www.world-nuclear.org/info/Copy%20of%20inf17.html

The authors of the present report remain convinced that, on the contrary, the number of nuclear power plants operating in the world will most likely decline over the next two decades with a rather sharper decline to be expected after 2020. 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.

Ken Silverstein, Director of the U.S. based consultancy *Energy Industry Analysis* states:

> "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'."[20]

In 2005 the U.S. passed legislation in order to stimulate investment in new nuclear power plants. Measures include a tax credit on electricity generation, a loan guarantee of up to 80% 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.

The licensing procedure has been simplified to avoid the lengthy processes of the past. The Ralph Nader founded public interest group *Public Citizen* views the new licensing conditions not only as heavy subsidy to the industry but as 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 was 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."[21] 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."[22] The Financial Times obtained confidential 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."[23] NRC Chairman Dale Klein stated that potentially necessary grid extensions could lead to further delays and indicated that he was surprised to learn that ""it may take as long to site, permit and build a transmission line for a new plant as to site, license and build the plant itself."[24]

[20] UtiliPoint International, 21 June 04
[21] http://www.citizen.org/cmep/energy_enviro_nuclear/newnukes/articles.cfm?ID=14159
[22] Moody's Corporate Finance, "New Nuclear Generation in the United States: Keeping Options Open vs Addressing An Inevitable Necessity", Special Comment, October 2007
[23] Financial Times, 24 October 2007.
[24] ibidem

Scepticism of the international financial institutions and analysts

In a new analysis Standard and Poor's stresses that a license to construct is not equal to construction.

> "Even with a COL, no utility will commit to a project as large and risky as a new nuclear plant without assurance of cost recovery. In arriving at debt rating opinions, Standard & Poor's doesn't expect full and unfettered recovery of all requested costs. Rather, we look for a regulatory framework that provides for a fair opportunity to recover prudently incurred costs, even through changing regulatory commissions. Without such a framework, a utility's financial condition may rapidly deteriorate. (…) Construction contracts are another issue. In the past, engineering, procurement, and construction contracts were easy to secure. However, with increasing raw material costs, a depleted nuclear-specialist workforce, and strong demand for capital projects worldwide, construction costs are increasing rapidly. Designers and engineers are still developing cost estimates for new nuclear plants. All of this can significantly affect utilities, as they may be unable to find EPC [Engineering, Procurement and Construction] contracts and may have to look for other ways to insulate themselves from construction risk and cost overruns."[25]

In an October 2007 "Special Comment" the capital market service company Moody's delivers a stunning U.S. nuclear sector analysis:

> "Moody's does not believe the sector will bring more than one or two new nuclear plants on line by 2015, a date cited by a majority of the companies currently highlighting their nuclear ambitions. The complexity associated with the permitting process as well as the execution risks associated with construction projects of this nature should not be underestimated. (…)
> Moody's believes that many of the current expectations regarding new nuclear generation are overly ambitious. In fact, the timing associated with commencing construction and making the next nuclear unit commercially available could be well beyond 2015 and the costs associated with the next generation of nuclear build could be significantly higher than the approximately $3,500/kW estimates cited by many industry participants."[26]

Moody's low estimate for new nuclear capacity in the U.S. is $5,000/kW and its high estimate is $6,000/kW. Actually, the international financing market's reluctance towards nuclear energy is not new. With the exception of a 1959 loan to Italy, the World Bank, for example, has never financed a nuclear power plant and there are no signs that it would have changed its financial risk analysis. But even in Asia, where many nuclear optimists see the basic hope for a nuclear revival, the Asian Development Bank does not finance nuclear projects. The bank has defined clear policy on the issue in 1994 and has confirmed it in 2000:

> "Continued use of nuclear power in developed and developing countries and its further expansion require not only firm assurances that technical and institutional measures will be effective in protecting public health and safety, but also sustained public confidence and broad political support. The technical complexity of nuclear power technology is a barrier to public understanding, which makes it difficult for members of the public to evaluate safety questions for themselves. The Bank is very much aware of this background and has not been involved in the financing of nuclear power generation projects in the DMCs [Developing Member Countries] due to a number of concerns. These concerns include issues related to transfer of nuclear technology, procurement limitations, proliferation risks, fuel availability and procurement constraints, and environmental and safety aspects. The Bank will maintain its policy of non-involvement in the financing of nuclear power generation"[27].

In the past the European Investment Bank (EIB) has funded nuclear power and fuel cycle facilities projects worth over €6 billion. However, no loans had been made since the mid 1980s, due to the slowdown of

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[25] Swami Venkataraman, "Which Power Generation Technologies Will Take The Lead In Response To Carbon Controls?", Standard & Poor's, 11 May 2007
[26] Moody's Corporate Finance, op.cit.
[27] Bank Policy Initiatives for the Energy Sector, February 1994, Asian Development Bank, page 10, paragraph 25.

nuclear power ordering in the EU. However, in June 2007 the Bank published a new position paper - 'Clean Energy for Europe' and on nuclear power it noted that 'EIB financing may be requested for investments in new generation capacity, in the nuclear fuel cycle and in research activities'. In July 2007, the Bank awarded a loan of up to €200 million for the URENCO enrichment facilities in the UK and Netherlands[28]. However, no loan requests or attributions for new nuclear power plants have been reported.

Lack of students, workforce and manufacturing capacity

> *"The single most important factor in assuring quality in nuclear plant construction is prior nuclear experience (i.e., licensee experience in having constructed previous nuclear power plants, personnel who have learned how to construct them, experienced architects-engineers, experienced constructors, and experienced NRC inspectors),"*
>
> U.S. Nuclear Regulatory Commission (NRC), NUREG-1055[29]

Investment and construction ratios of the 1980s cannot simply be repeated thirty years later.[30] The nuclear industry and utilities face challenges in a radically changed industrial environment. Today the sector has to deal with waste management and decommissioning expenses that far outweigh estimates of the past, it has to compete with a largely modernized gas and coal sector and with new competitors in the new and renewable energy sector.[31] In particular, it has to face the problems of rapid loss of competence and lack of manufacturing infrastructure.

Keynote speakers at the American Nuclear Society's 2007 Annual Meeting pointed out that "a nuclear renaissance is far from being a sure thing". [32] 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.[33] Furthermore, he said only 8 percent 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."[34] In France, the situation is no better. About 40% of the national utility EDF's current staff in reactor operation and maintenance will retire by 2015. Starting in 2008, the utility will try to hire 500 engineers annually. Reactor builder AREVA has already started hiring 400 engineers in 2006 and another 750 in 2007. The level of success of the hiring efforts is not known. It is obvious that the biggest share of the hired staff are not trained nuclear engineers or other nuclear scientists. The CEA affiliated national Institute for Nuclear Sciences and Techniques (INSTN) has only generated

[28] EIB and Financing of Nuclear Energy, July 2007, European Investment Bank http://www.eib.org/about/publications/eib-and-financing-of-nuclear-energy.htm

[29] U.S. NRC, "Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants", NUREG-1055, May 1984

[30] Besides the fact that the repetition of the history of cancelled projects, bankrupt utilities and cost overruns, especially in the US, could hardly be a goal for the current nuclear industry. In the US alone, 138 reactor projects were abandoned (see CEA, "Nuclear Power Plants in the World", Edition 2000) and the cost overruns on practically all the plants were spectacular (see recent analysis by N.E.Hultman, J.Coomey, D.M.Kammen, "What History Can Teach Us about the Future Costs of U.S. Nuclear Power", Environmental Science & Technology, 1 April 2007

[31] see Amory B. Lovins' brilliant analysis "Mighty Mice", Nuclear Engineering International, December 2005

[32] 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

[33] 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/)

[34] ibidem

about 50 nuclear graduates per year. EDF has called upon the institute to double the number over the coming years.[35]

In 1980, there were about 65 university nuclear engineering programs operating in the U.S.. Today, it's only around 29. 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.[36] Starting from a virtual hiring freeze in the 1980s, a slow resumption by the end of the 1990s, the company has jumpstarted the process in the period 2001-2005 with 400 new hires per year that have been 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.
A nuclear power plant construction infrastructure assessment carried out in 2005 on behalf of the U.S. Department of Energy concludes that qualified boilermakers, pipefitters, electricians, rebar ironworkers, health physicists, operators and maintenance personnel are all "in short supply".[37]

If it is as difficult to hire sufficient staff for the current programs, one wonders where the trained workforce for a major expansion will come from. The entire utility sector is not considered attractive by young people. "Today's most talented and promising students want to work in glamorous high-tech fields—not in the stodgy old utility industry", says a 2005 analysis by the Hay Group entitled "Workforce Trends to Deliver Utility Industry Knock-out Blow". In the UK the situation is similar and university acceptances in Mechanical, Civil and Electrical Engineering, Physics and Chemistry fell by a quarter between 1994 and 2000. And as of 2002, there was not a single undergraduate course in nuclear engineering in the UK. 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 the nuclear energy carries no buzz of excitement for new students, making it all the harder for it to attract the brightest and best."[38]

In Germany the 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 include still 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.[39] While 46 students obtained their diploma in 1993, they were zero in 1998. In fact, between the end of 1997 and the end of 2002 only two students successfully finished their nuclear studies. In total about 50 students from other options continue 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.[40]
Various countries have attempted to coordinate efforts to avoid the deepening of the competence gap. The UK has just launched a nuclear industry oriented National Skills Academy that is intended to improve the standard of industry training, increase productivity and tackle skills shortages across the UK. In Germany a

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[35] 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
[36] 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
[37] MPR, "DOE NP2010 Nuclear Power Plant Construction Infrastructure Assessment", 21 October 2005
[38] Philip Thomas, "The Future Availability of Graduate Skills", presentation to the BNIF/BNES Conference *Energy Choices*, 5 December 2002
[39] P. Fritz and B. Kuczera, "Kompetenzverbund Kerntechnik – Eine Zwischenbilanz über die Jahre 2000 bis 2004", Atomwirtschaft, June 2004
[40] Lothar Hahn, presentation at the IAEA sponsored "International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development", 7-10 September 2004

"nuclear competence alliance" between the four major research centres with links to academic institutions, utilities and the industry has been established in 2000 but, so far, has not been able to stop the erosion of well educated young people able to replace the rapidly aging current workforce. As Lothar Hahn, managing director of the German company GRS (Society for Reactor Safety), points out, the consequences could be extremely 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 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."[41]

In the 1980s there were about 400 nuclear suppliers and 900 nuclear certifications in the U.S. These shrank to less than 80 suppliers and fewer than 200 certifications.[42] The DOE nuclear power plant construction infrastructure assessment quoted above concludes that major equipment (reactor pressure vessels, steam generators, and moisture separator reheaters) for the near-term deployment of Generation III[43] units would not be manufactured by U.S. 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."[44] JSW has supplied about 130 or 30% of the currently operating nuclear reactor vessels in the world.[45] In fact, only JSW can forge components from ingots up to 450 t[46] as needed for the EPR and other Generation III reactor pressure vessels and it has announced to further invest 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. JSW's capacity for nuclear products is fully booked to the end of 2010.[47] 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.

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[48] 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

[41] 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

[42] Nucleonics Week, 15 February 2007; an unknown portion of that development is due to takeovers.

[43] 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 US include the AP1000 by Westinghouse, the Advanced Boiling Water Reactor (ABWR) and the Economic Simplified Boiling Water Reactor (ESBWR) by General Electric.

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

[45] WNN, "Japan Steel Works prepares for orders", 16 May 2007

[46] 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.

[47] Nucleonics Week, 8 November 2007

[48] Most of the large nuclear plants under construction or in planning have four steam generators.

extension measures – steam generator and vessel head replacement – also for the U.S. market.[49] 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."[50] The U.S. Nuclear Regulatory Commission's Chairman Dale Klein has warned that it will take more time to inspect foreign made components than to provide quality control at home.[51]

Rhetoric rather than reality

Much of the optimism displayed by the nuclear lobby is limited to rhetoric. The *New York Times* ironically summed up the issue under the headline "Hopes of Building Nation's First New Nuclear Plant in Decades" in the following way: "The companies, including the two largest nuclear plant owners in the United States and two reactor manufacturers, have not specified what they would build or where. In fact, they have not made a commitment to build at all. But they have agreed to spend tens of millions of dollars to get permission to build, and they anticipate tens of millions from the federal government, which requested such proposals in November. The money would go to finish design work useful for a new generation of reactors and to develop a firm estimate of what such plants would cost."[52] Three years later the nuclear industry seems to consider the incentives created with the 2005 U.S. Energy Act insufficient. The utility NRG that filed the first nuclear license request in three decades in the U.S. admitted it was seeking financial support from the Japanese government to help build two new nuclear units in Texas. NRG's CEO David Crane stated: "We believe by working with Japanese partners we'll be able to get Japanese financial support which we think will be a big help to the equity in the project and will take a little bit of pressure off the U.S. government's federal support".[53]

The overall nuclear industry strategy is quite clear. In the absence of a short or medium term revival of the nuclear industry, hopes remain with an entirely new generation of nuclear power plants, so-called Generation IV reactors. They would be much smaller in size (100 MW to 200 MW) and capital investment, represent a more flexible solution due to much shorter building times and a lower potential risk due to smaller radioactive inventories and passive safety features. In the meantime, nuclear utilities try to extend plant lifetime as much as possible and do their best to keep up the myth of a nuclear future.

Former NRC Commissioner Peter Bradford, who was involved in the licensing of some 25 nuclear reactors, comes to a severe judgement on the prospects of nuclear power:

> "Those who tell you things like "It could save the earth"[54] or "Clean, green atomic energy can stop global warming" [55] or "Nuclear energy just may be the energy source that can save our planet from catastrophic climate change"[56] are inviting you into a dangerous lala land in which nuclear power will be oversubsidized and underscrutinized while other more promising and more rapid responses to climate change are neglected and the greenhouse gases that they could have averted continue to pollute the skies at dangerous rates."[57]

Long-time energy sector observer Walt Patterson, Associate Fellow of the Energy, Environment and Development Programme at the UK's Royal Institute of International Affairs (Chatham House) agrees. He has detected a sort of ramping "nuclear amnesia":

[49] see CPDP, Compte Rendu du Débat Public EPR "Tête de série", Paris 29 November 2005
[50] Nucleonics Week, 8 November 2007
[51] Financial Times, 24 October 2007
[52] The New York Times, 31 March 04
[53] Reuters, 26 September 2007
[54] National Geographic, April, 2006
[55] Wired Magazine, February, 2005
[56] Patrick Moore, Washington Post, April 16, 2006
[57] Peter A. Bradford, "Nuclear Power and Climate Change", Society of Environmental Journalists Panel Debate, Burlington, Vermont, October 27, 2006

> "Those suffering from nuclear amnesia have forgotten why nuclear power faded from the energy scene in the first place, how many times it has failed to deliver, how often it has disappointed its most determined advocates, how extravagantly it has squandered unparalleled, unstinting support from taxpayers around the world, leaving them with burdens that may last for millennia."[58]

In June 2005, the trade journal Nuclear Engineering International published the analysis of the 2004 Edition of the World Nuclear Industry Status Report under *their* headline. "On the way out - In sharp contrast to multiple reporting of a potential 'nuclear revival', the atomic age is in the dusk rather than in the dawn".

At the end of 2007, we have nothing to add.

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[58] The World Today, "Nuclear Amnesia", April 2006

Table 1: Status of Nuclear Power in the World in 2007

Countries	Nuclear Reactors[59]				Power[60]	Energy[61]
	Operate	Average Age	Under Construction[62]	Planned[63]	Share of Electricity[64]	Share of Commercial Primary Energy[65]
Argentina	**2**	**29**	**1**	**1**	**7%(–)**	**2%(–)**
Armenia	**1**	**27**	**0**	**0**	**42%(+)**	**?%**
Belgium	**7**	**27**	**0**	**0**	**54%(–)**	**15%(–)**
Brazil	**2**	**16**	**0**	**1**	**3%(–)**	**2%(=)**
Bulgaria	**2**	**18**	**2**	**0**	**44%(+)**	**22%(+)**
Canada	**18**	**23**	**0**	**4**	**16%(+)**	**7%(–)**
China	**11**	**7**	**5**	**30**	**2%(–)**	**1% (=)**
Czech Republic	**6**	**16**	**0**	**0**	**32%(+)**	**14%(+)**
Finland	**4**	**28**	**1**	**0**	**28%(+)**	**20%(–)**
France	**59**	**23**	**1**	**0**	**78%(+)**	**39%(–)**
Germany	**17**	**25**	**0**	**0**	**32%(–)**[66]	**12%(–)**
Hungary	**4**	**22**	**0**	**0**	**38%(+)**	**12%(+)**
India	**17**	**16**	**6**	**10**	**3%(–)**	**1%(=)**
Iran	**0**	**0**	**1**	**2**	**0%(=)**	**0%(=)**
Japan	**55**	**22**	**1**	**12**	**30%(+)**	**13%(–)**
Korea RO (South)	**20**	**14**	**3**	**5**	**39%(–)**	**15%(+)**
Lithuania	**1**	**20**	**0**	**0**	**72%(–)**	**24%(–)**
Mexico	**2**	**16**	**0**	**0**	**5%(–)**	**2%(=)**
Netherlands	**1**	**34**	**0**	**0**	**4%(–)**	**1%(=)**
Pakistan	**2**	**22**	**1**	**2**	**3%(+)**	**1%(=)**
Romania	**2**	**6**	**0**	**2**	**9%(–)**	**3%(=)**
Russia	**31**	**25**	**7**	**8**	**16%(–)**	**5%(=)**
Slovakia	**5**	**19**	**0**	**2**	**57%(–)**	**23%(+)**
Slovenia	**1**	**26**	**0**	**0**	**40%(–)**	**?%**
South Africa	**2**	**23**	**0**	**1**	**4%(–)**	**2%(=)**
Spain	**8**	**24**	**0**	**0**	**20%(–)**	**9%(+)**
Sweden	**10**	**28**	**0**	**0**	**48%(–)**	**33%(=)**
Switzerland	**5**	**32**	**0**	**0**	**37%(–)**	**22%(+)**
Taiwan	**6**	**26**	**2**	**0**	**20%(–)**	**8%(–)**
Ukraine	**15**	**19**	**2**	**2**	**48%(+)**	**15%(+)**
United Kingdom	**19**	**26**	**0**	**0**	**18%(–)**	**8%(–)**
USA	**104**	**28**	**1**	**7**	**19%(–)**	**8%(=)**
EU27	**146**	**24**	**4**	**5**	**30%**	**13%(–)**
Total	**439**	**23**	**34**	**89**	**16%**	**6%(–)**

[59] according to IAEA PRIS January 2008, http://www.iaea.org/programmes/a2/index.html unless noted otherwise
[60] in 2006, according to IAEA PRIS November 2007, http://www.iaea.org/programmes/a2/index.html
[61] in 2006, according to BP Statistical Review of World Energy, June 2007
[62] as of 1 January 2008
[63] adapted from WNA 2007, http://www.world-nuclear.org/info/reactors.html
[64] +/-/= in brackets refer to change versus level in 2003 (reference for the 2004 World Nuclear Industry Status Report)
[65] +/-/= in brackets refer to change versus level in 2003 (reference for the 2004 World Nuclear Industry Status Report)
[66] German statistics (AG Energiebilanzen) give the share in the gross national power generation as only 26.4%, in decline since 1997

Overview by region/country[67]

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 4.4% (down from 6% in 2003) of the country's electricity. The reactors are the only operating nuclear power plants in the African continent.

The South African, State owned, utility Eskom is heavily involved in the development of the PBMR (Pebble Bed Modular Reactor). Current planning anticipates construction start of a first unit by 2009 and start-up by 2014. In November 2004, a contract was awarded to Mitsubishi Heavy Industries (MHI) of Japan for the basic design and research and development of the PBMR helium driven Turbo Generator System, as well as the core barrel assembly.[68] There has been considerable international interest in the PBMR project but foreign investors seem to come and go. The British company BNFL had invested $15 million to obtain a 20% equity stake in the enterprise. The now Japanese owned Westinghouse took over 15% of the equity stake from BNFL. Peco Energy – later Exelon Corp - of the U.S. had acquired a 12.5% stake. In December 2001 Exelon said that they were considering building a PBMR reactor in the U.S. in parallel to those proposed in South Africa. However, following the change in management at Exelon, the company withdrew from the PBMR project in April 2002. The only other partners in the development of the PBMR is the South African Industrial Development Corporation, which is owned by the South African Government, and Eskom.

Negotiations with the French reactor builder AREVA for shared research and development into the modular high temperature reactor failed. Concerns have been voiced by French industry representatives that the smaller reactor design, of between 125-165 MW, may increase the unit cost of electricity and make it uneconomic.

The Americas

Argentina operates two nuclear reactors that provide less than 6.9% (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, 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".[69] 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.

Brazil operates two nuclear reactors that provide the country with 3.3% 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 for nuclear weapons by the Brazilian military, practically the entire

[67] Unless otherwise mentioned, the figures on the numbers of reactors operating and the nuclear share in the electricity generation are taken from the IAEA's Power Reactor Information System (PRIS) on-line data and reflect the situation in 2006. The figures on the nuclear share commercial primary energy production are taken from BP, *Statistical Review of World Energy*, June 2007. The numbers of reactors under construction are essentially based on the IAEA's PRIS.
[68] see http://www.pbmr.com/index.asp?Content=8
[69] http://www-pub.iaea.org/MTCD/publications/PDF/cnpp2003/CNPP_Webpage/pages/..\countryprofiles\Argentina\Argentina2003.htm

program was abandoned. Only the first reactor covered by the program, Angra-2, was finally connected to the grid in July 2000, after 24 years of construction.

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 programme 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 moderated by heavy water.

Officially, there are 18 reactors in operation, all of which are CANDUs providing 15.8% (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 October 2007 only four of the eight reactors had returned to operation.

Despite these technical problems Atomic Energy Canada Limited (AECL) have, with the support of the Canadian Export Credit Agency, undertaken an aggressive marketing campaign to sell reactors abroad and to date 12 units having 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 programme. 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, which is to be a light water reactor design.

Canada is the world's largest producer of uranium and in 2005 produced close to 30% 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 654 MW reactors. The first unit went into commercial operation in 1990 and the second in April 1995 with an average construction time of 16 years. In 2006, nuclear power produced 4.9% (down from 5.2% in 2003) of the country's electricity.

The **United States** have more operating nuclear power plants than any other country in the world, with 104 commercial reactors providing 19.4% of the electricity (down from 20% in 2003). Although there are a large number of operating reactors in the U.S., the number of cancelled projects – 138 units – is even larger. It is now 34 years since a new order has been placed that has not subsequently been cancelled (October 1973). In 2007 for the first time in three decades, utilities have requested a license to build a nuclear plant. NRG plans to build two reactors at the South Texas site that already operates two Westinghouse pressurised water reactors and UNISTAR has proposed the building of an AREVA designed U.S.-EPR at Calvert Cliffs. In addition, the utility TVA and the NuStart consortium have applied for a license to build two Westinghouse AP1000 units at the Bellefonte site in Alabama, while "the actual decision to build would be taken later by the company's board".[70] The U.S. Nuclear Regulatory Commission expects a total of 21 applications for 31 units until 2009.[71] However, this is no guarantee of actual construction.

[70] http://www.world-nuclear-news.org/newNuclear/Application_to_build_two_US_nuclear_reactors_filed_311007.shtml?jmid=1134748963
[71] http://www.nrc.gov/reactors/new-licensing/new-licensing-files/expected-new-rx-applications.pdf

The problems of the nuclear industry in the U.S. were compounded, though not caused by the near disaster at Three Miles Island in 1979. The main problems of the industry were economic; problems in construction; and opposition to them; which led to increased construction times and subsequently increased construction costs. Many utilities went bankrupt over nuclear projects. The estimated cost of building a nuclear power plant rose from less than $400 million in the 1970s to around $4000 million by the 1990s, while construction times doubled from the 1970s to 1980s.[72] These facts led the U.S. business magazine *Forbes* in 1985 to describe the industry as "the largest managerial disaster in U.S. business history, involving $100 billion in wasted investments and cost overruns, exceeded in magnitude only by the Vietnam War and the then Savings and Loan crisis".

The last reactor to be completed was Watts Bar 1, in 1996 and the construction license on a further four (Watts Bar 2, Bellefonte 1 and 2, and WNP1) 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 Watts Bar 2 reactor for $2.5 billion. Construction had been started construction in 1972, which was frozen in 1985 and abandoned in 1994. It is expected to take until 2012 to finish the 1,200 MW reactor. Watts Bar 1 was one of the most expensive units of the U.S. nuclear program, its completion took 23 years.

Despite the failure to so far 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 availability of U.S. reactors has increased significantly from 56% in the 1980s to 88.4% in 2006. As a result, along with new capacity coming on line and reactor uprates the output from U.S. reactors has tripled over this period. The lack of new reactor orders means that around 30 percent of the country's reactors will have operated for a minimum of 40 years by 2015. Originally it was envisaged that U.S. 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 October 2007, 48 U.S. nuclear plants had been granted a life extension license, 10 more have applied and around 20 have submitted letters of intent[73].

The election of George W Bush in 2000 was expected to herald a new era of support from 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 licence process has been developed. This will enable designs to reactors to receive generic approval and utilities will then only have to apply for construction licences, which do not involve questioning of the reactors designs. To date, generic approval licences have been awarded to the General Electric Advanced Boiling Water Reactor, the Combustion Engineering System 80+ Advanced Pressurized Water Reactor and Westinghouse's AP-1000 reactor. As of 2003, three utilities, Dominion Resources, Exelon and Entergy had applied for early site permits (ESP). Four years later, only one additional utility has applied for an ESP. In March 2007 Exelon has been granted an ESP by the NRC.

The July 2005 U.S. Energy Act aimed at stimulating investment in new nuclear power plants. Measures include a tax credit on electricity generation, a loan guarantee of up to 80% 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. But the crucial ingredient for a nuclear revival in the country is still lacking: a wave of reactor orders.

James E. Rogers, chief executive of Duke Energy, stresses that a new nuclear power plant would cost as much as a quarter of his company's value on the stock market. At PSI Energy, he spent much of his time "cleaning up the financial fallout from an abandoned nuclear project" that cost his company $2.7 billion. Duke Energy, Rogers says, won't be "the first person on the beach. Having started my career fixing a

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[72] for a cost analysis of operating US reactors see N.E.Hultman, J.G.Koomey, D.M.Kammen, "What history can teach us about the future costs of U.S. nuclear power – Past experience suggests that high-cost surprises should be included in the planning process", Environmental Science & Technology, 1 April 2007

[73] http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html

company that was almost knocked out of the game because of its investment in nuclear and the change in public opinion . . . I'm very optimistic about the role nuclear can play in the future, but I'm cautiously optimistic."[74]

Virtually all spent fuel remains in on-site storage facilities. The Federal Government is responsible for the final disposal of the waste and plans to construct a final disposal site at Yucca Mountain in Nevada. In July 2004, the U.S. Court of Appeals for the District of Columbia Circuit ruled that the U.S. Environmental Protection Agency (EPA) radiation release regulations for Yucca Mountain violated the Nuclear Waste Policy Act. This was because the EPA had proposed that the waste must only be contained for 10 000 years, rather than the National Academy of Science's recommendation of a health standard that would protect the public for between 300 000 and 1 million years. Furthermore, the court ruled that the NRC will have to wait for a new regulation from the EPA on the issue, which may take up to a decade.

Asia

China operates 11 reactors (one more than in 2003) that generate 1.9% (down from 2.2% in 2003) of the country's electricity. Five additional units totalling 3.32 GW are under construction. China has the lowest share of nuclear power in its electricity mix of all nuclear countries. This is likely to remain the case, even if the country embarks on a significant new building program, since overall power consumption is expected to increase rapidly.

In July and September 2004 the Chinese State Council approved three twin reactor projects at Lingdong, Sanmen and Yangjiang. According to the Uranium Information Center in Melbourne, Australia, "the Sanmen and Yanjiang plants are subject to an open bidding process for third-generation designs, with contracts being awarded in 2005. Westinghouse bid its AP1000 (which now has U.S. NRC final design approval), AREVA (Framatome ANP) will bid its EPR of 1600 MWe and Atomstroyexport is expected to bid its AES-92 (V-392 version of VVER-1000) or possibly the larger VVER-1500/V-448. Bids will be assessed on level of technology, the degree to which it is proven, price, local content, and technology transfer."[75]

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 loose 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 when the deal was announced in 1985. 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, Framatome exported just two more units to China over the 20-year period. But China also acquired two Canadian reactors and two Russian plants, while negotiating with fiercely competing U.S., Russian and Franco-German consortia over scarce follow-up orders and developing its own technology. The key phrase is technology transfer.
The contracts for the Lingdong, Sanmen and Yangjiang were not allocated to foreign bidders in 2005 as planned. The current five units will be essentially equipped with Chinese manufactured equipments, with some notable exceptions like the turbine generator sets that will be provided by the French company Alstom.
Westinghouse won the battle against AREVA for four units of Generation III design. The World Nuclear Association reports:

> "In July 2007 Westinghouse, along with consortium partner Shaw, signed the AP1000 contracts with SNPTC, Sanmen Nuclear Power Company, Shangdong Nuclear Power Company (a subsidiary of CPI) and China National Technical Import & Export Corporation (CNTIC). Specific terms were not disclosed. In September 2007 Sanmen Nuclear Power Co signed a $521 million contract with Mitsubishi Heavy Industries and its partner Harbin Power Equipment Company for two steam turbine generators of 1200 MWe. Full construction is to start in 2009 and the first power is expected at Sanmen late in 2013."[76]

[74] Washington Post, 8 October 2007
[75] http://www.uic.com.au/nip68.htm
[76] http://www.world-nuclear.org/info/inf63.html

On 26 November 2007 that AREVA finally announces the signing a commercial contract. The three-year delay of the Generation III reactor sale to China is a clear example of the long lead times of nuclear power projects, even under favourable political circumstances. Nevertheless, AREVA announced the deal as "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".[77]

It is highly unlikely that nuclear power will play a major role in China's energy balance over the next 20 or 30 years, even if a major enlargement program did get underway as the official government forecasts suggest.[78] The International Energy Agency (IEA) in its World Energy Outlook 2007 does not judge Chinese projections credible:

> "The government's target is to have 40 GW in place by 2020, implying that China must add to the plants now operating 31 GW of new plants, as well as 18 GW of nuclear capacity under construction in that year. Although efforts to build more nuclear power plants have been intensified in recent years, the target set by the government seems ambitious given the current level of development, the long construction times and the current global bottlenecks in nuclear component manufacturing, which impose extended delays on delivery. In the Reference Scenario, installed nuclear capacity reaches 21 GW in 2020 and 31 GW in 2030."[79]

That is practically half of the Chinese projections for 2020, but corresponds to the experience with Chinese nuclear planning in the past. It is all the more surprising that the IEA considers an "alternative policy" scenario where the installed nuclear capacity reaches 55 GW by 2030, still less than the current installed capacity in France. Even under this highly unlikely scenario, nuclear power would not provide more than 6% of the nations power.

China has vast cheap coal resources and it is an illusion to imagine that nuclear developments will prevent China from using its coal. The key challenge will be to slow down the enormous increases on the demand side and assist the country to clean up its coal power plant technology.

India operates 17 reactors (three more than 2004) with a total capacity of 3,779 MW that provide just 2.6% 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 2004). The current operating reactors are mainly of a smaller capacity, ranging from 90-200 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 to 10 GWe of operating nuclear capacity installed by year 2000—requiring a tenfold increase from the 1985 base. In reality, installed capacity rose to only 2.2 GWe and its actual (operating) capacity by no more than 1.5 GWe.

More recently 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.[80] There is no evidence 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 foreign official 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 the 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

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[77] AREVA, Press Release, 26 November 2007

[78] Such an expansion would mean to connect to the grid about two reactors or over 2,000 MW per year, which is highly unlikely considering past experience. One particularly wonders, how the country could achieve grid connection of "several hundred" reactors by 2040, as suggested by AREVA CEO Anne Lauvergeon (*Le Monde*, 12 Oct. 04)

[79] OECD International Energy Agency, "World Energy Outlook 2007 – China and India Insights", London, 7 November 2007

[80] India e-news, 23 May 2006

statement with the Indian Prime Minister the ground was laid for a far reaching cooperation agreement.[81] While the agreement has been subject to severe criticism in the U.S.[82], the Indian Prime Minister has admitted to unexpected difficulties from right and left wing parties at home. Manmohan Singh's admission to the U.S. President has been seen by commentators "as an indication that he is not willing to risk bringing down the government before scheduled elections in 2009 for the sake of the nuclear agreement."[83]

Japan operates 55 reactors that in 2006 provided 30% of the country's electricity (up from 25% in 2003). But in 2002 nuclear energy had produced almost 35% of Japan's electricity. On 9 August 2004 five workers were killed after a steam leak at the Mihama-3 station – a dreadful day, particularly in Japan, since this is the anniversary of the Nagasaki bombing. The subsequent investigation revealed a serious lack in systematic inspection in Japanese nuclear plants and led to a massive inspection program. The terrible event is only one in a series of serious accidents at Japanese nuclear facilities: the fast breeder Monju sodium leak in December 1995 (the reactor is still shut-down), the Tokai reprocessing waste explosion in March 1997, the criticality accident at the Tokai fuel fabrication facility in September 1999 and the massive falsification scandal starting in August 2002 that lead to shut down all of Tokyo Electric Power Company's 17 nuclear reactors. TEPCO officials had falsified the inspection records and attempted to hide cracks in reactor vessel shrouds in 13 of its 17 units.[84] 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%.

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 are expected to remain closed for damage verification and repairs for at least one year. 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 whether the units can ever 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. So far, TEPCO projects the impact of the quake on its FY2007 results to be some 603.5 billion yen (€3.6 billion), 440 billion yen coming from fuel costs and the remaining 163.5 billion yen from restoration expenses.[85]
Officially there is one reactor listed as under construction, down from three in 2003. The Monju reactor is considered in "long term shutdown". Further construction plans are vague and have been scaled back several times.
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 of about 43 t, of which about 37 t are in France and the UK.

Pakistan operates two reactors that provide 2.7% of the country's electricity (up from 2.4% in 2003). One additional unit 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.[86] Immediately following India's series of nuclear weapons tests in 1998, Pakistan also

[81] 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
[82] 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
[83] WNA, "US-India deal not dead despite difficulties", 18 October 2007
[84] see also http://cnic.jp/english/newsletter/nit92/nit92articles/nit92coverup.html
[85] http://www.world-nuclear-news.org/corporate/Kashiwazaki_Kariwa_results_and_emissions_double_whammy-011107.shtml
[86] see Mycle Schneider, "Nucléaire : Paris, plaque tournante du trafic pakistanais", Politis, Paris, 1989

exploded several nuclear devices. International nuclear assistance is practically impossible, given the fact that Pakistan, just 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 predominant military character.

On the Korean Peninsula, the **Republic of South-Korea** (ROK) operates 20 reactors that provide 38.6% of the country's electricity (down from 40% in 2003). In addition two reactors are listed as under construction. For a long time, South-Korea, besides China, has been considered the main future market for nuclear power expansion. This is far from certain now. "The anti-nuclear movement is going global", proclaimed South-Korea's energy minister, Bong-Suh Lee, at the 1989 World Energy Conference in Montreal. "We have to stop it before it... stops nuclear generation worldwide." 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 – has hit expansion plans in the 1990s. There are still some plans for new reactors but the program has come to a virtual halt.

The **Democratic People's Republic of Korea** (DPRK) does not have any nuclear power reactor operating. A 1994 international agreement (KEDO) provided for the construction of two power reactors with financial and technical assistance from the U.S., the EU and a number of other countries. In return the DPRK should abandon all nuclear weapons related research and development activity. In 2002 the U.S. accused the DPRK of violating the agreement. While the U.S. accusation turned out to be false 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. However, after an intensive round of disarmament talks, the country on 13 February 2007 signed a "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.[87] However, there is no talk over the completion of the two power reactors that were under construction under previous agreements.

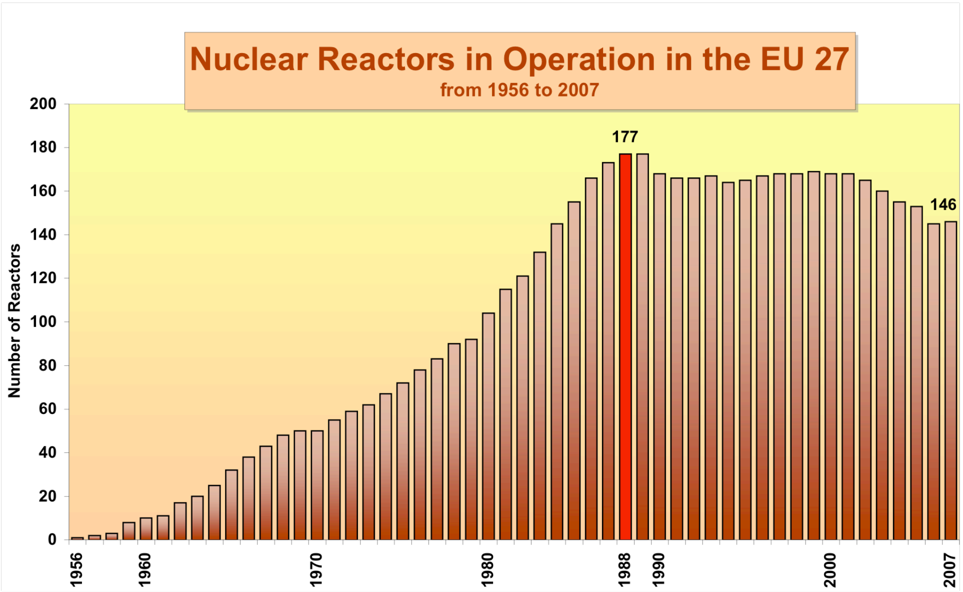
Taiwan operates six reactors that provide 20% of the country's electricity (down from 21.5% in 2003). Two 1350 MWe Advanced Boiling Water Reactors are listed under construction at Lungmen, near Taipei. They were scheduled for start-up in 2006-2007, which has been delayed to 2010. The most recent operating unit started up in 1985. All of the power plants are U.S. delivered. For the two plants under construction, initial bids to supply the units on a turnkey basis were rejected, and contacts were awarded to General Electric for the nuclear islands, Mitsubishi for the turbines and others for the remaining equipments. Construction began in 1999. "When the two reactors were one third complete a new cabinet cancelled the project but work resumed the following year later after legal appeal and a government resolution in favour. But the project was put about a year behind".[88] The project is now three to four years behind.

[87] http://www.fmprc.gov.cn/eng/zxxx/t297463.htm
[88] http://www.world-nuclear.org/info/inf115_taiwan.html

Europe

In October 2007, 15 of the 27 countries in the enlarged European Union (EU27) operated 146 reactors, about one third of the units in the world, down from 151 units in 2003 and 177 reactors in 1989.
The vast majority of the facilities, 125 (down from 132 in 2003), are located in eight of the western EU15 countries and only 21 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 2006, nuclear power produced 30% (down from 31% in 2003) of the commercial electricity in the EU. Moreover, almost half (45%) of the nuclear electricity in the EU27 has been generated by one country only: France.

Graph 7



© Mycle Schneider Consulting *Source: IAEA, PRIS, 2007, MSC*

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 one fifth.

The 125 operating nuclear power reactors in the EU15 as of the end of 2007 – that is 32 units less (!) than in 1988-89 when the number of operating units peaked – provide:

• about one third of the commercial electricity production;
• 13% of commercial primary energy consumption;
• about 6% of final energy consumption.

One reactor is currently under construction in the EU15, in Finland. A second one is officially started construction in France in December 2007. No building site had been opened in the EU15 since the French Civaux-2 unit got underway in 1991. Besides 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 in 25 years.

The following chapter gives a short overview per country (in alphabetical order).

Belgium operates seven reactors and has with 54.4% (down from 55.5% in 2003), behind Slovakia, Lithuania and France, the fourth highest nuclear share in its power mix in the world. In 2002, Belgium passed nuclear phase-out legislation that requires 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.
While the legislation has been passed under a government that included a coalition with the Green Party, the following governments, not including any green ministers, have not overturned the phase-out law.

Finland currently operates four units that supply 28% (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). The Bavarian Landesbank – the Siemens headquarter is located in Bavaria – granted a loan of €1.95 billion, over 60% of the contract value, at a particularly preferential interest rate of 2.6%. The French public COFACE export credit agency covered an additional €720 million loan. The construction started in August 2005. Two and a half years later the project is over two years behind schedule and at least 50% over budget, the loss for the provider being estimated at €1.5 billion. It remains unclear who will cover the additional cost.

In an unusually critical report the Finnish safety authorities 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 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 (...)."[89]

On the attitude of AREVA NP as the vendor, the Finnish safety authorities note:

> "At this stage of construction there has already been many harmful changes in the vendor's site personnel and even the Site Manager has retired and [has been] replaced. This has made overall management, as well as detection and handling of problems difficult. (…) The incompetence in the constructor role becomes obvious in the preparations for concreting of the base slab. (…) The consortium has a habit of employing new people for problem solving, which seems to have resulted in even more confusion about responsibilities."[90]

The power situation of Finland is quite unusual and is the world's number five in per capita consumption of electricity, number two, just after Sweden, in the EU. The average power consumption of a Finn is 2.4 times that of a German and three times that of an Italian. In order to satisfy that extraordinary level of electricity consumption, Finland also imports significant quantities of electricity, occasionally exceeding 10 Billion kWh per year, including from Russia's Leningrad Chernobyl-type RBMK reactors. If Finland reduced its per capita power consumption to Germany's level, the country would save some 44 Billion kWh

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[89] 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
[90] ibidem

of electricity per year, which is twice the amount the four Finnish operating reactors produced together in 2006 and almost three times the amount that the proposed new EPR is expected to generate.

In fact, the circumstances of the EPR order are as extraordinary as the power situation of Finland. The Framatome-Siemens consortium offered a fix price for a turn-key facility, except for site preparatory work and excavation. This is an unprecedented situation in a high-risk financial environment. It remains to be clarified who would be responsible for any to-be-expected cost increases beyond the agreed price. The cost burden for European fabrication is already considered too high by the consortium itself, as it ordered the main components, the reactor pressure vessel and the steam generators in Japan. Suppliers and the utility TVO, main ordering entity amongst a group of 61 clients, declined to indicate whether further components have been ordered outside the EU. In any case, it is unclear whether the facility would qualify for a "made in EC" certificate, considering the entire fabrication and assembly of key components will be manufactured in Japan.

France is the worldwide exception in the nuclear sector. 33 years ago, the French Government has launched the world's largest public nuclear power program as a response to the so-called oil crisis in 1973. However, less than 13% 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.
In 2006, the 59 French reactors[91] produced 78.1% of the electricity (up from 77.7% in 2003), although only about 55% of its installed electricity generating capacity is nuclear. In other words, France has a huge overcapacity that led to dumping electricity on neighbouring countries and stimulated the development of highly inefficient thermal applications. A historical winter peak-load of 86 GW is to be compared with an installed capacity of over 120 GW. Even a comfortable 20% reserve, leaves a theoretical overcapacity of more than the equivalent all of the 34 units of 900 MW. No wonder that the equivalent of a dozen reactors operate only for export and France remains still the only country in the world that shuts down nuclear reactors on certain weekends because it cannot sell their power – not even for dumping prices.

On the other hand, the electricity seasonal peak-load 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 about 55 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 2005, France imported 10 TWh net peak power from Germany for an unknown but probably high price. As a consequence, the national utility EDF (Electricité de France) decided to reactivate over the coming years 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 (that phased out nuclear energy after the Chernobyl accident in 1986) and 15% higher than the EU27 average. French primary energy consumption is also significantly higher than, for example, in Germany.

Considering the existing overcapacities and the average age of about 23 years, France does not need to build any new reactors 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.

[91] Essentially pressurised water reactors, 34 x 900 MW, 20 x 1300 MW and 4 x 1400 plus one 35-year-old 250 MW fast breeder reactor (Phénix, Marcoule).

• 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.

Therefore it will be many years, if not decades, before capacity constraints require new base load power plants. If the French government and EDF have announced their intention to go ahead with a new unit, then this is because the nuclear industry faces a serious problem of maintaining competence in the field. On 21 October 04, EDF has made public Flamanville as the site of the EPR project. Flamanville is only 15 km from the La Hague reprocessing facilities (see hereunder). The site selection came as a surprise to many specialists because it does not fit the economical and technical criteria, but appears to be compensation for the expected cuts in the plutonium business with the completion of work for foreign clients.

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, called reprocessing. Its 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 only a few months worth of foreign fuel remains under contract. Most of the former clients like Belgium and Switzerland have turned away from plutonium separation, or will do so shortly – German utilities have been prohibited by law to ship fuel to reprocessing plants as of July 2005 – or started up own plutonium plants like Japan. The La Hague operator AREVA NC therefore entirely depends on the domestic client EDF for future business. While the existing contract expired in 2007, even this does not cover all the spent fuel already in storage or discharged over that time period and therefore it is clear that there is not and will not be enough business for both reprocessing lines.

An in-depth investigation into the environmental and health consequences of La Hague and the equivalent UK facility at Sellafield has been carried out on behalf of the European Parliament in 2001.[92] This study concluded that these plutonium factories are by far the single most polluting nuclear facilities in the EU. Their radioactive emissions under normal operating conditions correspond to a major accident every year.[93]

Germany operates 17 reactors that, according to the IAEA, provide 31.8% (up from 28.1% in 2003) of the electricity in the country. However, according to German official sources, indicate a nuclear share in the gross national power generation of only 26.4%, in decline since 1997 when the nuclear share stood at 30%.[94]
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 definitely. 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, three top managers of the operator Vattenfall were sacked and the units are to undergo extensive reviews and upgrading and as of the end of 2007 were still not back in operation. At the same time two 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 remains shut down. It is being speculated, that the operator RWE is prolonging the outage in order to push the planned final shutdown date of unit A beyond the next federal elections, scheduled for 2009, in the hope that a pro-nuclear government would overrule current phase-out legislation. The current "grand coalition" government between Christian Democrats and Social

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[92] Mycle Schneider (Dir.), et al., *Possible Toxic Effects from the Nuclear Reprocessing Plants at Sellafield (UK) and Cap de la Hague (France)*, Final Report for the Scientific and Technological Options Assessment (STOA) Program, Directorate General for Research, European Parliament, Luxemburg, November 2001, 170 p.
[93] A new analysis will be published shortly, Mycle Schneider, Yves Marignac, "Reprocessing in France", International Panel on Fissile Materials (IPFM), forthcoming
[94] AG Energiebilanzen, "Bruttostromerzeugung in Deutschland von 1990 bis 2006 nach Energieträgern", 22 August 2007

Democrats has confirmed the phase-out legislation. While the nuclear lobby has not abandoned hopes to overturn the phase-out decision no utility is willing to order a new plant. In a generally hostile public environment, nuclear power has no future in Germany. In the meantime, nuclear power generation has dropped by 16% in the first nine months of 2007 compared to the same period in the previous year.

The **Netherlands** operate a single, 34 year old 450 MW plant that provides 3.5% (down from 4% in 2003) 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 EUR 250 million towards sustainable energy projects. The government added another EUR 250 million, in the process avoiding the compensation claim they would have faced had they continued towards early shutdown."[95]
In early 2004, the Borssele operator EPZ extended a reprocessing contract with COGEMA. This is a curious decision considering that there are no possibilities in the Netherlands to use separated plutonium. EPZ has refused to disclose its plans for the plutonium, but it seems that it will pay French companies to get rid of it.

Spain operates eight reactors (one less than in 2003) that provide 19.8% (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 has 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.

Sweden operates 10 reactors (one less than 2003) that provide 48% (down from 50% in 2003) of the electricity. Sweden is the most power consuming country in the EU and number four 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 absorb about 40 TWh, more than a quarter of the country's power consumption.

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 rather a "program limitation" 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. So the first reactor (Barsebäck-1) was shut down in 1999 and the second one (Barsebäck-2) went off-line in 2005. Unlike in the German or Belgian cases, the Swedish government agreed to pay compensation for the plant closures (about 900 million euros for Barsebäck-1). State negotiator Bo Bylund stated in October 2004 that he expects a third Swedish power unit to be closed soon after 2010, and the other closures to follow at a pace of approximately one unit every three years. This would mean that Sweden's last unit would be closed "sometime between 2020 and 2030" corresponding to a reactor lifetime of about 40 years. Industry Minister Leif Pagrotsky expressed his wish for a speedier phase out of the remaining 10 units, saying: „I hope that the closure could be arranged as soon as possible."[96]

The **United Kingdom** operates 19 reactors (4 less than 2003) that provide 18.4% (down from 22% in 2003) of the country's electricity. Many of the UK's nuclear plants are relatively small, particularly inefficient and over 30 years old. Germany produces more than twice the amount of electricity per installed reactor than the UK. The productivity of the British reactors might further decline following the unexpected discovery of

[95] http://www.world-nuclear.org/info/inf107.html
[96] NucNet, 6 October 04

aging problems that turn out “more severe that previously thought”.[97] The Advanced Gas cooled Reactors (AGR), are “proving increasingly unreliable”.[98] If British Energy does not build new reactors, warns the nuclear lobby’s World Nuclear News, “by 2023 it will only be operating Sizewell B - a modern design pressurized water reactor - as the AGRs are retired.”[99]
The UK nuclear industry has gone through troublesome decades. Ever since Margaret Thatcher failed in the first attempt of privatization in the late 1980s when the nuclear kWh turned out to be twice as expensive as previously indicated, nuclear utilities and fuel industries have moved between scandal and virtual bankruptcy. In September 2004, the European Commission accepted a UK Government €6 billion restructuring package to stop the privately owned nuclear generator British Energy from going into liquidation. The funding was part of a larger process of establishing a specific Nuclear Decommissioning Agency (NDA). The NDA was to generate part of the funds needed to decommission the UK’s nuclear facilities – currently estimated to the equivalent of over €100 billion – from the operation of the THORP reprocessing and the SMP plutonium fuel manufacturing plants. However, both 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 building of over 80 m3 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. Its commercial reopening is currently planned for the spring 2008.

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.[100] And her colleague that held the Industry Minister’s chair, Patricia Hewitt, clarified in *The Times*[101]: “Our priority is energy efficiency and renewable energy. We have no proposals now for building new nuclear power stations but at some point in the future new nuclear build might be necessary if we are to meet our carbon targets. Before any decision is taken on this there would need to be the fullest public consultation and the publication of a White Paper setting out the Government's proposals. Current economics of new nuclear build make it an unattractive option and there are important issues around the legacy of nuclear waste. We are confident that renewable energy will provide a significant and growing contribution to Britain's energy needs.”

However, the two ministers quoted above are not in office anymore 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 equally considered inappropriate by a number of environmental and consumer organisations and Greenpeace filed an official complaint over the conduct of the process with the Market Research Standards Board (MRSB), following their withdrawal along with other NGOs from the consultation a month earlier.[102] 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 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.[103]

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[97] WNN, “Aging causes grey hairs at British Energy”, 26 October 2007, http://www.world-nuclear-news.org/regulationSafety/Aging_causes_grey_hairs_at_British_Energy_261007.shtml?jmid=1128393678
[98] ibidem
[99] ibidem
[100] *The Observer*, 19 September 2004
[101] *The Times*, 18 September 2004
[102] http://www.greenconsumerguide.com/index.php?news=3545
[103] *The Guardian,* 23 October 2007

In March 2006 the UK Government's Sustainable Development Commission issued its report on nuclear energy and came up with the following conclusion[104]:

> "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) simple doesn't justify the substantial disbenefits and costs that would be entailed in such a programme."

The only Non-EU Western European country that operates nuclear power plants is **Switzerland**. It operates five reactors that cover 37.4% (down from 39.7%) 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?"[105] 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 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.

Nuclear Power in Central and Eastern Europe

In **Bulgaria** in 2006 nuclear power provided 43.6% (up from 37.7%) of the country's electricity, but on 31 December 2006, to fulfil 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 a result of the closure. At the Kozloduy site two VVER 1000 reactors remain in operation.

In 2003 the Government announced its intention to restart the construction at the Belene site in Northern Bulgaria. Construction of a reactor initially began in 1985 but following the political changes in 1989 construction was suspended and formally stopped in 1992, in part due to concerns of the geological stability of the site. In 2004 a call for tender for the completion of the 1,900 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 lead by Skoda and one by Atomstroyexport (ASE), were withdrawn. In October 2006 the ASE consortium, associating the Franco-German AREVA NP and Bulgarian firms, was awarded the €4 billion contract, although as of October 2007 no final contract had been signed.

Controversy remains over the completion of the Environmental Impact Assessment (EIA), which does not contain adequate information on the seismic conditions, nor does it address beyond design basis accidents or give details of the potential impacts of decommissioning[106]. 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[107]. In February 2007 the Bulgarian authorities announced construction plans to the European Commission, as they are required to do under the Euratom

[104] Sustainable Development Commission, *Is Nuclear the Answer?*, London, March 2006
[105] 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 04
[106] Greenpeace, "Comments on the non-technical summary of the EIA report of the Investment Proposal of the Belene Nuclear Power Plant", June 2004
[107] Answers of the EIA team on question 29 by NGOs and citizens during the hearings on the Framework of the EIA for Belene, 2004

Treaty. A Belene construction project has been established in which the State utility Natsionalna Elektricheska Kompania (NEK) will retain overall control, with 51%, but the remaining shares have been put to tender, with a number of companies, including ENEL, EDF, Suez's Electrabel, E.ON, RWE, and CEZ all said to have expressed an interest. The total cost of the project is now estimated by the operator to be around €7 billion (€4 billion for the power stations plus associated infrastructure development costs).

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 31.5% (up from 31.1%) of the country's 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 reactors were eventually started in 2000 and 2002. The International Energy Agency has suggested that *'*despite low operating costs, amortising Temelin's costs – a total bill estimated at CZK99 billion (€3.7 billion), plus CZK10 billion (€0.37 billion) of unamortised interest – will create a significant financial burden for CEZ'.[108]
Even after the reactors began operating the controversy has not stopped as technical problems, especially those relating to the uniquely large turbines have caused a number of unplanned outages. The turbines problem was more or less resolved by 2004. However, since then, the biggest – and relevant also from the nuclear safety perspective – problem that keeps load factors low is the problem with deformations of fuel elements. As a result the capacity factor of both units remain low, at only about 70%, well below the international average for plants of the same vintage. Furthermore, since 2000, in total 20 INES-1 rated events took place at Temelin, with increasing tendency (2000 – one, 2001 – two, 2002 – two, 2003 – two, 2004 – three, 2005 – five, 2006 – four, 2007 – two by mid year).
The Dukovany plants have operated since the first half of the 1980s and are subject to engineering changes to both extend the life of the reactors while simultaneously expand their output by about 15%. It is now envisaged by the operators that the power plant will continue until 2025.

There is one nuclear power plant in operation in **Hungary** at Paks, which houses four VVER 440-213 reactors providing 37.7% (up from 32.7% in 2003) of the country's electricity production. The reactors started commercial operation in the early 1980s and have been the subject to engineering works to continue their operation for up to 50 years with an expanded output of up to 20%. In April 2003 the second reactor at the site experienced the country's worst ever nuclear accident, rated on the international scale as a 'serious incident' (level 3), which resulted in the evacuation of the main reactor hall and the venting of radioactivity into the outside environment. During the cleaning of fuel rods inadequate cooling was applied which resulted in the severe damaging of all of the 30 fuel assemblies. The reactor was out of operation for 18 months.
In 1998 the operator of the Paks power plant proposed building additional nuclear capacity, but this was rejected by the national utility MVM. However, in 2007 plans for the construction of new nuclear units have once again been floated by Government officials, although they are not part of any approved energy policy.

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 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 time was said to be due to the large output from the station. However, even after the closure of unit one in 2004 the power station is still responsible for 72.3% (down from 79.9%) of the country's electricity. This is because the power station is far too large for the country's relatively small demand. The country's dependency on one reactor for such a large percentage of its electricity is highly risky from a security of supply perspective.

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. It is reported that as host Lithuania will provisionally have 34% of the project with the other partners having 22% of a project that may contain 3 GW of nuclear power, however,

[108] International Energy Agency, 'Energy Policies in IEA Countries, Country Review - Czech Republic', IEA 2001

the final ownership allocation is still to be finalised. If the project is to proceed it would also require the construction of additional transmission links, in particular between Lithuania and Poland, costing approximately €300 million. During 2007 an Environmental Impact Assessment was to be undertaken and completed in 2008. However, in early 2008 it has been reported that "Poland's newly-elected Liberal Democratic Congress government has not shown the enthusiasm of its predecessor for participation in the Ignalina nuclear project in neighbouring Lithuania" and that the Polish participation is "not predestined".[109]

The Cernavoda nuclear power plant hosts the only CANDU (Canadian designed) reactor in Europe in **Romania**. The power plant was started under the regime of Nicolae Ceausescu and was initially proposed to house five units. Construction was started in 1980, 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, including a $140 million Canadian loan and a €223 million Euratom loan, was connected to the grid in August 2007.
Nuclear power provided 9% (down from 9.3%) of Romania's electricity in 2006.
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 shall complete and provide operation and maintenance, and a private investor. Bids are to be submitted by late 2007 with work said to begin in 2008 and a tentative operational date of unit 3 in 2014 and unit 4 in 2015. In view of the past experience the schedule seems extremely optimistic.

The utility Slovak Electric (SE) operates all the nuclear power plants in **Slovakia** at two sites: Bohunice, which houses three VVER 440 units and Mochovce which has two. The Bohunice power station has the EU's remaining operational VVER 440-230 unit, which is scheduled for closure in 2008, with the first reactor closing in 2006. As with other VVER 440-213 units engineering plans are being implemented to extend their operating lives for 40 years, which would enable the station to operate until 2025.
The Mochovce units were only completed in 1998 and 1999. They were to have been the first reactors to receive funding for completion by the European Bank for Reconstruction and Development (EBRD) in 1995, however in the final week before a likely positive decision by the Bank's board of directors, the Slovakian authorities withdrew the loan application. It was said that the withdrawl was due to the conditions and price of the project and that it would be completed at a lower cost using more Russian and Slovak engineering. At that time it was assumed that completing the reactors that were officially 90% and 75% complete would cost in the order of €800 million. However, when finally completed the completion cost was thought to be around double that amount.
Nuclear power provided 57.2% (57.4% in 2003) of the electricity in the country in 2006.
In October 2004 the Italian utility ENEL was successful in its bid to acquire 66% of the state utility SE. As part of its bid ENEL proposed to invest nearly €2 billion in new generating capacity, which was reported to included the completion of Mochovce 3 and 4. 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 to that end. Despite pressure from the Slovak Government to restart construction in 2007 the approval and bidding process has not been completed. The reactors are scheduled to be completed by 2012 and 2013. If this project proceeds, the EU would see 40 years old Soviet reactor design without modern containment systems being constructed, which would create a very dangerous precedent. It is not currently envisaged that a new environmental impact assessment will be undertaken with approval based on the 1986 building permit.

The Krsko nuclear power plant in **Slovenia** was the world's first reactor to be jointly owned by two countries– Croatia and Slovenia. The reactor is a 696 MW Westinghouse pressurised water reactor that was connected to the grid in 1981 and is due to operate until 2021. Nuclear power provided 40.3% (40.5% in 2003) of the electricity in the country in 2006.
The output is shared between the two countries. Discussions are underway for the construction of a second reactor at the site, with a decision in principle expected in the next year.

[109] WNN, 3 January 2008

Russia and the Former Soviet Union

Armenia has one remaining reactor, called Armenia-2, at the Medzamor nuclear power plant, which is situated within 30 km of the capital Yerevan. The reactor is of the early Soviet design, a VVER 440-230, and has raised considerable concerns over the years, including within the nuclear community. However, it continues to operate largely due to the high percentage, 42% (up from 35.5% in 2003), of the country's electricity that it delivers. The reactor is due to close in 2016. The Armenian Government is investigating the financing and constructing of an additional reactor, with the Energy Minister stating to Parliament in September 2007 that it would cost $2 billion and take four and half years to build.

There are 31 operating reactors in **Russia** with a total installed capacity of 21.7 GW. In 2006 the nuclear fleet generated 144 TWh, providing 15.9% (down from 17% in 2003) of the country's electricity. Of the reactors in operation: 15 are of the early design, four first generation VVER 440-230 and 11 RBMK reactors, that are being closed in EU Member States as part of the accession agreements; four are small (11 MW) boiling water reactors used for cogeneration in Siberia; one fast breeder; and 11 second generation light water reactors (two VVER 440-213 and nine VVER 1000s). The average age of the reactors in operation is 25 years and only two have been completed in the last 10 years.

There are seven reactors officially under-construction, of which four were started over 20 years ago (Volgodonsk-2[1983]; Kursk-5 [1985], Kalinin-4 [1986] and Balakovo-5 [1987]). Of the other reactors, one is the fast breeder at Beloyarsk and two are small pressurised water reactors (30 MW) for the Arkhangelsk region to be placed on barges. It appears that Balakovo-5 has "disappeared from the list" and "completion has been deferred" due to Russia's utility UES putting it "as low priority".[110] However, another unit, the new VVER 1200 at Novovoronezh has appeared on the Russian construction list.[111]

In September 2007 AtomEnergoProm announced plans for the construction of an additional eight VVER 1200 by 2016 with further reactors to be built after this. In total the Government body expects that the current nuclear capacity will more than double by 2020. Over past years the Government has been quick to develop new 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. Despite the fact that these plans have not materialised, the improved economic situation in Russia makes large expenditure on infrastructure projects more possible. In October 2006 a US$ 55 billion nuclear energy development program was adopted. Nearly half of this proposed programme, $26 billion was to come from the federal budget, with the rest coming from the industry.

Over the last decade there has not been much change in the nuclear sector with few plants opening or closing. However, this situation will not continue as a large number, up to 17, of the country's reactors are expected to close in the next 10 years. Therefore, unless the major construction plan envisaged by the Federal Task Program is actively developed Russia will see a major decline in its nuclear output by 2020.

Russia is constructing more reactors for export than it is for its domestic market, with sales of the newer design, the AES 91 and AES 92, in Bulgaria, China and India. A number of other reactor designs are being developed, including smaller 300 MW boiling water reactor. In addition Rosatom has been given approval for the construction of reactors on barges, the so-called floating reactors.

Russia has developed the whole nuclear fuel cycle. Russian uranium resources are around 5% of the world's total with the largest mines close to the Chinese/Mongolian border. 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.

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[110] http://www.uic.com.au/nip62.htm

[111] ibidem; In order to unify the sources, we have decided to base the table of units officially under construction in Annex 1 on the data provided by the IAEA PRIS, even if it is obviously contradicting other sources.

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 and has resulted in a curtailing of significant levels of reprocessing in Russia. The construction of the RT-2 plant at Krasnoyarsk, proposed for reprocessing of VVER 1000 fuel, has been stopped and now only the VVER 440 fuel is reprocessed.

Ukraine has fifteen reactors in operation providing 47.5% (up from 45.9% in 2003) of the country's electricity. 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 developed 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 in the early stages of decommissioning.

Since 1986 three reactors have been completed, Zaporozhe 6, Khmelnitsky 2 and Rovno 4. The later 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 to start the construction of 11 more reactors by 2030, it is as yet unclear which designs, sizes and locations will be chosen for these reactors, with decisions scheduled for 2008. The plan further envisages that the existing reactors will be replaced, therefore a total of 22 new reactors are proposed.

Conclusions

The status and perspectives of the nuclear industry in the world have been subject to a large number of publications and considerable media attention over the last few years. The present report attempts to provide solid elements of key information for intelligent analysis and informed decision-making.

As of the end of 2007 there are 439 nuclear reactors operating in the world. That is 5 less than five years ago. There are 34 units listed by the International Atomic Energy Agency (IAEA) as "under construction". That is about 20 less than in the late 1990s.
In 1989 a total of 177 nuclear reactors had been operated in what are now the 27 EU Member States. That number shrank to 146 units as of the end of 2007.

In 1992 the Worldwatch Institute in Washington, WISE-Paris and Greenpeace International published the first *World Nuclear Industry Status Report*. As a first updated review in 2004 showed the 1992 analyses proved correct. In reality, the combined installed nuclear capacity of the 436 units operating in the world in the year 2000 was less than 352,000 megawatts – to be compared with the forecast of the International Atomic Energy Agency (IAEA) from the 1970s of up to 4,450,000 megawatts. Today the 439 worldwide operating reactors total 371,700 megawatts. Nuclear power plants provide 16% of the electricity, 6% of the commercial primary energy and 2-3% of the final energy in the world – the tendency is downwards – less than hydropower alone. Twenty-one of the 31 countries operating nuclear power plants decreased their share of nuclear power within the electricity mix in 2006 if compared with 2003.

The average age of the operating power plants is 23 years. Some nuclear utilities envisage reactor lifetimes of 40 years or more. Considering the fact that the average age of all 117 units that have already been closed is equally about 22 years, the doubling of the operational lifetime seems already rather optimistic. However, we have assumed an average lifetime of 40 years for all operating reactors and those that are currently under construction[112] and have calculated how many plants would be shut down year by year (see graph 6). The exercise enables an evaluation of the 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 units currently under construction with a scheduled start-up date, 70 reactors (40,000 MW) would have to be planned, built and started up until 2015 – one every month and a half – and an additional 192 units (168,000 MW) over the following 10-year period – one every 18 days. This result has not changed from the 2004 analysis.
Even if Finland and France each build a reactor, China went for an additional 20 plants and Japan, Korea or Eastern Europe added a few units, the overall worldwide trend will most likely be downwards over the next two or three decades. With extremely long lead times of 10 years and more, it is practically impossible to maintain or even increase the number of operating nuclear power plants over the next 20 years, unless operating lifetimes would be substantially increased beyond 40 years on average. There is currently no basis for such an assumption.
Lack of trained workforce, massive loss of competence, severe manufacturing bottlenecks (a single facility in the world, Japan Steel Works, can cast large forgings for certain reactor pressure vessels) lack of confidence of international finance institutions, strong competitors from highly dynamic natural gas and renewable energy systems exacerbate the aging problems of the industry.
Two and a half years after construction start, the world's largest nuclear builder's show case pilot project, AREVA's EPR reactor Olkiluoto-3 in Finland, is over two years behind schedule and at least €1.5 billion (50%) over budget.
In June 2005, the trade journal *Nuclear Engineering International* published the analysis of the 2004 Edition of the World Nuclear Industry Status Report under *their* headline. *"On the way out - In sharp contrast to multiple reporting of a potential 'nuclear revival', the atomic age is in the dusk rather than in the dawn"*.

At the end of 2007, we have nothing to add.

[112] The calculation excludes reactors that do not have a scheduled start-up date. That concerns 10 of the 34 units listed by the IAEA as under construction as of the end of 2007.

Appendix-1: Nuclear Reactors Listed as "Under Construction" *as of 31 December 2007*

Country	Units	MWe (net)	Construction Start	Planned Grid Connection
ARGENTINA	1	692	1981/07/14	?
BULGARIA	2	1906		
Belene-1		*953*	1987/01/01	?
Belene-2		*953*	1987/03/31	?
CHINA	5	3220		
Hongyanhe		*1000?*	2007/08/18	?
Lingao-3		*1000*	2005/12/15	2010/08/31
Lingao-4		*1000*	2006/06/15	?
Qinshan-II-3		*610*	2006/03/28	2010/12/28
Qinshan-II-4		*610*	2007/01/28	2011/09/28
FINLAND	1	1600	2005/08/12	2010/12/01*
FRANCE	1	1600	2007/12/03	Summer 2011
INDIA	6	2910		
...Kaiga-4		*202*	2002/05/10	2007/07/31**
...Kudankulam-1		*917*	2002/03/31	2009/01/31
...Kudankulam-2		*917*	2002/07/04	2009/07/31
...PFBR		*417*	2004/10/23	?
...Rajasthan-5		*202*	2002/09/18	2007/06/30**
...Rajasthan-6		*202*	2003/01/20	2007/12/31
IRAN	1	915	1975/05/01	2007/11/01***
JAPAN	1	866	2004/11/18	2009/12/01****
PAKISTAN	1	300	2005/12/28	2011/05/31
RUSSIA	7	4585		
...Balakovo-5		*950*	1987/04/01	2010/12/31
...BN-800		*750*	1985*****	?
...Kalinin-4		*950*	1986/08/01	2010/12/31
...Kursk-5		*925*	1985/12/01	2010/12/31
...Severodvinsk-1		*30*	2007/04/15	?
...Severodvinsk-2		*30*	2007/04/15	?
...Volgodonsk		*.950*	1983/05/01	2008/12/31
SOUTH KOREA	3	2880		
…Shin-Kori-1		*960*	2006/06/16	2010/08/01
…Shin-Kori-2		*960*	2007/06/05	2011/08/01
…Shin-Wolsong-1		*960*	2007/11/20	2011/05/28
TAIWAN******	2	2600		
...Lungmen-1		*1300*	1999	2010
...Lungmen-2		*1300*	1999	2010
UKRAINE	2	1900		
...Khmelnitski-3		*950*	1986/03/01	2015/01/01
...Khmelnitski-4		*950*	1987/02/01	2016/01/01
USA	1	1165	1972/12/01	?
Total:	**34**	**27139**		

Sources: IAEA PRIS, December 2007, except otherwise noted

Notes:
* This date refers to the new planned start-up of the plant. However, the plant owner TVO has so far reported dates for the "commercial operation" of the plant, that usually takes place several months after the initial start-up. It is possible that the new delays reported in December 2007 will postpone commercial operation to the end of 2011. (TVO, Press Release, 28 décembre 2007, see http://www.tvo.fi/1016.htm
** As of the end of 2007, the unit was not reported as connected to the grid.
*** As of the end of 2007, the unit was not reported as connected to the grid.
**** This date refers to the planned start of commercial operation of the plant.
***** 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.
****** Data on Taiwan from http://www.world-nuclear.org/info/inf115_taiwan.html