THE WORLD NUCLEAR INDUSTRY STATUS REPORT 2004

by

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Introduction and General Overview

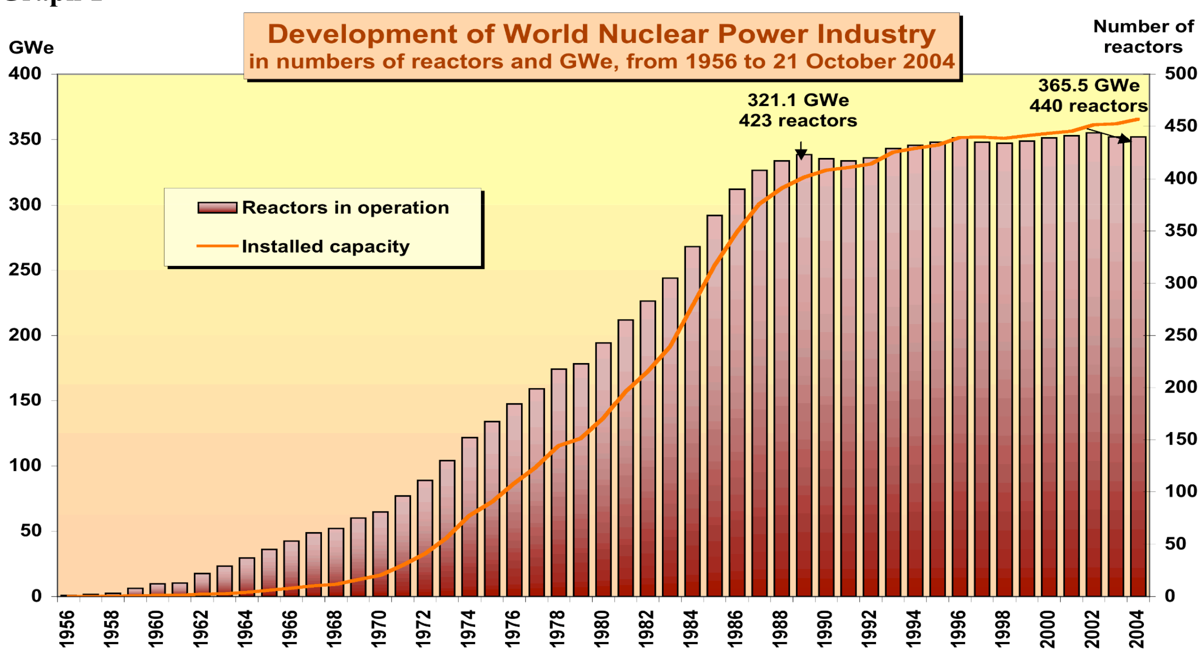
Fifty years ago, in September 1954, the head of the US Atomic Energy Commission stated that nuclear energy would become "too cheap to meter": The cost to produce energy by nuclear power plants would be so low that the investment into electricity meters would not be justified. By coincidence the US prophecy 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, under the original slogan "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.
Twelve years ago, the Worldwatch Institute in Washington, WISE-Paris and Greenpeace International published the *World Nuclear Industry Status Report 1992*. In the current international atmosphere of revival of the nuclear revival debate – it has been a periodically recurring phenomenon for the past twenty years - two of the authors of the 1992 report, Mycle Schneider and Antony Froggatt, now independent consultants, have carried out an updated review of the status of the world nuclear industry.

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 7% above the 1992 figure. The analysis in the 1992 Report proved correct. At the end of October 2004 the 440 worldwide operating reactors – just four more than in 2000, but four less than at the historical peak in 2002, cumulated 365,500 MW of installed capacity (see Graph 1).

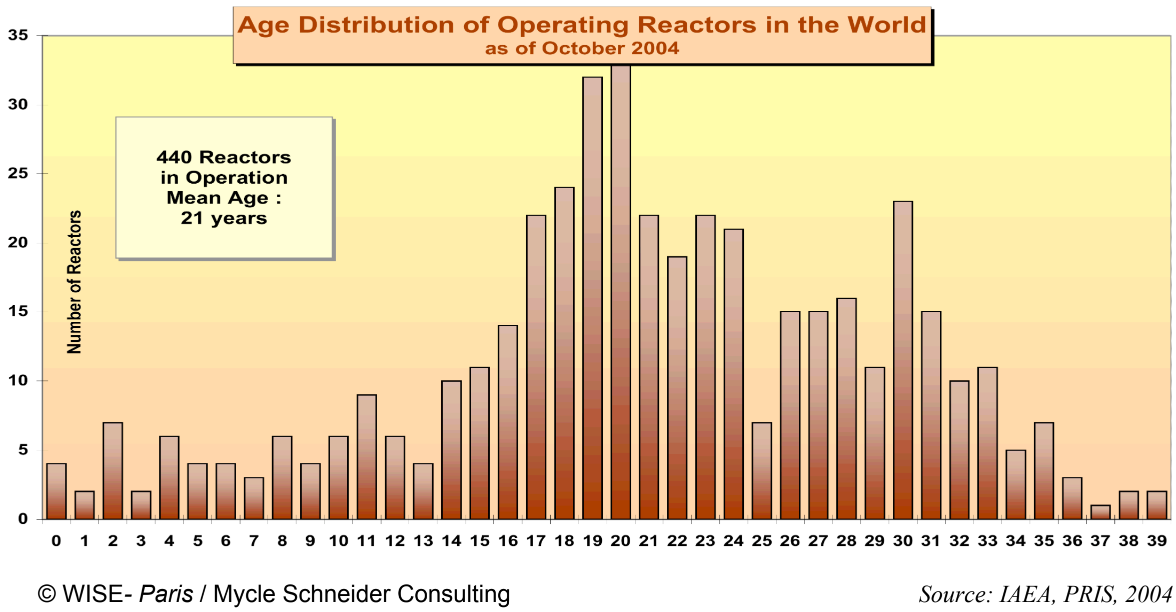
Graph 1



© WISE- *Paris* / Mycle Schneider Consulting *Source: IAEA, PRIS, 2004*

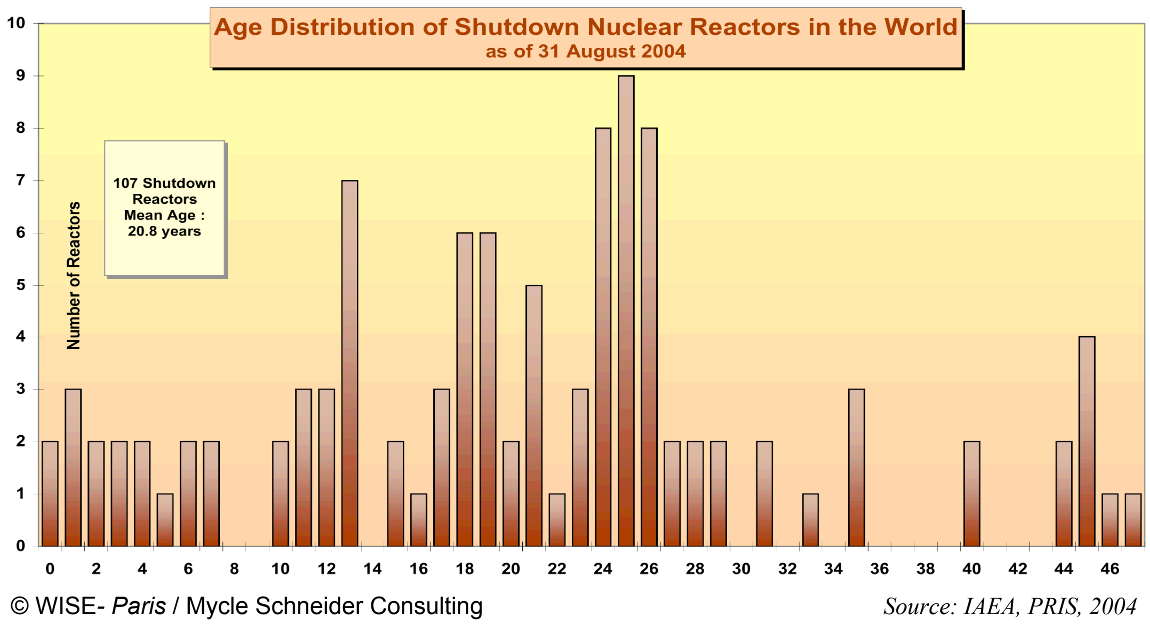
The total installed capacity has increased faster than the number of operating reactors because units that are being shut down are usually smaller than the new ones coming on-line and because of uprating of capacity in existing plants. According to the World Nuclear Association, in the USA the Nuclear Regulatory Commission has approved 96 uprates since 1977, a few of them "extended uprates" of up to 20%.[1]
However, in the absence of significant new built, the average age of operating nuclear power plants in the world has been increasing steadily and stands now at 21 years (see Graph 2).

Graph 2



In total 107 reactors have been permanently shut down definitely with an average age of also about 21 years, the figure is up four years from the situation in 1992 (see Graph 3). Over the last 12 years, 32 reactors have been shut down and 52 have been connected to the grid, which corresponds to a net addition of one and a half reactors per year.

Graph 3

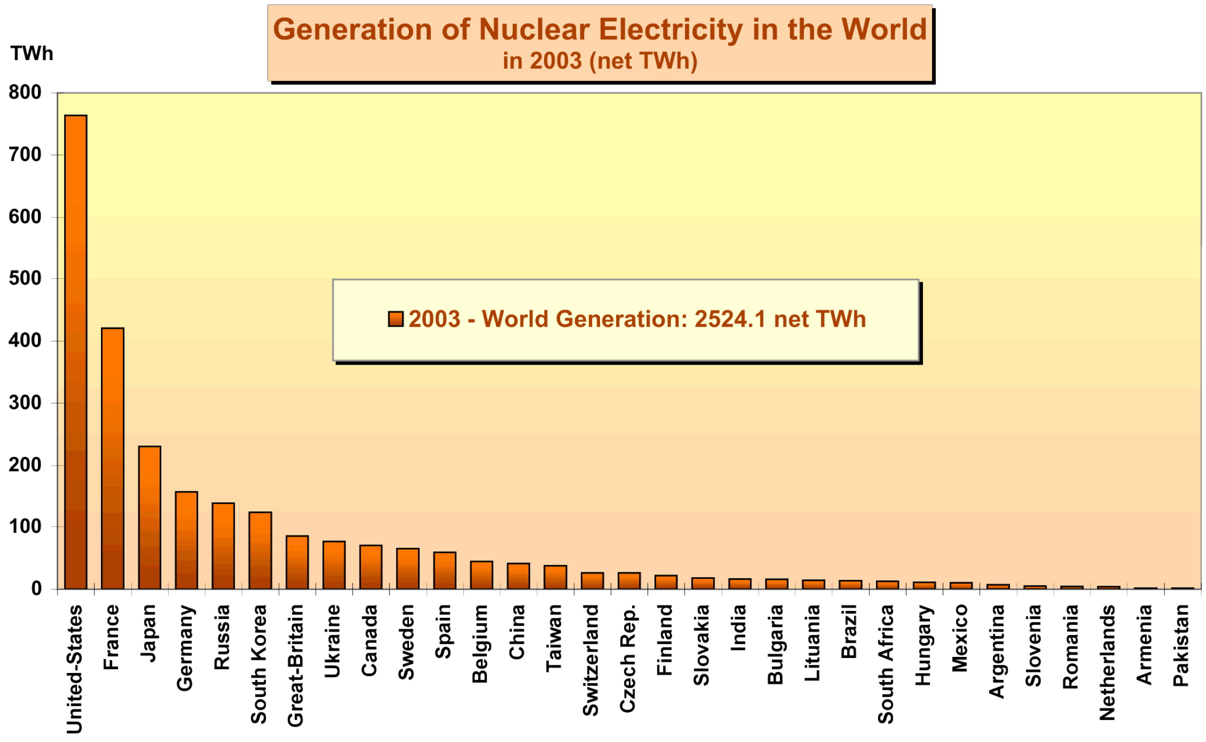


[1] http://www.world-nuclear.org/info/inf17.htm

The annual nuclear capacity increase since year 2000 corresponds to about 3,000 MW, including uprating. This figure should be compared to the global increase in all electricity generating capacity of about 130,000 MW to 180,000 MW *per year*. This leaves nuclear power with a market share of roughly 1.5% - 2.5% of the annual increase. Therefore the increased output from nuclear power will not allow nuclear power to even maintain the current 16% share in the world power production and the 6% in the commercial primary energy or about 2% to 3% final energy. All these parameters are already on the decline.

Nuclear energy remains limited to a restricted number of countries in the world. Only 31 countries, or 16% of the 191 UN 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 about 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, has started many years ago.

Graph 4



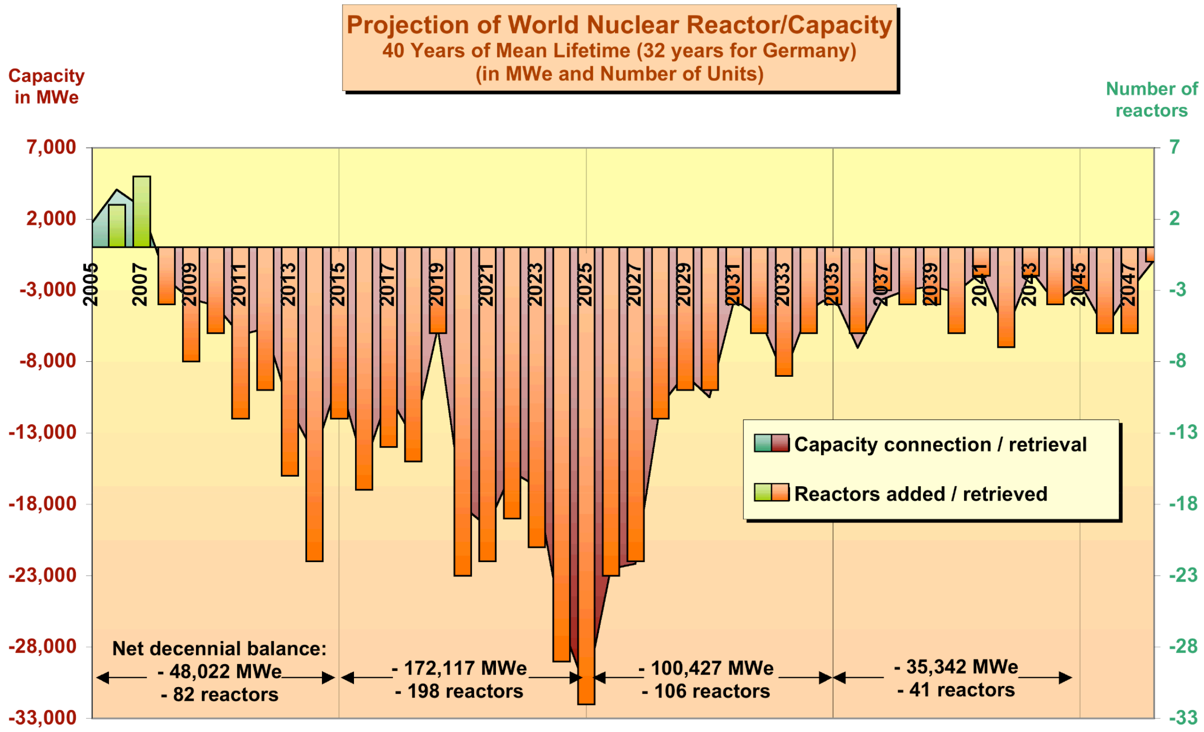
Source: IAEA, PRIS, 2004

The international nuclear industry proclaims a rosy future. "Rising gas prices and greenhouse constraints on coal have combined to put nuclear power back on the agenda for projected new capacity in both Europe and North America," says the World Nuclear Association.

The Vienna based International Atomic Energy Agency (IAEA), however, sees the future mainly restricted to Asia: "Twenty-two of the last 31 nuclear power plants (NPPs) connected to the world's energy grid have been built in Asia, driven by the pressures of economic growth, natural resource scarcity and increasing populations. Of the new NPPs presently under construction, 18 of the 27 are located in Asia, while construction has virtually halted in Western European and North American countries with long-standing nuclear power programmes."[2] But as Graph 5 shows, current numbers of reactors under construction fall far short of the number necessary to even replace existing units.

[2] IAEA, Press Release, 26 June 04

Graph 5



© WISE- *Paris* / Mycle Schneider Consulting *Source: IAEA, PRIS, 2004*

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 in order 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 18 German nuclear plants that, according to German legislation, will be shut down at an average age of about 32 years – which is optimistic as the average age of reactors closed to date is 21 years, but which seems possible given the progress that has been achieved on the current generation of plants compared to the previous one. Graph 5 illustrates the results. Over the next 10 years, 82 new reactors would have to start up operation. The calculation takes into account 18 reactors with a firm start-up date of the 27 units listed as under construction by the IAEA as of June 2004. In other words, another 73 reactors would have to be planned, built and started up until 2015. This is virtually impossible given the long lead times for nuclear power projects. One EPR in Finland and one more in France won't change that picture. Further more, over the next 20 years a total of 280 units would have to be replaced in order to maintain the same number of plants operating than today. China is said to have plans for up to 32 new nuclear plants until 2020. A prospect that seems highly unlikely but not impossible. But even such an extraordinary undertaking in terms of capital investment, technical and organizational challenge would cover hardly more than 10% of the number of units that reach age forty.

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 key problems with nuclear power have not been overcome and will continue to constitute a severe disadvantage in global market competition. Ken Silverstein, Director of the US 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".[3]

In particular in the US, the nuclear industry has put up a smoke screen in front of its own difficulties to survive, but it does not seem to work. "The political reality in the US today would lead to the conclusion that there will not be any more nuclear power plants built in this country for a long time", says James A. Baker, the former secretary of state to President George H.W. Bush.[4] French establishment analyst Jean-Marie Chevalier, Director of the Geopolitical Center for Energy and Primary Materials (CGEMP) corroborates Baker's point of view: "[President George W.] Bush can always say that nuclear power should be re-launched. Investors are not queuing up, because nuclear power has as the enormous disadvantage today to require a very capitalistic investment and it is very long to build. Nobody knows what the electricity markets will be in seven or eight years when the plant will be built. And therefore, the financing bodies, the bankers are currently very, very hesitant about nuclear power."[5] Actually, the bankers' reluctance towards nuclear energy is not new. 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 hope for a nuclear revival, the Asian Development Bank does not finance nuclear projects.

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."[6] But not even the ultra-pro-nuclear Bush administration seems willing to spend the money. The US Department of Energy (DOE) cut the 2005 budget request for the Nuclear Power 2010 Program by 47% to modest US$ 10 million while the nuclear industry is asking for US$ 60 million to US$ 80 million. At a 10 February 2004 congressional hearing, a DOE representative has suggested that the cut came because DOE did not have sufficient support from industry about new plant construction to pursue the program "in a more aggressive way."[7] The *New York Times* seems right.

The international energy industry as a whole remains extremely sceptical about nuclear power. Leonardo Maugeri, senior vice president for corporate strategies at ENI, the Italian oil and gas giant, wrote in Newsweek: "Many energy industrialists think nuclear is the answer, but they rely on a misleading analysis of its cost competitiveness. Even if you ignore the political concerns surrounding nuclear waste, producers often fail to correctly calculate the real price of electricity produced from nuclear energy. It costs about as much to close a nuclear plant as it does to build a new one, which is why nuclear power companies are now lobbying worldwide to delay planned plant closings."[8]
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.

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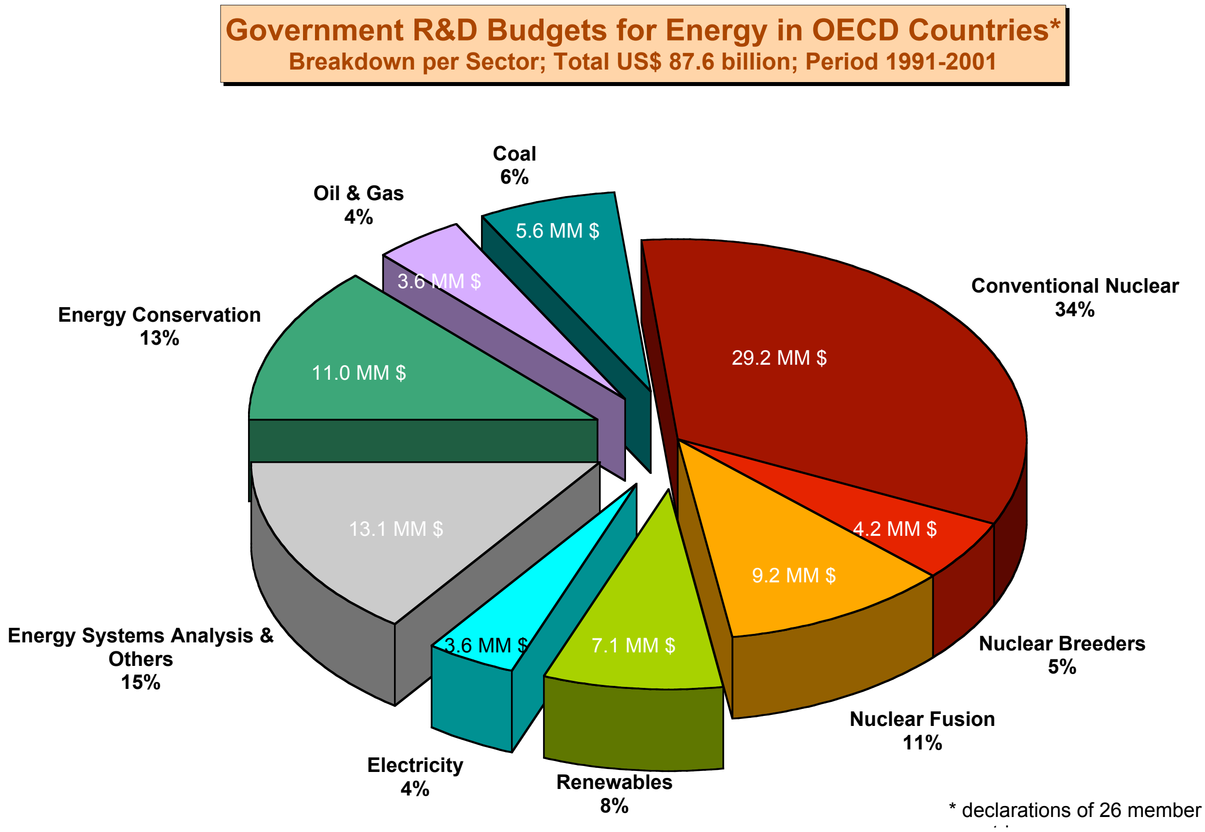
[3] UtiliPoint International, 21 June 04
[4] Financial Times, 29 June 04
[5] www.cite-sciences.fr/francais/ala_cite/science_actualites/sitesactu/magazine/article.php?id_mag=3&lang=fr&id_article=1423
[6] The New York Times, 31 March 04
[7] NucNet, 6 and 16 March 04
[8] Newsweek, 20 September 04

The 2004 Energy Policy Review by the OECD's International Energy Agency (IEA)[9] analyses governmental energy research and development (R&D) budgets: "Support for renewable energy technologies and energy efficiency has formed the bulk of measures taken or planned over the past few years. Conversely, there continues to be relatively limited support for nuclear energy, although it remains attractive from a climate change point of view. (…) The government R&D budget for fossil fuels and nuclear fission has seen a significant drop since the early 1980s while nuclear fission still has the largest share." Indeed, considering its limited significance in the world's energy supply, nuclear energy – fission and fusion – still absorb vast amounts of R&D money. As illustrated in Graph 6, half of the energy R&D budget of US$ 87.6 billion spent by 26 OECD member states between 1991 and 2001 went to nuclear research.

Graph 6



© WISE- *Paris* / Mycle Schneider Consulting *Source: IEA, Energy Policies of IEA Countries - 2003 Review*

Already in its 2003 World Energy Outlook, the International Energy Agency stated: "The nuclear share of energy use for electricity production is expected to decline in most regions of the world as a result of public opposition, waste disposal issues, concerns about nuclear arms proliferation, and the economics of nuclear power. The nuclear share of electricity generation worldwide is projected to drop to 12 percent in 2025 from 19 percent in 2001." The 2004 edition of the World Energy Outlook still assumes that nuclear power "will decline progressively", because it will have "trouble competing with other technologies". Even under a new "alternative" scenario that assumes a 13% increase of nuclear energy generation between 2002 and 2030 – considering that no new country would go nuclear – the nuclear share in world commercial primary energy would only represent 5%. Furthermore, only 10% of the CO_2 emission savings in the "alternative" scenario would stem from increased nuclear. The lion share of greenhouse gas emission reductions comes from energy efficiency measures. Still no sign of a "nuclear revival".

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[9] OECD-IEA, "Energy Policies of IEA Countries – 2003 Review", Paris, 2003

Table 1: Status of Nuclear Power in the World in 2004

Countries	Nuclear Reactors[10] Operate	Average Age	Under Construc-tion	Planned[11]	Power Share of Electricity[12]	Energy Share of Com.Primary Energy[13]
Argentina	2	26	1	1	9%	3%
Armenia	1	24	0	0	36%	23%
Belgium	7	24	0	0	56%	19%
Brazil	2	13	0	1	4%	2%
Bulgaria	4	19	0	0	38%	20%
Canada[14]	17	20	0	2	13%	6%
China	10	4	1	4	2%	1%
Czech Republic	6	13	0	0	31%	13%
Finland[15]	4	25	1	0	27%	19%
France[16]	59	20	0	1	78%	38%
Germany	18	23	0	0	28%	11%
Hungary	4	19	0	0	33%	10%
India	14	17	8	0	3%	1%
Iran	0	0	2	1	0%	0%
Japan	54	20	2	12	25%	10%
Korea DPR (North)[17]	0	0	1	1	0%	0%
Korea RO (South)	19	12	1	8	40%	14%
Lithuania	2	19	0	0	80%	38%
Mexico	2	13	0	0	5%	2%
Netherlands	1	31	0	0	5%	1%
Pakistan	2	19	0	1	2%	1%
Romania	1	8	1	0	9%	3%
Russia	30	23	3	0	17%	5%
Slovakia	6	17	0	0	57%	21%
Slovenia	1	23	0	0	40%	21%
South Africa	2	20	0	0	6%	2%
Spain	9	23	0	0	24%	10%
Sweden	11	26	0	0	50%	33%
Switzerland	5	29	0	0	40%	21%
Taiwan	6	23	2	0	22%	9%
Ukraine	14	17	3	0	46%	14%
United Kingdom	23	26	0	0	24%	9%
USA	104	25	0	0	20%	8%
EU25	**151**	**22**	**1**	**1**	**31%**	**15%**
Total	**440**	**21**	**26**	**32**	**16%**	**6%**

[10] Figures mainly based on the International Atomic Energy's Power Reactor Information System (PRIS), see http://www.iaea.org/programmes/a2/index.html except for Planned reactors.
[11] Planned = *"Approvals and funding in place"*, according to World Nuclear Association's definition, see http://www.world-nuclear.org/wgs/decom/database/php/reactorsdb_index.php
[12] Share of national electricity consumption covered by nuclear power in 2003, figures based on IAEA-PRIS.
[13] Share of national commercial primary energy consumption covered by nuclear power in 2003, figures calculated by the authors on the basis of BP "Statistical Review of World Energy", June 2004
[14] In Canada, the WNA 'planned' figure is 2 laid-up Pickering-A reactors.
[15] The IAEA does not list yet the Finnish reactor as "under construction".
[16] The WNA does not list the French EPR project as "planned".
[17] The DPRK reactor projects have been frozen due to the international dispute about the alleged weapons program.

Overview by country[18]

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 6% of the country's electricity and 2% of its commercial primary energy. 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), which is one of the so-called Generation IV reactor designs. There has been considerable international interest in the PBMR project and the British company BNFL has invested $15 million to obtain a 20% equity stake in the enterprise. Peco Energy – later Exelon Corp - of the US has acquired a 12.5% stake. In December 2001 Exelon said that they were considering building a PBMR reactor in the US 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 partner in the development of the PBMR is the South African Industrial Development Corporation, which is owned by the South African Government.

Negotiations are ongoing with the French reactor builder Areva, for shared research and development into the modular high temperature reactor and a possible joint build, along with Westinghouse for participation in a US Government tender for a demonstration unit for hydrogen production. However, 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 9% of the electricity and 3% of the commercial primary energy in the country. 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 30 years ago 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".[19] Nevertheless, the IAEA estimates that the start-up of Atucha-2 is to be expected in 2005.

Brazil operates two nuclear reactors that provide the country with 4% of its electricity and less than 2% of its commercial primary energy. 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 world nuclear history. It covered 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 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.

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[18] Unless otherwise mentioned, the figures on 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 2003. The figures on the nuclear share commercial primary energy production are taken from BP, *Statistical Review of World Energy*, June 2004. The numbers of reactors operating are from the World Nuclear Association's (WNA) website and present the situation as of 1st of October 04. The numbers of reactors under construction are essentially based on the IAEA's PRIS.

[19] http://www-pub.iaea.org/MTCD/publications/PDF/cnpp2003/CNPP_Webpage/pages/..\countryprofiles\Argentina\Argentina2003.htm

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 21 reactors in operation, all of which are CANDUs, which provide 12.5% of the country's electricity and 6% of its commercial primary energy. Throughout their operational history the Canadian reactors have been plagued by technical problems that lead to construction cost over-runs and lower annual capacity factors. This was crowned on 13 August 1997, when 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 shut down 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, including first, "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 2004 only three 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 2003 produced 28% of the global total. However, its reserves are expected to only comprise of 14% of the world total and thus its importance in the world market may decrease over the coming decades.

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 and average construction time of 16 years. In 2003, nuclear power produced 5.2% of the country's electricity and 1.7% of its commercial primary energy.

The **United States** have more operating nuclear power plants than any other country in the world, with 103 commercial reactors providing 20% of the electricity and 8% of the commercial primary energy. The civilian reactors programme followed President Eisenhower's Atoms for Peace speech in 1954, which lead to the first commercial reactor beginning operation in 1957 at Shippingport in Pennsylvania.
Although there are a large number of operating reactors in the US, the number of cancelled projects is even larger, 138. It is now over 30 years since a new order has been placed that has not subsequently been cancelled (October 1973).

The problems of the nuclear industry in the US 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. 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. These facts led the US business magazine Forbes in 1985 to describe the industry as "the largest managerial disaster in US 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 at Watts Bar 1, in 1996 (construction started in 1973) 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.

Despite the failure to build more reactors the nuclear power industry remains active 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 US reactors has increased significantly from 56% in the 1980s to 90% in 2002. As a result, along with new capacity coming on line and reactor upgrades the output from US reactors has tripled over this period.

The lack of new reactor orders mean that around 30 percent of the country's reactors will have operated for a minimum of 40 years by 2015, with the first four power plants reaching their 40th year by 2006. Originally it was envisaged that US reactors would operate for 40 years, however, proposals are being developed and implemented to allow the reactors to operate for up to 60 years. Already, 26 US nuclear plants have been granted a life extension license, 18 more have applied and a further 32 have submitted letters of intent, accounting for 75 percent of the operating plants[20].

The election of George W Bush in 2000 was expected, by some, 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 appears unlikely to be met. To reduce uncertainties regarding new construction a two-stage licence process is being 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. Three utilities, Dominion Resources, Exelon and Entergy have also now applied for early site permits. However, the crucial ingredient for a revival is still lacking: a wave of reactor orders.

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 US Court of Appeals for the District of Columbia Circuit ruled that the US 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 Nuclear Regulatory Commission will have to waited for a new regulation from the EPA on the issue, which may take up to a decade.

Asia

China operates 10 reactors that generate about 2% of the country's electricity and 0.8% of its commercial primary energy. One additional reactor of Russian VVER design is under construction. China has one of the lowest shares 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 will bid its AP 1000 (which now has US 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

[20] Nuclear Power's Changing Future: Fastest Growth in Asia, International Atomic Energy Agency, 26th June 2004.

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."[21] 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. EDF managed the construction of the two units together with Chinese engineers. Already 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 US, Russian and Franco-German consortia over scarce follow-up orders and developing its own technology. The key word is technology transfer.
It is highly unlikely that nuclear power will play a major role in China over the next 20 or 30 years, even if a major enlargement program did get underway and up to 28,000 MW were added by 2020.[22] China has vast cheap coal and gas 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.

India operates 14 reactors that provide just 3.3% of its electricity and 1% of its commercial primary energy. The insistence on the term *commercial* has particular significance in countries like India and China where a large share of the primary energy is provided by non-commercial biomass.
Power generating capacity in India is about 120,000 MW – that is comparable to France – for a country with 20 times the population of France. Only 2% of the installed capacity is nuclear.
While about 80% of the population is grid connected, power cuts are frequent.
India lists eight units as under construction. The current operating reactors are mainly of the 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 set to 10,000 MWe of operating nuclear capacity installed by year 2000—requiring a tenfold increase from the 1985 base. In reality, installed capacity had risen to only 2,200 MWe and its actual (operating) capacity by no more than 1,500 MWe.
India was the first country to clearly use designated "civil" facilities for military purposes. Its 1974 nuclear 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.

Japan operates 54 reactors that in 2003 provided 25% of the country's electricity and 10% of its commercial primary energy. In 2002 nuclear energy had produced almost 35% of Japan's electricity. Five workers were killed after a steam leak on 9 August 2004 at the Mihama-3 station – a dreadful day, particularly in Japan, since this is the anniversary of the Nagasaki bombing. The pipe rupture revealed a serious lack in systematic inspection in Japanese nuclear plants and led to an unplanned massive inspection program. The terrible event is only the latest 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.[23] 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.

[21] http://www.uic.com.au/nip68.htm
[22] Such an expansion would mean to connect to the grid about two reactors or 2,000 MW per year, which is highly unlikely considering past experience. One 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)
[23] see also http://cnic.jp/english/newsletter/nit92/nit92articles/nit92coverup.html

There are officially three reactors listed as under construction. Further plans are vague. The official government Long Term Plan for Nuclear Development is currently under review. The major decision to be taken in the short term concerns the fate of the plutonium separation plant in Rokkasho-mura. The reprocessing facility with a nominal annual throughput of 800 t is in its start-up phase. However, the crucial final step, that is the introduction of plutonium, has not been taken yet and is currently scheduled for 2005. 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 40 t, of which about 35 t in France and the UK.

Pakistan operates two reactors that provide 2% of the country's electricity and less than 1% of its commercial primary energy. 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. Immediately following India's series of nuclear weapons tests in 1998, Pakistan also 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 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 19 reactors that provide 40% of the country's electricity and 14% of its commercial primary energy. In addition one reactor is 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 being 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, skepticism has hit politics and administration and the program has come to a virtual halt. Recent revelations of past secret and illegal experiments involving plutonium separation and uranium enrichment, have shed doubts over the exclusively peaceful nature of the program.

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 US, the EU and a number of other countries. In return the DPRK should have abandoned all nuclear weapons related research and development activity. In 2002 the US accused the DPRK of violating the agreement. While the US accusation turned out to be wrong, the DPRK decided to quit the Non-Proliferation Treaty and openly prepared for the reactivation of nuclear weapons related activities. As a consequence, the reactor building project was frozen.

Taiwan operates six reactors that provide 22% of the country's electricity and 9% of its commercial primary energy. Two 1350 MWe Advanced Boiling Water Reactors are listed under construction at Lungmen, near Taipei. They are scheduled for start-up in 2006-2007 but may be further delayed. The most recent operating unit started operating in 1985. All of the power plants are US delivered. For the two plants under construction, initial bids to supply the units on a turnkey basis were rejected, and contacts were awarded to General Electric for the nuclear islands, Mitsubishi for the turbines and others for the rest. 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 favor. But the project was put about a year behind".[24]

[24] http://www.world-nuclear.org/info/inf63.htm

Europe

In October 2004, 13 of the 25 countries in the enlarged European Union (EU25) operated 151 reactors, about one third of the units in the world, down from 172 reactors in 1989, that is minus 12%.
The vast majority of the facilities, 132 units, are located in eight of the western EU15 countries and only 19 in the 5 new Member States with nuclear power. In other words, nine out of ten operating EU25 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 2003, nuclear power produced 31 % of the commercial electricity but provided less than 15% of the commercial primary energy in the EU25. Moreover, almost half (45%) of the nuclear electricity in the EU25 has been generated by one country only: France.

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 132 operating nuclear power reactors in the EU15 as of 1 October 04 – that is 25 units less (!) than 15 years ago – provide:
- about one third of the commercial electricity production;
- < 14% of commercial primary energy consumption;
- < 7% of final energy consumption.

One reactor is currently under construction in the EU15, in Finland. No building site had been opened 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 55.5%, behind Slovakia, Lithuania and France, the fourth highest nuclear share in its power mix in the world. Nuclear power provides 19% of the commercial primary energy in the country. In 2002, Belgium passed nuclear phase-out legislation that requires the shut-down of the Belgian 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, which included a coalition with the Green Party, the following government, not including any green ministers, has not put into question the phase-out law.

Finland currently operates four units that supply 27% of its electricity and 19% of its commercial primary energy. 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 (66% AREVA, 34% Siemens) to supply a 1,600 MW EPR (European Pressurized water Reactor).
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 (2002), 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 of electricity per year, which is twice the amount the four Finnish operating reactors produced together in 2003 and almost three times the amount that the proposed new EPR is expected to generate. Given the current Finnish energy policy, there is no chance of a consumption reduction. The main Finnish utility TVO does not even have *any* Demand Side Management program in place.

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.[25] 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. Exactly 30 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 absorbed by 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 2003, the 59 French reactors[26] produced 78% of the electricity and 38% of the commercial primary energy in the country, although only about 55% of its installed electricity generating capacity is nuclear. In other words, France has installed 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 80,000 MW is to be compared with an installed capacity of over 120,000 MW. 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.

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 50,000 MW. That implies 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. 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 EU25 average. French primary energy consumption is also significantly higher than, for example, in Germany.

Considering the existing overcapacities and the relatively young nuclear plants, with an average age of less than 20 years, France does not need to build any new reactors in a long time. Other factors equally play in that direction:

[25] The World Bank and the Asian Development Bank, for example, never financed nuclear projects in particular because of the high financial risk.
[26] Essentially PWRs, 34 x 900 MW, 20 x 1300 MW and 4 x 1400 plus 1 old 250 MW fast breeder reactor (Phénix, Marcoule).

• The nuclear industry has admitted privately for years that the country has gone too far with its nuclear share in the overall mix and that in the future, the nuclear contribution should not exceed some 60% of the power production.
• It is inconceivable that France will build new reactors with the sole aim of exporting power. That would be far too expensive and would have no perspective in a liberalized energy market given the large overcapacities internationally.
• Electricité de France is intending to operate its reactors now for at least 40 years, while the oldest commercial reactor has been operating for 23 years.

Therefore it will be many years, if not decades, before capacity constraints would need new built base load power plants in France. If the French government and the utility EDF have announced their intention to go ahead with a new unit, then this is because the international 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, that came as a surprise to many specialists because it does not seem to fit the economically and technically most appropriate criteria, seems to prepare the ground for a compensation to cuts in the plutonium business that will basically be out of work shortly.

At the same time the French state utility EDF has to prepare for market opening and partial privatization with many questions still in the open. The British magazine *The Economist* came to the following severe conclusions: "The Economist has examined EDF's finances. What emerges is a picture of a group that has used some questionable accounting practices; that has never really made a profit; that has made imprudent use of funds set aside for nuclear decommissioning and waste-management; that lacks transparency over the level of its nuclear provisions; and that has indulged in a reckless and costly strategy of international expansion[27]."

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. It's two La Hague facilities are licensed to process 1,700 t of fuel per year. However, all the significant foreign clients have finished their contracts and 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 are prohibited to ship fuel to reprocessing plants as of July 2005 – or are building their own plutonium plants like Japan. The La Hague operator COGEMA therefore entirely depends on the domestic client EDF for future business. While the existing contract expires in 2007, it 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.[28] 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.

Germany operates 18 reactors that provide 28% of the electricity and 11% of the primary energy in the country. 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 and can transfer remaining kWh from one reactor to another unit. The first unit has already been shut down under the phase-out law. The second one is

[27] The Economist, *Electricité de France: A very big French turn-off*, 1 July 2004
[28] 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.

to be closed in 2005. The construction of new nuclear plants and spent fuel reprocessing (beyond quantities of fuel shipped to reprocessing plants until 30 June 2005) is prohibited.
While some representatives of the conservative Christian-Democrats have suggested that they might attempt to reverse the phase-out law, the key ingredient, a utility willing to order a new plant is missing. In a generally hostile public environment, nuclear power has no future in Germany.

The **Netherlands** operate a single, 31 year old 450 MW plant that provides 4-5% of the country's power and 1% of its commercial primary energy. The original political decision to close down the reactor by 2004 has been successfully fought in the courts by the operator. The current government plans to introduce legislation that would allow the government to limit the plant's operating lifetime.
In early 2004, the Borssele operator EPZ has extended a reprocessing contract with COGEMA. This is a curious decision considering the fact that there are no possibilities in the Netherlands to use separated plutonium. EPZ has refused to disclose its plans for the plutonium. On 1st July 2004, the lower house of the Dutch parliament approved a resolution that asked the government to:
• "Change the pertinent laws and regulations in the sense that the permission of government and parliament is required for extension of reprocessing contracts or alternative back-end solutions;
• "To investigate the available (back-end) alternatives, such as reprocessing and direct storage, and to review these options in the light of environment, safety, proliferation and financial aspects;
• "To use all possible means to prevent - pending further decisions of parliament - an irreversible decision about reprocessing by EPZ."

Spain operates nine reactors that provide 24% of the electricity and 10% of the primary energy 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.

Sweden operates 11 reactors that provide 50% of the electricity and one third of the primary energy. The high primary energy share is due to the specific very high per capita electricity consumption in Sweden that makes it the most power guzzling 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) is supposed to go 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."[29]

[29] NucNet, 6 October 04

The **United Kingdom** operates 23 reactors that provide 24% of the country's electricity and 9% of its primary energy consumption. 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 UK nuclear industry has gone through troublesome years. Ever since Margaret Thatcher's failed privatization attempt in the late 1980s when the nuclear kWh turned out to be twice as expensive than indicated before, 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 is part of a larger process of establishing a specific agency for decommissioning the country's nuclear facilities. In October 2004, it was reported that the Commission might request an investigation into the establishment of the National Decommissioning Agency[30].

The nuclear lobby in the UK recently 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", the Environment Secretary, Margaret Beckett, stated.[31] And her colleague that hold the Industry Minister's chair, Patricia Hewitt, clarified in *The Times*[32]: "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."

The only Non-EU Western European country that operates nuclear power plants is **Switzerland**. It operates five reactors that cover 40% of the country's electricity and 21% of the commercial primary energy 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?"[33] Switzerland is the only nuclear country that repeatedly has experienced 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. Currently, there are no prospects for any new nuclear plans in Switzerland.

New EU Member States

In May 2004 ten new countries joined the European Union, half of which have nuclear power plants in operation, these included: Czech Republic, Hungary, Lithuania, Slovakia and Slovenia. The two additional countries expected to join the EU in the next few years, Bulgaria and Romania, also exploit nuclear technology.

The enlargement of the EU has impacted on the nuclear sector both in old and new Member States. In new Members, the EU has required the development of closure timetables for the first generation of Soviet designed reactors – the RBMKs (Chernobyl type, water cooled, graphite moderated) and VVER 440-230s (VVERs are light water reactors). These timetables were agreed to in the Accession Partnership agreements signed between the EU and former accession countries in December 1999. Although there are historic, in that the EU has for the first time required the closure of reactors on safety grounds, the closure agreements

[30] The Independent, *European probe could scupper Britain's £48bn nuclear clean-up*, 10 October 04
[31] *The Observer*, 19 September 04
[32] *The Times, 18 September 04*
[33] 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

extended by on average five years existing international closure plans for the reactors in question and failed to follow the lead set in Eastern Germany, where all operating and planned Soviet designed reactors were closed or abandoned immediately following unification in 1989.

Despite calling for the closure of some reactor designs and operational and design changes in the later VVER designs, the EU does not have specific nuclear safety standards to which new Member States must require their nuclear power stations to conform too. This is because under EU law nuclear safety standards remain the competence of Member States. The European Commission has attempted to use the enlargement process to highlight this situation and during 2003/4 proposed new legislation that would for the first time give competence to the European Commission in the field of nuclear safety and radioactive waste. However, these proposals were not accepted by the Council of EU Member States in June 2004. Subsequently, in September 2004, the European Commission re-proposed the legislation, somewhat to the surprise of the Member States Governments, who had only just rejected this text in a similar version.

The energy sectors of the new Member States of the EU have a number of key differences with that of the older Member States. Firstly, there is a greater dependency on coal for electricity production and consequently much less use of natural gas, with nuclear power, across the region supplying a similar level as the EU average. Secondly, far higher levels of energy intensity, the amount of energy used to produce goods, which on average is at least double the level of the old Member States. Finally, considerable overcapacity for example it Lithuania it is 240%, (the difference between peak demand and installed capacity), while in Slovakia it is 94%; Czech Republic 51%; and Hungary 44%.

The **Czech Republic** has six reactors in operation, all second generation VVER reactors, four 440-213s at Dukovany and two VVER 1000s at Temelin. Together nuclear power contributes 31% to the total electricity consumption and 13% of total energy consumption. In 1998, the Czech utility CEZ announced that a substantial 35 billion CZK (750 million Euro) modernisation program would be undertaken at the Dukovany power station by 2005. The upgrading program is designed to extend the life of the reactors from 30 to 40 years. The Temelin reactors are much more recent and unit 1 only began commercial operation in June 2002 and unit 2 in May 2003 and were completed with technical assistance from the US company Westinghouse.

In March 1994, the US Export-Import Bank approved a loan guarantee of $317 million for work performed by Westinghouse Electric Corporation, however, it wasn't until October 1996 that the Czech Government approved the necessary State Guarantees. This was an indication of the delays and problems that the project was to face and when finally complete the project was around 5 years late and 30 billion CZK (900 million Euro) over budget. Some of these problems were the result of the mixing of different technologies and design philosophy's at a relatively late stage of construction. The 2004 State energy policy envisages building two or more large reactors, probably at Temelin, eventually to replace Dukovany after 2020.

Hungary has four VVER440-213 reactors at one operating nuclear power plant at Paks, close to the Danube provides 32% of the countries electricity and 10% of the total energy consumption. Construction started on the reactors between 1974-9 and they become operational between 1983-7. Prior to 2003 the reactors had a relatively good operating record, however, on 10 April 2003 insufficient cooling was applied to part of the fuel elements during a cleaning process in a special tank outside the reactor pressure vessel. The crane needed to remove the elements was unavailable and consequently the temperature continued to increase. The incident, that could have turned into a devastating accident, was discovered when a sudden increase of the radioactive gas Krypton-85 was detected inside the cleaning equipment and in the reactor hall. As a result ventilation systems were deployed and the noble gases were released to the environment through the smoke stacks. Later an attempt was made to open the lid of the washing container but one of the pulleys of the crane broke and the lid was only partially opened. At this time, there were 30 fuel assemblies (about 3 tonnes of uranium, several critical masses) in the cleaning tank.

Six months after the accident, the safety authorities could not exclude that fuel elements did reach "criticality either during or following the incident". The authorities concluded in particular that "from too much trust in any subcontractor should be refrained also in the case of its high reputation".[34] The fuel cleaning equipment had been provided by Framatome ANP. As a result of the accident the second unit was out of action for over a year and was only reconnected to the grid in September 2004.

Lithuania is now the only country in the EU that has operating RBMK reactors and has the highest percentage of nuclear electricity of any country in the world (80%). Nuclear power covers 38% of the country's commercial primary energy consumption. Under the terms of the Accession partnership agreement unit 1 will close before the end of 2004 and unit 2 by the end of 2009. The Ignalina nuclear power plant was built in the 1970s and 1980s and at the time housed the largest reactors in the world, two 1500 MW reactors. The power plant was never designed for domestic use in Lithuania, but supplied electricity to the northwest of Russia and Belarussia. In fact prior to the political changes in 1992, very little of Ignalina's electricity production was used in Lithuania. However, following independence the Government took control of the facility, and mothballed much of its other generating facility. Since the overcapacity is close to 250%, the closure of Ignalina-1 does not represent any particular technical problem.

Slovakia is the only new Member State that appears to have formal plans for the construction of more reactors. The country has six reactors in operation, four at Bohunice and two at Mochovce which provide 57% of the country's electricity and 21% of total energy consumption. The first two reactors at Bohunice, are VVER 440-230 reactors and subject of a closure plan, which will see cessation of operation between 2006-8. The Mochovce reactors were initially planned to be completed using funds from the European Bank for Reconstruction and Development and Euratom. However, in 1995, just prior to agreement being reached on the €1 billion completion plan, the Slovakian Government withdrew the project and instead reworked the project with greater involvement of Russia, but still with support from French and German companies and financing. The reactors were eventually completed in 1998 and 1999. In 2003 the Slovak Government called for tenders for the privatisation of the generation sector of the electricity sector, the bidders were required to include plans for the completion of the third and fourth units at Mochovce. In the autumn of 2004, ENEL, of Italy, was chosen as the preferred bidder.

The only non-Soviet designed reactor in an EU new Member State is in **Slovenia**, where a 650 MW pressurized water reactor, built by Westinghouse has been operating since 1981, providing 40% of the total electricity and about 21% (2002)[35] of the commercial primary energy produced in Slovenia. The reactor at Krsko is unique in that it is co-owned by the Croatian and Slovenian Governments. Since the political changes in the region the operation and ownership of the reactors has been in dispute. However, in July 2001 an agreement appeared to have been reached by which a 50:50 split in ownership was confirmed with a similar division of costs and output, with the establishment of a new company Elesgen. However, the decommissioning strategy, which the Croatian side dispute, was not included in this agreement.

By the end of the decade, Romania and Bulgaria are expected to have also joined the EU. **Bulgaria**, is the only country that has so far closed down reactors as a result of its future accession, with the first two units of the Kozloduy power plant closed in 2002, with units three and four scheduled for closure in 2006, but nuclear power still provides 38% of the country's electricity and 20% of the commercial primary energy. There are two additional reactors, both VVER 1000s also in operation at Kozloduy. In 2004 the Government called for tenders for the completion of the Belene nuclear power plant. Construction was stopped at the site in 1990 and the facility was mothballed. Initially, three consortia submitted bids to complete the facility: France's Framatome and Russia's Atomstroiexport; and another grouping lead by Czech Skoda Praha; and another lead by AECL of Canada. However, the last consortium has withdrawn its application citing lack of transparency in the process. A decision on the successful bidder to build the between 1600-2000 MW of new capacity is expected by the end of the 2004.

[34] L. Vöröss, « Lessons learned from the INES-3 event at Paks NPP on April 10, 2003 », HAEA, Hungary, November 04, http://www.eurosafe-forum.org/forum2003/seminaires/seminaire_1_6.pdf

[35] http://www.eva.ac.at/enercee/slo/energysupply.htm#h2

Romania has only one nuclear power station, at Cernavoda. As early as 1979, Canada's export credit agency, the Export Development Corporation (EDC), provided a $1 billion loan to Romania for the construction of the nuclear station which began in 1980. At the time, the Romanian dictator Ceaucescu had grandiose plans for five or more reactors, but these plans collapsed through lack of funds. Unit 1 was completed in 1996 and now provides 9% of the country's electricity and 3% of the commercial primary energy. Funding for the completion of unit 2 was agreed in 2004, with the awarding of a €212 Euratom loan along with financing from Canada, French, Italian and US sources and is expected to enter service in 2007. In September 2004, the Government announced that it was seeking private financing to complete unit 3 at Cernavoda.

Russia and the Former Soviet Union

The only **Armenian** nuclear power plant was commissioned in 1976 and the two VVER 440-230 reactors entered into operation in 1977 and 1980. The reactors at Medzamor are less than 30 Km from the centre of the capital Yerevan. Safety concerns heightened by the 1988 earthquake lead to the closure of both reactors in 1989. However, the reactors were not decommissioned but kept in a prolonged shut down condition.
In April 1993, due to the severe economic situation and apparent lack of alternatives a decision was taken to restart unit 2, which now contributes 35% of the country's electricity and 22.5% (2001)[36] of the commercial primary energy. Armenia has no fuel cycle facilities and is reliant on Russia for its fuel.

In June 1954 at Obninsk, **Russia,** the world's first nuclear reactor was connected to the grid. Since then 40 commercial reactors have been put into operation in Russia, ten of which have been shut and are now waiting decommissioning. Today, nuclear power contributes to 16.5% of the country's electricity supply and around 5% of the commercial primary energy consumed. As with other countries that were developing nuclear power in this era, the civilian nuclear power programme was fully integrated into the development of nuclear weapons material.

In the 1960s the Soviet Union began to develop commercial scale reactors, focusing on two major designs, the RBMKs – larger versions of water cooled, graphite moderated plutonium production reactors – and the VVERs – pressurised water reactors. These designs were developed in different sizes and exported to countries in Europe and beyond.

The disaster at the Chernobyl nuclear power plant in Ukraine in April 1986 had a huge impact on the global nuclear industry and in particular in Russia. Since then only four new reactors have been connected to the Russian grid (Balakovo 2,3,4 and Smolensk 3) and the three reactors officially under-construction, according to the IAEA, were all ordered prior to 1986. The first of these, "under construction" reactors, Kalinin 3, went critical on 26 November 04, with an RBMK – the same design at Chernobyl – due for operation in 2006 at (Kursk 5) and Rostov (or Volgodonsk) 2 due to start in 2007. A further three reactors are said to also have financing for completion secured. An investment plan of 290 billion roubles (US$9.7 billion) has been developed for projects until 2010: 35% of this for upgrading existing capacity and 56% for new capacity[37]. However, it must be noted that the Russian industry has on numerous occasion announced ambitious new construction plans.
The first generation of Russian reactors, some RBMKs and the VVER 440-230s, were originally intended to operate for 30 years. Late in 2000, plans were announced for lifetime extensions of twelve first-generation reactors and the extension period envisaged is now 15 years, necessitating major investment in refurbishing them by 2006. So far three 15-year extensions have been issued, for Novovoronezh-3, Kursk-1 and Kola-1. Replacement of all these units after 2015 is planned[38]

[36] http://library.iea.org/dbtw-wpd/Textbase/stats/nmcbalancetable.asp?nonoecd=Armenia&COUNTRY_LONG_NAME=Armenia
[37] Nuclear Power In Russia: World Nuclear Association, March 2004: http://world-nuclear.org/info/inf45.htm
[38] ibid

Despite no new reactor orders domestically, a number of Russian reactors have been ordered for export. The nuclear export agency, Atomostroyexport, took over the completion of the Bushehr power station in Iran, from the German company Siemens, but this is now suspended. It sold two reactors to China for the Lianyungang power plant and two reactors to India for the Kudankulam power plant.

In March 2004, Minatom (the Ministry for Atomic Power) was formerly disbanded and replaced by the Russian Federal Atomic Energy Agency. The full implications of Minatom's demise are not yet clear, although it would appear to signal a reduction in power and influence for the nuclear body, which is now subordinated both to the newly formed Ministry of Industry and Energy and the Ministry of Defence.[39] A month later, the Federal Service for Environmental, Technological, and Nuclear Oversight was formed by presidential decree. The new service absorbed the Federal Inspectorate for Nuclear and Radiation Safety (known as Gosatomnadzor, or GAN) the Federal Service for Technological Oversight, and the environmental oversight functions of the Federal Service for Oversight of the Environment and the Use of Nature[40].

Despite its reduced national programme, the Russian industry plays an important role internationally with its fuel services. Russia produces 8.5% of the global fresh uranium total, however, taking into account down blending of Highly Enriched Uranium and the re-enrichment of depleted uranium, Russia supplied 35% of EU uranium in 2003. Through the 1993 US-Russia non-proliferation *Megatons to Megawatts* programme 200 tonnes of HEU have been down blended to create 6,000 tonnes of fuel, which has been used in US and European reactors. This programme is expected to finish in 2013[41].

In 1995, the Russian Government passed three decrees affecting the return of spent nuclear fuel to Russia. As a result, under Russian Environmental Law it is only possible for spent fuel to be accepted into Russia for the purpose of reprocessing after which all waste must be returned. However, in 2000 Minatom began preparing a proposal to overturn this 1995 Law. At the time of the launch of the new Law, Minatom claimed that the change would fund the further development of nuclear energy.

The revised legislation has been approved by the Lower House of the Russian Parliament and was approved by President Putin in June 2001. However, there was a procedural mistake in adopting these Laws as they were not considered by the Council of Federation (Upper House of the Parliament), which is required for all laws, which relate to “customs regulations”. In the past a number of companies from around the world have expressed an interest in exporting their radioactive waste. Minatom claims that revenues generated from the import of waste would be placed in a separate fund, three quarters of which would be used to fund the cold war nuclear waste legacy, with the remaining funds were to be used at the Krasnoyarsk site. Today, the reprocessing plant at Krasnoyarsk has been abandoned and is currently being dismantled. Furthermore, only two countries, Bulgaria and Ukraine have firm plans to send their spent fuel to Russia for reprocessing and even these contracts may be cancelled in the near future.

In **Ukraine**, nuclear power today contributes 46% to the country’s electricity production and 14% of the county’s commercial primary energy. The first reactors to be built in Ukraine were at Chernobyl, where six RBMK reactors were scheduled to operate. Only four reactors were ever completed, due to the accident at unit 4 in April 1986. Currently, there are fifteen reactors in operation, the most recently completed reactors, were the Khmelnitsky 2 and Rovno 4 reactors, which began operating in the summer of 2004 and were said to be the replacement reactors for the remain Chernobyl units closed by 2000. However, due to the economic decline in the country during the early 1990s Ukraine’s peak demand, when construction was restarted in 1995, was around 30,000 MW, with an installed capacity of around 54,000 MW and thus there is substantial reserve capacity, about 80%, or over twenty times the operational capacity of Chernobyl.

[39] Nuclear Engineering International, April 2004
[40] http://www.nti.org/db/nisprofs/russia/govt/nucleara.htm
[41] Euratom Supply Agency, Annual Report 2003. European Commission: http://europa.eu.int/comm/euratom/ar/ar2003.pdf

As a result of the accident Chernobyl unit 4 never re-opened, but the other reactors gradually returned to operation. The remaining three units continued to operate until an accident occurred in Unit 2, in October 1990. The Supreme Soviet of Ukraine adopted on 2 August 1990 a moratorium to stop the construction of new nuclear power units in the Ukraine. The construction work at unit 6 at Zaporozhe was interrupted and the construction of 4 new VVER type reactors at Khmelnitsky and Rovno was also halted. However, at the end of 1993, the Ukrainian Parliament approved a Cabinet of Ministers decision to both delay the closure of Chernobyl and lift the moratorium on completion of nuclear power plants in Ukraine. Within two months the European Commission sent a team to Kiev to assess the economic viability of completion of Khmelnitsky 2 and Rovno 4 reactors and Zaporozhe 6. This team concluded that completion was economically viable concluding "*that the closure of Chernobyl and the completion of the three new reactors would cost around 1.35 billion ECU*"[42] As a result of this the G7/EU and the Ukrainian Government signed a Memorandum of Understanding in December 1995, which sought to finance replacement power projects for Chernobyl, possibly including the completion of two VVER reactors, Khmelnitsky 2 and Rovno 4 (K2R4) if the reactors were the least cost option. To assess this, one of the potential co-financers, the European Bank for Reconstruction and Development, appointed an independent Panel to assess the economic due diligence. It was said that given the sensitivity of this issue, it was of the utmost importance that an independent authority undertakes this work.[43] The Panel's findings are unambiguous "We conclude that K2/R4 are not economic. Completing these reactors would not represent the most productive use of $US1bn or more of EBRD/EU funds at this time".[44]

Despite this, the EBRD continued with the project and ordered new economic analysis from a nuclear construction firm, Stone and Webster, who reached a different conclusion, namely that the completion of the reactors was indeed the least cost option, under their scenarios. This allowed the project to proceed and in December 2000, to coincide with the final closure of the Chernobyl station, the EBRD and European Commission gave provisional approval for part financing of a $1.5 billion project to complete the reactors, with the final agreement to be signed within 12 months. However, on the day the agreement was to be finally signed, in November 2001, the Ukrainian Government rejected the proposal, citing its excessive costs and financial conditions.

Over the next years, the K2R4 reactors were gradually completed using Ukrainian and Russian resources and became operational in 2004. The EBRD and European Commission in July 2004 agreed to fund a $120 million post completion project, which, the funders claim, will enable the project to meet the original EBRD design specification.

Although Ukraine has some uranium reserves and through the VostGOK facility in 2003 produced some 600 tonnes of uranium a year, it relies on Russia for its fuel services.

Some VVER-440 and -1000 spent fuel is sent to Russia for storage or reprocessing and some is kept in dry storage facilities on site. Preliminary site investigation is underway to develop geological disposal sites for intermediate and high level waste.

[42] Background Document. Solving Ukraine's nuclear crisis - the European Union's Strategy. Memo/94/44, Brussels, June 23, 1994.

[43] Terms of Reference for Economic Due Diligence by an International Panel of Experts, EBRD 2nd August 1996.

[44] Economic Assessment of the Khmelnitsky 2 and Rovno 4 Nuclear Reactors in Ukraine, Volume 1: Main Report, 4th February 1997, (Panel) page 6

The Chernobyl Disaster – A Human Tragedy for Generations to Come[45]

"At least three million children in Belarus, Ukraine and the Russian Federation require physical treatment (due to the Chernobyl accident). Not until 2016, at the earliest, will we know the full number of those likely to develop serious medical conditions."[46]

Kofi Annan
Secretary-General of the United Nations
July 2004

On 26 April 1986, unit number four of the Chernobyl nuclear power plant exploded. Reconstruction of the event, so far as is practicable today, suggest that a "power excursion" increased the nominal energy output within four seconds by a factor of 100; then a hydrogen explosion peeled open the reactor containment leaving the molten nuclear fuel and the burning graphite reactor core open to the atmosphere. No modern reactor containment has been designed to withstand such huge levels of abrupt energy liberation. A graphite fire that lasted for several days pumped radioactivity high into the atmosphere, spreading around the northern hemisphere of the globe.

Chernobyl, 100 km north of the Ukrainian city of Kiev, then in the Soviet Union, has a synonym for industrial disaster, environmental pollution and devastating health effects. The farther you go away from "ground zero" the more surprising are the levels of impact, the closer you get and the longer you wait, the more terrifying are the overall health consequences, the established ones and those to be expected.

Over 18 years after the worst industrial catastrophe in human history, the lack of public information and collective consciousness of the terrible consequences of the event is stunning.

Part of the uniqueness of the Chernobyl accident is the geographical dimension of radioactive contamination. The general public is unaware and thus totally ignorant that, for example:

- Still today, in 2004, in the United Kingdom, at some 1,500 miles (2,500 km) distance from Chernobyl, a total of 382 farms with some 226,500 sheep on over 200,000 acres (80,000 ha) of land remains under restriction order since Chernobyl.[47] Lambs are raised on contaminated pastures and, according to a complex field management scheme, have to be transferred to "clean" pastures for several months until the ratio of caesium in the meat (radioactivity per kilo) has decreased (primarily via the body weight gain as the lambs mature) below legal limits.
- In the most severely contaminated areas of Southern Germany, soil contamination of up to 70,000 Bq/m2 of caesium-137 was measured. Had they been in Belarus, Russia or Ukraine these areas would thus have been designated a contaminated zone.[48] In 2004 German hunters are still compensated for contaminated wild game and some varieties of mushrooms and berries continue to exceed the limits.
- While after the accident farmers across the border in Germany and Italy ploughed their crops under, the French government considered that no precautionary measures were necessary. Although, contamination levels of over 10,000 Bq/l of Iodine-131, 20 times the EU legal limit, were identified in milk from Corsica, no advice was given in particular to protect children.[49]

About 400,000 people have been dislocated from their homes in the worst Chernobyl fallout regions in Belarus, Ukraine and Russia. Some families had to move several times because certain of the new locations turned out to be equally contaminated as the places they left in the first place. For many people, in particular in the West, large-scale evacuations and the enforcement of an exclusion zone around the destroyed reactor

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[45] Excerpts from a book chapter under the same title by Mycle Schneider from *Rethinking Nuclear Energy After September 11, 2001,* Global Health Watch, IPPNW, Geneva-New York, September 2004 (see www.ippnw.ch)
[46] www.chernobyl.info
[47] Originally, in 1986, in total over 3.3 million sheep on 4.2 million acres (1.7 million ha) of land were under restriction order. UK Food Standards Agency, e-mail to the author, 20 February 2004
[48] http://www.chernobyl.info/en/Facts/Health/ConsequenceOtherCountries/#Sources
[49] See the excellent analysis in Corinne Castanier, *Contamination des sols français par les retombées de l'accident de Tchernobyl,* CRIIRAD, 24 April 03

has given the false impression that the remainder of the population must have been safe and therefore lives in safe places today. Reality is different with the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) stating[50]:

> *"Eighteen years ago today, nearly 8.4 million people in Belarus, Ukraine and Russia were exposed to radiation. Some 150,000 square kilometres, an area half the size of Italy, were contaminated. Agricultural areas covering nearly 52,000 sq. km, which is more than the size of Denmark, were ruined. Nearly 400,000 people were resettled but millions continued to live in an environment where continued residual exposure created a range of adverse effects.*
> *Now, roughly 6 million people live in affected areas. Economies in the region have stagnated, with the three countries directly affected spending billions of dollars to cope with the lingering effects of the Chernobyl disaster. Chronic health problems, especially among children, are rampant."*

It is part of the inhuman side of today's news jargon to present the public perception of human suffering to numbers of the dead and, this being so, who pays attention to the wounded, the economically mutilated and the homeless? The Chernobyl disaster is a particularly striking example for this lack of interest and support for the living and (yet) surviving.

Demographic Disaster. Following the Chernobyl accident, the birth rate in many of the regions of serious fallout began to decline rapidly. In the Gomel region in Belarus, between 1986 and 2000, the birth rate fell by 44%, mortality increased by over 60% and natural population growth vanished from +8% to –5%.

General State of Health and Various Disabilities. The UNDP-UNICEF mission sums up in 2002[51]: "The health and well-being of populations in the affected regions is generally very depressed. (…) Life expectancy for men in Belarus, Russia and Ukraine, for example, is some ten years less than in Sri Lanka, which is one of the twenty poorest countries in the world and is in the middle of a long drawn out war. (…)" Moreover, the situation is *worsening* at frightening speed. In 1991, the Ukrainian government had registered around 2,000 individuals with "disabilities connected with the Chernobyl disaster", but their number had risen to almost 100,000 by 1 January 2003.[52]

Psycho-social Problems. About 14% or 15,000 of the 110,000 children examined under the US-Agency for International Development's (AID) Chernobyl Children Illness Program (CCIP) were found to be in need of assistance,[53] with "children found to have severe depression and suicidal tendencies are given immediate consultation by the mobile team psychologists.

Dramatic Increase in Thyroid Cancers. The Belarus Government has stated that from 1986 to 2001, there were 8,358 cases of thyroid cancer in Belarus alone, of which 716 occurred in children, 342 in adolescents and 7,300 in adults.[54] According to a recent study,[55] age-adjusted average thyroid cancer incidence rates in Belarus have increased between 1970 and 2001 almost 9-fold (+775%) among males and 20 times (+1925) among females.

Hereditary effects. Beyond the devastating consequences for the living, the Chernobyl effects have moved into the following generations. Sperling et al. reported that in West Berlin, as early as January 1987, there was a significant increase in Down's syndrome; a cluster of 12 cases was found compared with two or three expected. After excluding factors that might have explained the increase, including maternal age distribution, only exposure to radiation after the Chernobyl accident remained.[56]

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[50] UN-OCHA, *Chernobyl : Needs Great 18 Years After Nuclear Accident,* Office for the Coordination of Humanitarian Affairs, United Nations, Press Release, New York, 26 April 04

[51] *The Human Consequences of the Chernobyl Nuclear Accident - A Strategy for Recovery,* Report commissioned by UNDP and UNICEF with the support of UN-OCHA and WHO, 25 January 02

[52] Report of the Government of Ukraine, Annex III of UNSG, *Optimizing the international effort to study, mitigate and minimize the consequences of the Chernobyl disaster*, Report of the Secretary-General, UN General Assembly, 29 August 03

[53] UNSG, *Optimizing the international effort to study, mitigate and minimize the consequences of the Chernobyl disaster*, Report of the Secretary-General, UNGA, 29 August 03

[54] Report of the Government of Belarus, Annex 1 of UNSG, *Optimizing the international effort to study, mitigate and minimize the consequences of the Chernobyl disaster*, Report of the Secretary-General, UN General Assembly, 29 August 03

[55] Martin C. Mahoney, et al. *Thyroid cancer incidence trends in Belarus: examining the impact of Chernobyl,* International Journal of Epidemiology, electronic summary, 27 May 04

[56] Sperling, K.S., J. Pelz, R.D. Wegner et al. *Significant increase in trisomy 21 in Berlin nine months after the Chernobyl reactor accident: temporal correlation or causal relation?* Br. Med. J. 309: 157-161 (1994).

This brief review has explored the statistics of fact, leading to the axiom that the grand-grand-grandchildren of our children will suffer from the effects of an accident of a machine that was built to provide a service to people. That machine generated power for two years, four months and four days but the human suffering and health detriment will go on for generation after generation. Who would dare to say it was worth the risk?

Conclusion

On 31 December 04, the Lithuanian nuclear power station Ignalina-1 will be shut down for good. The closure is not only a consequence of the accession agreement between the Lithuanian government and the European Union (EU), it is also a further sign of a trend that has started some fifteen years ago: nuclear power is on its way out.

In 1989 a total of 172 nuclear reactors have been operated in what are now the 25 EU Member States. The shut-down of Ignalina-1 will bring this number down to 150 units by the end of 2004, that is 22 plants or 13% less than fifteen years ago.

In 1992 the Worldwatch Institute in Washington, WISE-Paris and Greenpeace International published the first *World Nuclear Industry Status Report*, which 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.”

As an updated review of the status of the world nuclear industry shows, 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 from the 1970s of up to 4,450,000 megawatts. At the end of October 2004 the 440 worldwide operating reactors totalled 365,500 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 average age of the operating power plants is 21 years. Some nuclear utilities envisage reactor lifetimes of 40 years or more. Considering the fact that the average age of all 107 units that have already been closed is equally about 21 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[57] and have calculated how many plants would be shut down year by year. 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. Roughly 80 reactors would have to be planned, built and started up over the next ten years – one every month and a half – and an additional 200 units over the following 10-year period – one every 18 days. Even if Finland and France did build an EPR and China went for an additional 20 plants and Japan, Korea or Eastern Europe added one or the other plant, the overall trend will be downwards. 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. And Ignalina-1 remains exactly on world average it will be shut down at age 21.

In sharp contrast to multiple reporting of a potential “nuclear revival”, the present analysis shows that the atomic age is in the dusk rather than in the dawn. What remains for future generations to remember is the legacy of long lived radioactive waste and the every present danger of nuclear proliferation.

[57] The calculation excludes reactors that do not have a scheduled start-up date. That concerns 9 of the 25 units listed by the IAEA as under construction.