The price-tag of

nuclear power

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Content

1. The price-tag of nuclear power

The nuclear industry is trying to make a come back by claiming to be a solution for the world's rapidly increasing demand for energy over the last decades and the threat of a dramatic climate change. Unproven and false statements claiming that: nuclear safety problems have been solved; solutions for a safe nuclear waste disposal exist; and proliferation could be kept under control are part of the current PR-war being fought by the nuclear lobby.

One may underestimate safety and proliferation concerns, but in a free market economy one question remains: Is nuclear power economically sound? The answer of the nuclear industry is clear: Yes, it is. But is this answer correct? No, it is not. If the European energy market were a level playing field, in which energy pricing reflected the true costs of producing energy from different sources, nuclear power would be economically insane. As it is now, no nuclear power plant will be built without shifting costs from companies to society or as a result of strategic considerations such as ensuring market control for a particular business, or due to the need to maintain a military nuclear programme.

2. Two different cases of nuclear economics: new-builds and plant lifetime extension

In discussion about an extended use of nuclear power it is essential to differentiate between two cases of nuclear economics: new builds and plant lifetime-extension. Although overall economic costs are the same, business costs differ dramatically.

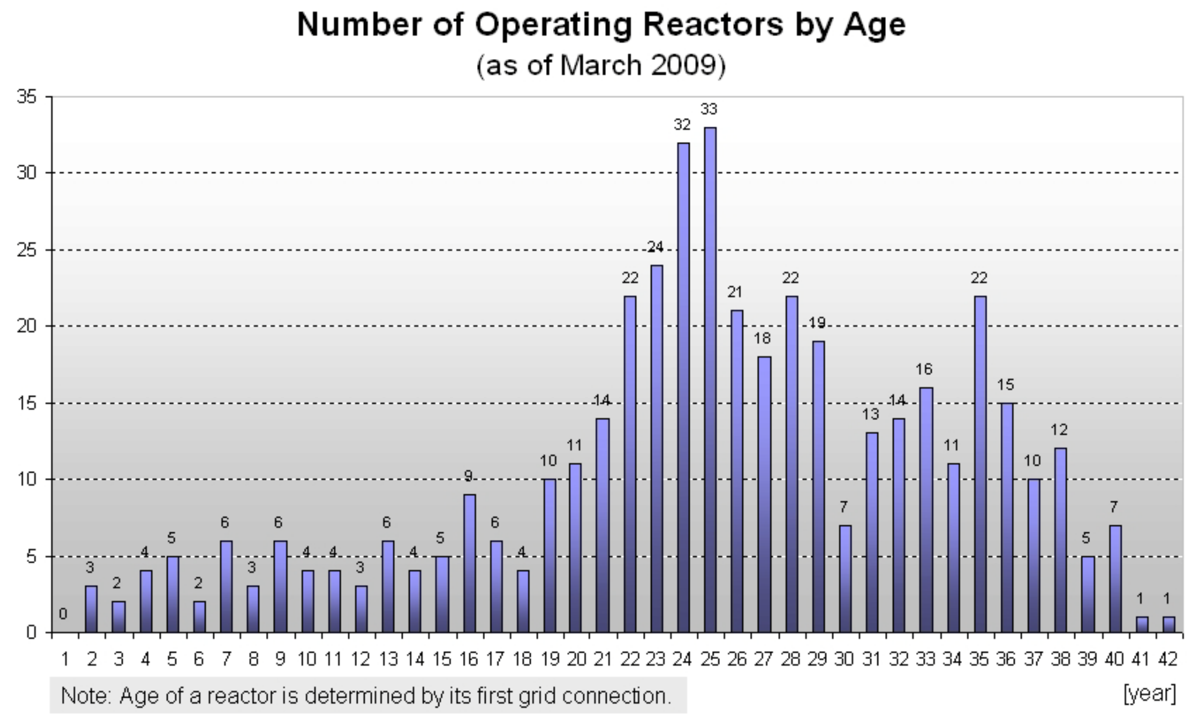

Figure 1: Number of Operating Reactors by Age (IAEA, 2009)

An aging generation of nuclear power plants is going to be in operation in the coming 30 years. For the nuclear industry and for some politicians, Plant Lifetime Extension (PLEX) seems to be an attractive opportunity to bridge the gap until new builds are online. Why are operators and energy enterprises so keen on PLEX?

“One of the major trends in the global energy and electricity sector is the privatisation of electric utilities and deregulation of electricity markets [….] Numerous studies have recently shown that for the commonly expected higher rates of return and short payback periods required today, it is difficult for new nuclear generation to compete with gas, combined cycle, or even with coal, in regions where coal is abundant and economical. Although the nuclear industry has been working on improving the economics of nuclear electricity generation, such as evolutionary and innovative improvements of NPP designs, further developments in these areas will be needed to respond to changing market conditions. High capital cost and long lead time make it more difficult for the new NPPs to be competitive with alternative options of electricity generation in many countries. These disadvantages do not apply to existing plants, particularly when capital investments may have been depreciated over the operating years, or recovered through stranded cost and ownership transfer.” (IAEA, 2002)

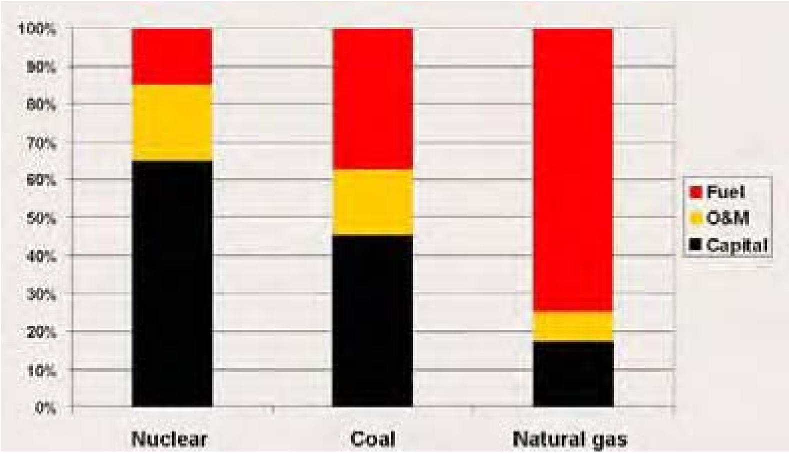

Figure 2: Comparison of cost structures for different power station types (Rogner, 2007)

As the IAEA document states, there is not much incentive for a profit oriented enterprise to build a new NPP. In contrast, generating electricity in an old NPP for as long as possible is profitable, because the investment has been recuperated long ago. The large fixed costs can be spread over more output. The increasing risk of an accident is covered by the government as nuclear operators do not cover full liability costs. Even costs for a higher amount of spent nuclear fuels and also more low- and intermediate waste do not influence business cost calculations. Therefore utility companies see life extension rather than the construction of a new NPP as a lucrative money-spinner. Although this opportunity seems so attractive for companies and politicians, it is essential to keep in mind that high costs have to be covered from taxpayer’s money while profits are going into the pockets of private companies.

One can easily see that new builds in a free market economy are not an attractive investment: But what about new builds that are currently under way, and what about less liberalised energy markets? Both of the new builds currently underway in Europe (EPR projects in Finland and France) have been developed and calculated under very specific conditions – and with a clear strategic goal of bringing the EPR into the market.

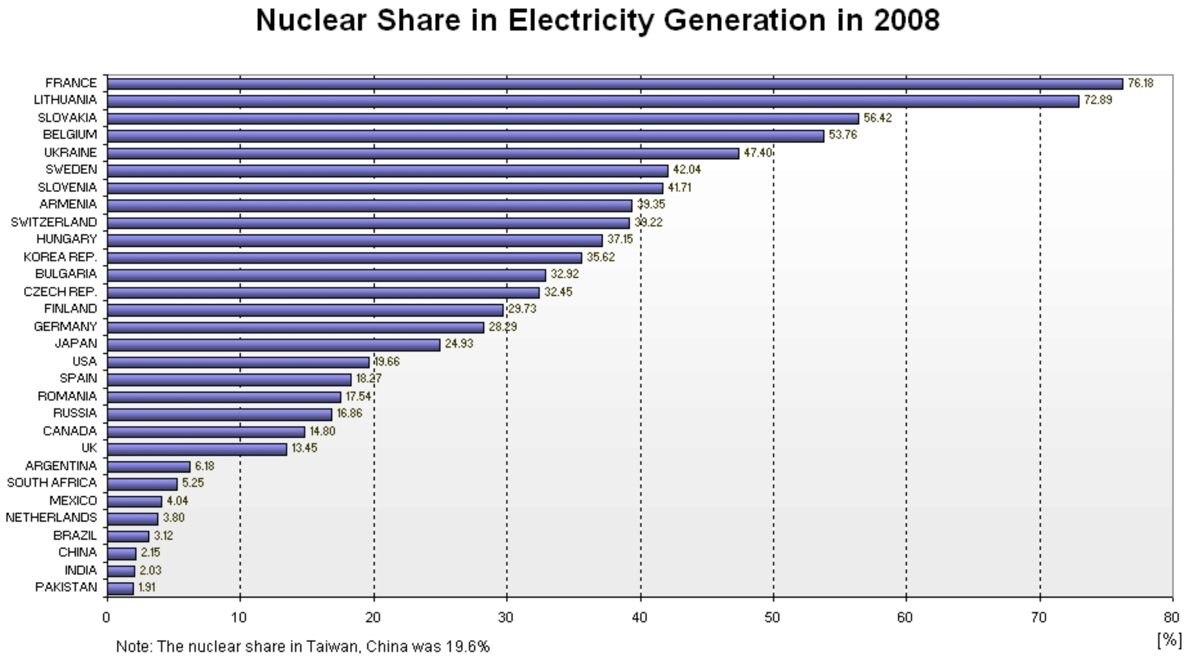

Figure 3: Nuclear share in electricity generation in 2008 (IAEA, 2009)

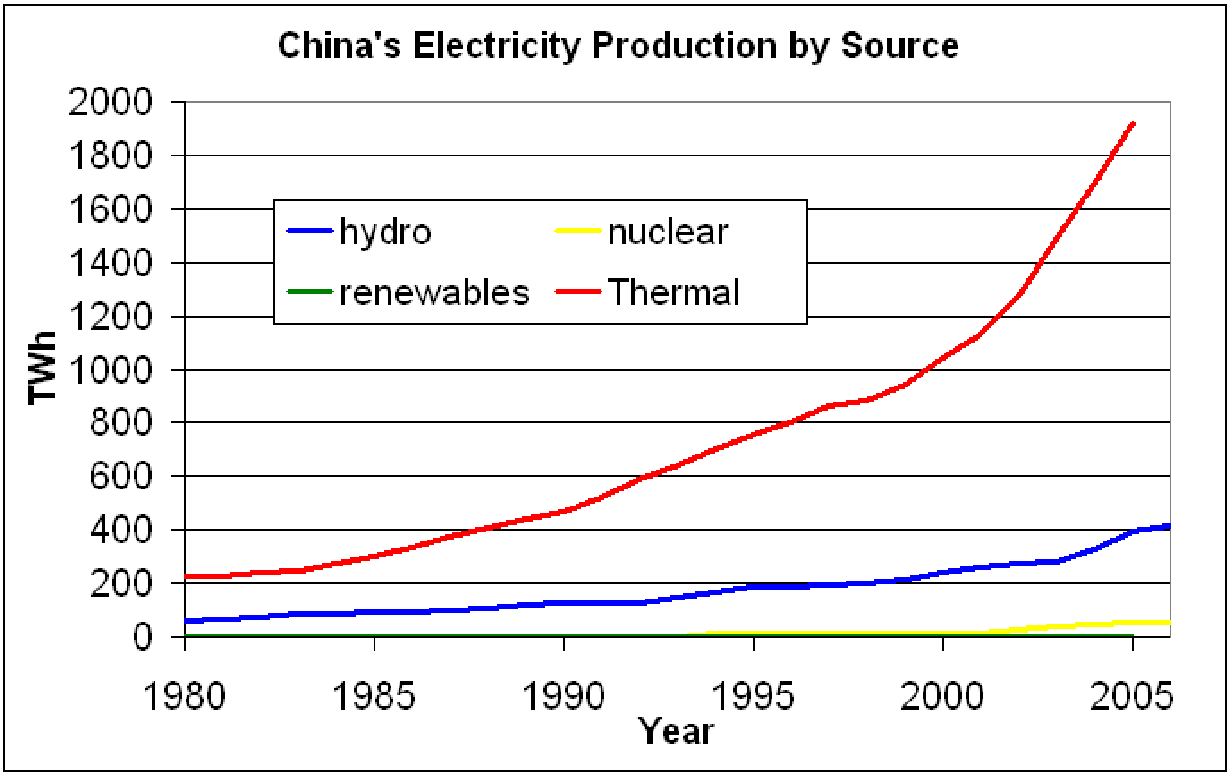

Figure 4: China's electricity production by source (Wikipedia, 2009)

Nuclear currently has only a marginal role in China’s energy supply. If nuclear investments were economic, China would not have invested in 160 GW of new coal plants to cover the drastic increase in energy demand between 2002 and 2005. But China is obviously interested in having a share in global nuclear production to keep up to date in this technology and to produce fissile material for military use.

In the US, where the energy market is widely liberalised, no new nuclear power plant has been ordered since 1973. In 2005, President Bush offered the nuclear industry a deal in which companies would be insured against delays in the licensing process for the 4 first new nuclear power plants. Additionally, loan guarantees have been implemented. But no new orders were made, leading to the conclusion that nuclear investments are not economically viable even under such conditions. But the nuclear industry is not giving up: In June 2009, US Senator Bob Bennett made new proposals to build up to 100 new nuclear plants in the next 20-25 years, at the same time proposing to cancel funding for renewable sources of energy and to shift money to nuclear.

PLEX case studies

There are nearly no valid data about the real costs of PLEX programs. In 2002, the IAEA published a report on investment costs for PLEX programs based on experiences in different countries. The range of costs is high and is between under 120 US$/kWe (e.g. Borssele, Kozloduy-5) to more than 680 US$/kWe (e.g. Pickering A, Canada). Even in this comprehensive study, data are not necessarily directly comparable and they have to be interpreted considering different types, size, and design of the plants as well as different regulatory and environmental requirements, spent fuel storage policy, the extent of modifications, labour costs etc.

In 2000, the German government, consisting of the Social Democrats (SPD) and Alliance '90/The Greens officially announced its intention to phase out the use of nuclear power. An agreement with energy companies on the gradual shut down of the country's nineteen nuclear power plants was enacted as the Nuclear Exit Law. It is based on the calculation of 32 years as the usual time of operation for a nuclear power plant but also on the total amount of produced nuclear power of 2,623 TWh. It is possible to transfer production allowance from one nuclear power plant to another with the permission of the Environment Ministry. The power plants Stade and Obrigheim were turned off on November 14th 2003, and May 11th 2005.

Because of increasing prices for fossil fuels, and the need to reduce greenhouse gas emissions, arguments for a "phase-out of the phase-out" are being discussed in Germany. In 2008, Chancellor Merkel and the conservative CDU shifted position to openly oppose to the phase-out, while the SPD (in coalition with the conservative CDU/CSU), continues to oppose nuclear power. A change in nuclear policy is a possibility after the next German federal election in autumn 2009. Germany is a major player in the European nuclear industry. It also plays a leading role in European energy issues more generally – not at least by inventing extraordinarily successful feed-in tariffs for renewable sources of energy. This is therefore a highly important and crucial decision, and will possibly influence European Union energy politics.

A lifetime-extension of about 8 years for the German nuclear fleet would mean an increase of the amount of nuclear electricity produced from 1,382 TWh today to 2,620 TWh (a 90% increase). As a consequence, nuclear power would be part of the German electricity mix until 2031. Due to the pricing in liberalised energy markets, such a lifetime-extension would mean a profit for energy companies of 66 to 84 billion Euro (Öko-Institut, 2008).

3. State aid for nuclear power in Europe

Historically, the high share of building costs for nuclear power plants was not a problem for the nuclear industry. In a monopolised energy market after the Second World War, investments were backed-up by money from taxpayers and customers.

Now, energy markets are becoming more and more liberalised, but nuclear power still maintains a protected position. While many industries in the European Union are regulated by a general European policy and have to operate in liberalised markets, the nuclear power sector falls under the EURATOM treaty. This treaty, written more than fifty years ago, shields the sector from standard competition and state aid-rules. The EURATOM treaty allows states and companies to receive loans from the European Commission to finance nuclear projects at low interest rates. The treaty also provides for nuclear research to be funded via the special EURATOM framework programme. In addition the treaty means that nuclear operators are protected from environmental liability. In short; EURATOM is one major reason why nuclear power is viable in Europe, and the European Union became one of the most important regions in the world for nuclear power.

In the past, the nuclear industry has received huge amounts of direct financial support, although it is difficult to quantify exactly how much due to a lack of available data and proper official reporting and controlling on this issue. According to a WISE study (WISE, 2005), the average amount of direct energy subsidies from EU member states, and the EU itself, to nuclear power amounted to approximately 4.6748 billion US Dollar annually in the period of 1990 to 1995. This represented over 23% of the total annual energy subsidies within the EU during that period.

Furthermore, there are so called “off-budget subsidies”, typically referring to transfers to energy producers and consumers that do not appear on national accounts as government expenditures. These subsidies include tax exemptions, credits, and regulatory support mechanisms, but especially liability limitations and decommissioning subventions. All these factors give nuclear power a head start when compared with other options for energy production, specifically renewable sources of energy. The decisions of the past are still dominating the energy market today, as energy saving measures as well as renewable sources of energy have to compete against nuclear power.

Nuclear technology has historically received the majority of all energy related research and development funding, both on the EU Member State level, and with the EU’s funding programme. The European Commission has estimated that between 1974 and 1998, Member States granted approximately 55 billion US Dollar in research and development assistance for nuclear technology alone from their national budgets. Furthermore, The Economist estimates that “more than half” of the energy subsidies every granted by the OECD have gone to nuclear technology. The research expenditure by Member States is shown in the graph below.
Nuclear fission and fusion continue to receive the largest share of funding, with the two options receiving three times more than all renewable research and development funds together over the last decade (Greens-EFA, 2005)

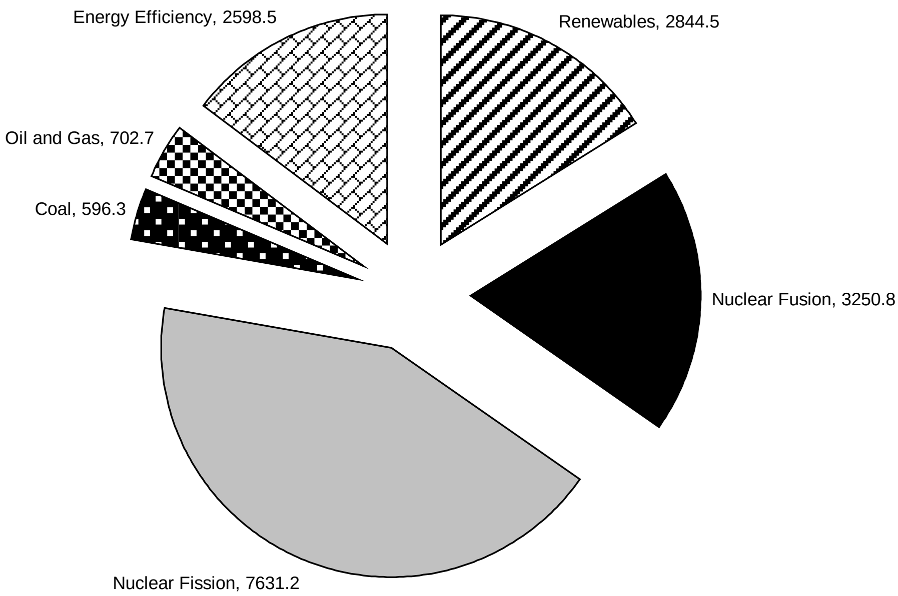

Figure 5: European States' Energy Research and Development Budgets 1992-2002 (Greens-EFA, 2005)
This includes: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK

After liberalisation of the energy market, the EUATOM treaty remains a supportive instrument for financing nuclear power through the money of European taxpayers: in 2009, the European Investment Bank gave a 400 million Euro loan (total investment 820 million Euro) for the expansion of the uranium enrichment capacity in Urenco's facility in Almelo, the Netherlands. According to the bank: "the Project will contribute to covering world and EU demand of enrichment services. Furthermore, it is an important objective of the EU to have sufficient enrichment capacity for security of supply reasons, as reflected in the EURATOM policy." (EIB, 2009).

Besides a range of loan facilities for nuclear power, the European Union provides funds for research into nuclear energy. These funds are more than those allocated for renewables or energy efficiency research. In the "EURATOM"-part of the Seventh Research Framework Programme (FP7), which runs from 2007 till 2011, 2.75 billion

Euro is budgeted for nuclear research (550 million Euro annually). A large part of this money is meant for fusion research, but also for research into radioactive waste handling and storage, and nuclear safety. In the non-nuclear part of FP7, which runs from 2007 to 2013, 2.35 billion Euro is budgeted for energy, of which two-thirds is earmarked to go into renewables and energy efficiency. That makes 224 million Euro annually, which is less than half of the money spent on nuclear research.

In another example of its distorting effects, the EUATOM treaty also makes it possible for Areva (the French nuclear power giant) to receive 610 million Euro of export credit from Coface, a French state agency which normally undewrites exports to developing countries or countries where political instability makes investments risky, for the constructing of a new reactor in Finland. TVO, the operator of Olkiluoto-3 (OL3), received an additional 2 billion Euro in low interest loans from the German state-owned Bayerische Landesbank (Biermayr and Haas, 2008).

4. Determinants of nuclear power costs

There are several important determinants of the cost of electricity generated by a nuclear power plant. About two thirds of the generation costs are fixed costs and one third running costs (Biermayer and Haas 2008). The main cost components are

- Building costs including cost of paying interest on the loans and repaying the capital (around 60% of total costs)
- Fuel costs (around 20% of total costs)
- Cost of operation, maintenance and repair (around 20% of total costs)

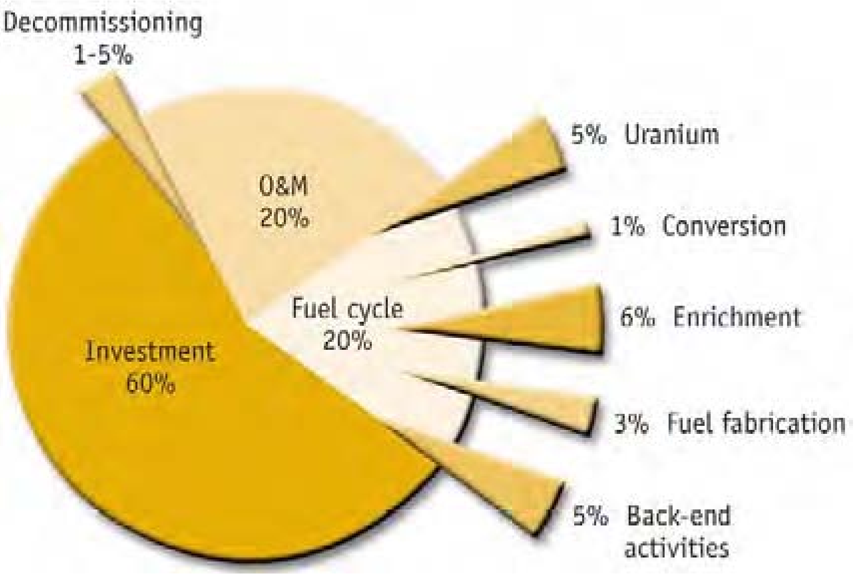

Figure 6: Costs for nuclear energy production (Rogner, 2007)

There are several additional determinants which are not, or only partly, seen on the balance sheet of the operator, but contribute to the overall costs:

- Decommissioning and waste management
- Liability for Nuclear Damage
- Opportunity costs

It is difficult to be precise in calculating these overall economic costs. For instance, there is no experience of how much final storage of nuclear fuel will cost, and the necessary infrastructure does not currently exist. Therefore, only estimates can be made.

4.1. Building Costs

Nuclear power plants contain a core of very dense, high-energy and highly radioactive nuclear fuel. To avert disaster, damage of this fuel has to be prevented at any cost. Therefore, designers need to plan systems which can contain – and shut down – the nuclear reactor in the most severe and unusual of circumstances, and which at the same time protects the plant from detrimental influences from “outside”. This need for exceptional safety provisions means that nuclear power plants are not only very complicated installations, but also very expensive ones.

There are ongoing efforts to make estimates of the cost of installing new nuclear capacity. The industry itself assesses the price of one installed nuclear kilowatt (overnight costs) to be between 1,500 and 3,500 US Dollar (World Nuclear Association, 2009a). Other studies estimate very low costs for new plants (Harding, 2007):

- GE/Westinghouse (1,000-1,500 US Dollar/kW)
- French Ministry of Economics, Finance, and Industry (1,664 US Dollar/kW)
- University of Chicago (1,500 US Dollar/kW)
- World Nuclear Association (1,000-1,500 US Dollar/kW), 2-3 US cent/kWh
- MIT Nuclear Study (2,000 US Dollar/kW)
- US Energy Information Administration (2,083 US Dollar/kW)

In fact, experience shows that buildings costs often go considerably over-budget. In the United States, an assessment of 75 of the country’s reactors showed predicted costs to have been 45 billion US Dollar (34 billion Euro) but the actual costs were 145 billion US Dollar (110 billion Euro). In India, the country with the most recent and current construction experience, completion costs of the last 10 reactors have averaged at least 300% over budget (Thomas et al., 2007).

In May 2008, Moody's Corporate Finance made an estimate for the US market, and they arrived at a price “potentially exceeding” 7,000 US Dollar/kW; much more than industry estimates. The same report estimated wind and solar power at 2,000 and 3,000 US Dollar/kW: “[O]ur concerns reside in the fact that nuclear generation has a fixed design where construction costs are rising rapidly, while other renewable technologies are still experiencing significant advancements in terms of energy conversion efficiency and cost reductions" (Moody's, 2008).

Interestingly, there was no economy of scale for construction of nuclear power plants in the past. The specific building costs per kWel have been increasing over time despite higher installed capacities. This is due to higher safety requirements and a decreasing number of new builds. This resulted in an opposite learning effect. Standardisation was not possible and every plant had to cover nearly all development costs for the specific site (Biermayr and Haas, 2008).

The main reasons for cost overruns are (Thomas, 2008; Biermayr and Haas, 2008; Harding, 2007):

- Forecasts of construction cost based on past cost should be treated with scepticism. Most utilities are not required to publish properly audited construction costs. And prices quoted by those interested in investment must clearly also be viewed with scepticism. This is also true for bids if an overshooting of prices has to be covered by the government or directly through taxpayers' money.
- Cost of capital can change: The cost of capital varies from country to country and from utility company to utility company, according to the 'country risk' (how financially stable the country is) and the credit-rating of the company. There will also be a huge impact on the cost of capital from the way in which the electricity sector is organised. If the sector is a regulated monopoly, the real cost of capital could be as low as 5-8% but might be as high as 15% in a competitive electricity market. Accordingly to Moody's report of 2008, "The cost and complexity of building a new nuclear power plant could weaken the credit metrics of an electric utility and potentially pressure its credit ratings several years into the project."
- Delays in building times: Due to the complexity of a nuclear power plant, complications often occur during construction. These complications result in cost increases. For example, in Finland, Areva sold OL3 to TVO, the Finnish operator, for 3.2 billion Euro "turn-key". Due to delays, the plants' start up, initially planned for 2009, is already postponed to 2012. Besides a cost

overrun of not less than 1.5 billion Euro, Nordic electricity consumers are estimated to be paying an additional 3 billion Euro to secure their electricity supply in the mean time due to the delays. Similarly, the Flamanville EPR project in France is suffering financial troubles. The original stated costs were 3.3 billion Euro, but these costs were re-stated in December 2008 at 4 billion Euro.

To what extent, if any, will the current financial crisis impact negatively upon the nuclear revival? On the occasion of the meeting of Energy Ministers of the Group of Eight (G8) on 24 and 25 May 2009, the IEA published a report entitled “The Impact of the Financial and Economic Crisis on Global Energy Investment” which predicts that the economic crisis could delay or cancel the construction of new nuclear reactors worldwide. Well-advanced projects should be completed. The other projects could be halted by significant obstacles: extended construction periods, staff shortage and long licensing processes. "The huge capital requirements combined with risks of cost overruns and regulatory uncertainties make investors and lenders very cautious, even when demand growth is robust," it said.

4.2. Fuel costs

There is a limited amount of rich uranium ore in the Earth's crust. When the rich ores are mined, there is a much higher amount of poorer ore available. A practically unlimited amount of uranium is dissolved in seawater. However, the estimate for uranium content of seawater is three parts per billion. To extract uranium from the sea would require significantly more energy than it will ever deliver in a nuclear power plant. To a certain degree, even the ore that can be mined will have a too low uranium content to be worthwhile extracting. Below a certain level of uranium content, it will cost more (fossil) energy to process it (i.e., to grind the uranium-containing granite rock, dissolve it into acid to extract the uranium, to ultra-centrifuge the won uranium for enrichment, to turn the enriched uranium into nuclear fuel, and to transport the radioactive material over long distances during each processing step) than it will ever generate in the nuclear power plant. This does not include the energy required for storing the final waste for hundreds of centuries. As soon as this energy threshold is reached, nuclear energy will have even more negative consequences for the climate than fossil energy.

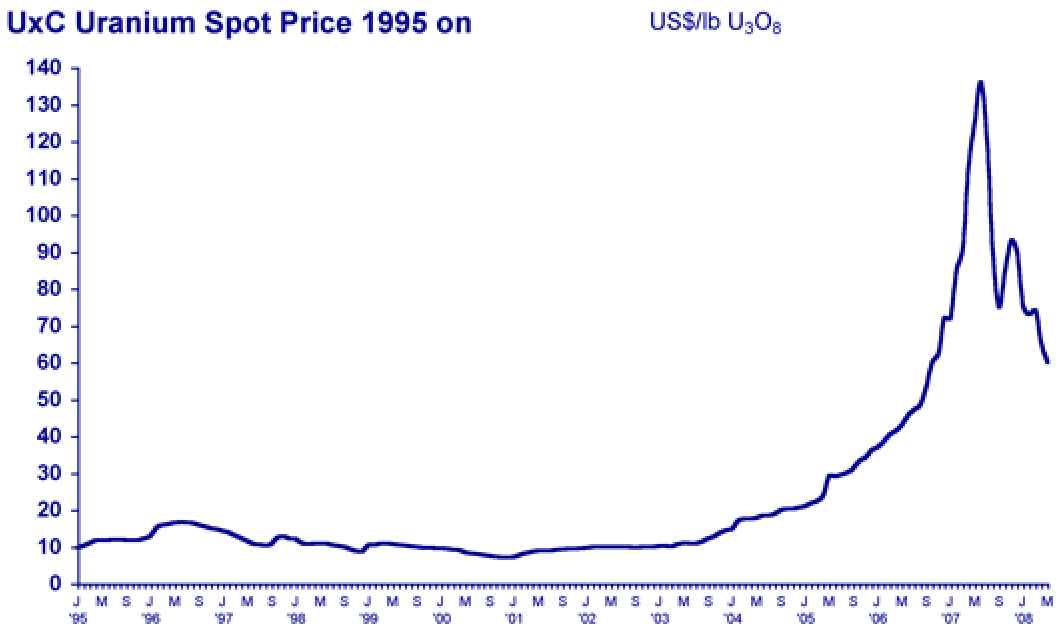

Figure 7: UxC Uranium spot price, from 1995 onward (World Nuclear Association, 2009b)

Fuel costs are a small part of the projected cost of nuclear power and are easier to calculate than building costs. Fuel costs have fallen in the last decades, and the world uranium price has been low since the mid-1970s, although in recent years the price of uranium has risen, more than doubling in 2006. Due to the increasing price of uranium, operators of nuclear power plants are currently considering other reactor fuels. The long standing price stability of nuclear power can therefore no longer be taken for granted. These higher uranium costs have yet to be reflected in fuel costs for reactors, although given that much of the cost of fuel relates to processing, including enrichment, the effect will be limited (Biermayr and Haas, 2008).

4.3. Non-fuel operations and maintenance cost

The non-fuel operations and maintenance (O&M) costs have a minor share of overall costs of nuclear energy production and are often neglected in discussion about nuclear economics. But, as Stephen Thomas stated: "However, the assumption of low running costs was proved wrong in the late 1980s and early 1990s when a small number of US nuclear power plants were retired because the cost of operating them was found to be greater than cost of building and operating a replacement gas-fired plant" (Thomas, 2005). And: "It is also worth noting that British Energy, which was essentially given its eight nuclear power plants when it was created in 1996, collapsed financially in 2002 because income from operation of the plants barely covered operating costs. This was in part due to high fuel costs, especially the cost of reprocessing spent fuel, an operation only carried out now in Britain and France. British Energy has subsequently acknowledged that expenditure in that time was not sufficient to maintain the plants in good condition. Average O&M costs for British Energy's eight plants, including fuel, varied between about 24.5 and 28.0 Euro/MWh from 1997 to 2004. However, in the first six months of fiscal year 2006/07, operating costs including fuel were 35.5 Euro/MWh because of poor performance at some plants." (Thomas, 2005)

Also, the Chernobyl accident provoked a phase of retrofitting plants with additional safety tools and better safety management. In case of another disaster this is expected to happen again.

Many O&M costs are largely fixed – the cost of employing the staff and maintaining the plant – and vary little according to the level of output of the plant so the more power that is produced, the lower the O&M cost per MWh. After liberalisation of the EU's energy markets, cost pressure for Europe's energy companies increased. Therefore, companies started a process of postponing safety checks for nuclear power plants, and began to reduce the number of employees in order to reduce O&M costs.

4.4. Comparing the costs of power generation

The nuclear industry claims proudly that electricity generating costs from nuclear are competitive against gas and coal. The World Nuclear Association even states in a 2008 briefing paper regarding generating cost comparisons: "For nuclear power plants any cost figures *normally* include spent fuel management, plant decommissioning and final waste disposal. These costs, while *usually external for other technologies*, are internal for nuclear power (ie they have to be paid or set aside securely by the utility generating the power, and the cost passed on to the customer in the actual tariff)." (World Nuclear Association, 2009a, emphasis added)

Again, this claim does not compare well with reality:

- “normally”: in many publications, it is not clearly visible and comprehensible how the costs are calculated. This is also true for the above named briefing paper, only linking to other studies without clear explanations, but used as a stand-alone tool in many debates.
- “Usually external for other technologies”: Fossil fuel and renewable plants have to calculate plant decommissioning and this is part of the budget. It is true that external costs of fossil fuels are not fully represented in prices, but a start for CO2 pricing is already implemented in European countries. Moreover, huge external cost are also forgotten by the nuclear industry and not included in generating costs (see above). It is not true that spent fuel management and final waste disposal are fully paid for by the nuclear industry. Other costs including liability in case of an accident are limited to a ridiculous extent.

When comparing costs it is therefore essential to know what kind of costs are included for all types of power generation. As the costs for nuclear waste disposal and even for decommissioning are more or less unknown, it may make sense to compare the business cost only. Fritsche (2007) gave the following data (without external costs) for Germany:

- New nuclear power plant 4.5-5.5 Eurocent/kWel
- Stone coal (imported coal) power station 4.0-5.0 Eurocent/kWel
- Gas and steam power station 4.0-5.0 Eurocent/kWel

Thomas (2005) analysed 10 recent studies to establish why they differ so much regarding generating costs. All studies claimed to be realistic but resulted in costs ranging from 1.81 US cent/kWel up to 9.06 US cent/kWel. Analysis showed that input parameters were completely different especially for building time, interest rate, lifetime etc.

Hultman et al. (2007) compared the power generating costs of 99 US reactors on an empirical basis. The costs also range here from 3.2 US cent/kWel up to 14.4 US cent/kWel although the interest rate was calculated with 6% for all reactors. 16% of the reactors have generating costs over 8 US cent and 5% over 12 US cent.

5. Hidden costs of nuclear power

The costs of waste disposal, decommissioning of plants at the end of their lifespan and provisioning for accidents have never been adequately accounted for, and will result in a massive burden on future economies and generations. Most of the costs of a serious nuclear accident will be covered by society and not by the plant operator's insurance. There is a huge gap between the expected costs of decommissioning and waste storage of the currently operating plants in the EU and the money set aside for that purpose by the operators.

5.1. Decommissioning and final waste storage

The ‘clean-up’ costs that follow the closure of a nuclear power station at the end of its working life are substantial and include the dismantling of the reactor and the management of radioactive waste including spent fuel produced during its operation. Typically, a reactor that operates for 40 years may take as long again to decommission. The waste produced in the reactor, particularly used fuel, will remain hazardous for significantly longer.

These liabilities are real costs that have mostly already been incurred. In principle, such liabilities are included in company financial statements (balance sheets). Normally they are discharged from income set-aside during the working lifetime of each reactor, as after a reactor is finally shut down, it no longer generates any revenue. The provisioning of such funds to meet future liabilities, if done adequately, contributes to the fulfilment of both the polluter pays principle and normal economic principles whereby the price charged for a product (electricity) reflects all the costs incurred in making it - including decommissioning costs - plus a profit margin for the company and its investors.

However, in practice there is mounting evidence that many nuclear firms within the EU are failing to meet these basic principles. The UK state aid cases of British Energy plc and BNFL plc have already been well documented. Across a total of 19 reactors and ancillary plant, these two firms have combined undiscounted liabilities amounting to around 55 billion Pounds (79 billion Euro), which according to official estimates are spread over the next 135 years. Both companies only avoided declaring themselves bankrupt due to the heavy intervention of the UK government, which offered substantial subsidies and moved to take direct responsibility for liabilities over the long term (FoEE, 2005).

In Slovakia, the state-controlled Slovak Decommissioning Fund was established in 1995, almost twenty years after the first of the currently operating nuclear reactors were commissioned. The national energy company SE did not have to repay the missing contributions from the period before 1995. Moreover, an important part of the contributions that SE paid to the Fund after 1995 were used instead to dismantle the experimental nuclear power plant Bohunice A-1 which was shut down in 1977 after two serious accidents.

In 2006, a new law was adopted in Slovakia for harmonising legislation with EU legislation. According to a study of the Wuppertal Institute by order of the European Commission in 2007: "The law has set the obligatory payment paid by the NPP operators too low compared to the size of the liabilities and lower than determined before the law had been adopted. The amount required by the new law from the financial payments from the NPPs operators will not cover the costs of decommissioning nuclear facilities." (Wuppertal Institute, 2006)

The EU has 20 operators of nuclear plants, at 67 locations in 16 member state territories. Between them they currently generate about a third of the EU's electricity. The European Commission estimates that approximately one third of the 145 power reactors currently operating in the European Union will need to be shut down by 2025. Friends of the Earth Europe estimates that the total combined liabilities held by these operators are, at today's prices, in excess of 500 billion Euro (FoEE, 2005).

The Wuppertal Institute in-depth analysis of European decommissioning systems (2007) came to the following results:

- Cost estimates are subject to a high degree of risk and uncertainty; expected costs have risen significantly in a number of countries while many estimates still contain a considerable range of possible costs.
- Differences in reported cost estimates occur due to varying discounting mechanisms and the timing of dismantling.

- Not all Member States require that funds be managed externally and segregated from the operator.
- In most countries there are only limited rights for the public to access information on decommissioning costs and funds.

5.2. Nuclear waste

Similar to the issue of decommissioning, there are also major uncertainties about the financing of final nuclear waste disposal. No final repository for high level nuclear waste has yet been put into operation. This makes it impossible to give a proper cost estimate of such a repository.

Although, in principle, nuclear operators should be fully responsible for nuclear waste costs, in practice it is hard to imagine that any commercial enterprise will cover costs arising for at least 250,000 years. Allowing for the waste disposal site to be guarded by only two persons for 250.000 years already means 4.4 billion working hours. Calculating 20 Euro per hour and per person, this means costs of more than 100 billion Euro!

Consequently, the US administration has calculated the cost of national waste disposal for the coming 100 years, and calls that a “full cost” calculation. The projected costs to build a nuclear waste repository at Yucca Mountain, to transport used radioactive fuel to Nevada from around the country and to operate the site for 100 years have grown to more than 90 billion US Dollar, according to US energy department calculations in 2008. The department's previous "total system life cycle" cost estimate for the repository was 57.6 billion US Dollar, in 2001.

5.3. Accident liability for third party damages

Recognising the cross border effect of nuclear incidents, two groups of countries agreed amongst each other in the early 1960s how to arrange the liability of nuclear power plants. This resulted in the Vienna (IAEA) and the Paris (OECD) conventions. Both included different, but limited, third party liability. These conventions are linked by a Joint Protocol, adopted in 1988.

In 2003 and 2004, protocols were passed on the Vienna and Paris conventions respectively, which changed the definition of nuclear damage and the scope of the coverage. Consequently, new minimum limits of liability were set as follows: Operators (insured) 700 million Euro; installation states (public funds) 500 million Euro; and collective states contributing 300 million Euro. This results in a total minimum liability of 1.5 billion Euro.

When attempting to set limits for liability it is helpful to consider the insurance costs of known disasters. Doing so demonstrates that 700 million Euro (approximately 990 million US Dollar) as a limit for liability is not a vast amount when compared to the costs of other disasters. For example (FoEE, 2007):

- Hurricane Katrina, August 2005, insurance compensated 45 billion US Dollar;
- Terrorist attacks on 9/11, 2001, 20.7 billion US Dollar;
- Exxon Valdez, March 1989 Clean-up of oil spill, 2.5 billion US Dollar; Settlements, 1.1 billion US Dollar; The economic loss (fisheries, tourism) suffered due to the damage to the Alaskan ecosystem was 2.8 billion US Dollar;

The above examples are all non-nuclear incidents. Unlike the event of a nuclear incident, the damage could be repaired and people could start rebuilding their homes once the fires were put out. Examples of damage following nuclear incidents include:

- 1 billion US Dollar for cleaning up Three Mile Island (in which the containment remained intact);
- 15 billion US Dollar estimate of the direct loss caused by the Chernobyl disaster in the former Soviet Union. It is estimated that the damages could accumulate to 235 billion Euro for Ukraine and 201 billion Euro for Belarus in the thirty years following the accident.

Various estimates have been given for the total damage which could be caused by accidents with nuclear power plants. They range from 83.252 billion Euro (Dreicer, Tort and Manen, 1995) to as much as 5.469 trillion Euro (Ewers and Renning 1992). Based on these estimates the cost of a large scale nuclear accident could be up to 8,000 times higher than the insurance currently available. So for every 8,000 Euro of damages only one Euro of compensation would be available from the insurance of the nuclear power plant.

A nuclear accident in Europe is far from impossible. And it is clear that such an accident will barely be covered by the nuclear power plant’s insurance. After the 700 million Euro from operators’ insurance is spent, states and the international community guarantee another 800 million Euro of compensation. Further costs will be covered again with taxpayer’s money or will lead to a decrease in welfare and social security, or both.

5.4. Opportunity cost

Opportunity cost is defined as the value of the next best alternative forgone as the result of making a decision. Opportunity cost analysis is an important part of a company's decision-making process but is not treated as an actual cost in any financial statement.

Governments should take opportunity costs into consideration while deciding on energy options. Bill Keepin and Gregory Kats, research scholars at the Rocky Mountain Institute, analyzed the effect of nuclear power compared with energy efficiency measures in reducing CO2 emissions. They found that even a massive worldwide nuclear power program sustained over a period of several decades could not 'solve' the greenhouse problem. Furthermore, less developed countries cannot support a major expansion of nuclear power on the scale that would be required to substantially reduce greenhouse gas emissions purely through the expansion of nuclear power. On the contrary, improving electrical efficiency can be seven times more cost effective than nuclear power for abating CO2 emissions. Therefore, nuclear power goes along with high opportunity cost. Spending money on an expensive and relatively ineffective option means using money that could be spent on more effective and cheaper measures.

Catherine Mitchell and Bridget Woodman (Mitchell and Woodman, 2006) from the Warwick Business School argue that far from complementing the necessary shift to a low carbon economy, the scale of the financial and institutional arrangements needed for new nuclear power stations means they would fatally undermine the implementation of low carbon technologies and measures such as demand side management. They will therefore ultimately undermine the shift to a true low carbon economy. A new nuclear programme would give the wrong signal to consumers and businesses, implying that climate protection is only a question of a better use of existing technologies and thereby weakening the urgent action needed on energy efficiency.

The Sustainable Development Commission says a decision to proceed with a new reactor programme will require "a substantial slice of political leadership … political attention would shift, and in all likelihood undermine efforts to pursue a strategy based on energy efficiency, renewables and more CHP." (SDC, 2006).

The developed world is currently dominated by centralised electricity generating systems. This centralised system is extremely environmentally damaging. By producing electricity through fossil fuels or nuclear, around two thirds of the fuel energy is thrown away as waste heat. There are also huge losses in the electricity transmission wires. Nuclear power stations are the epitome of centralised generation: they are large scale (up to 1 GW), remote, and heavily reliant on the transmission network. In contrast, renewable generation and combined heat and power stations lend themselves towards a more decentralised system and a greater use of demand management. Projects tend to be smaller and sited closer to the point of demand, with greater flexibility. Customer involvement - a key aspect to behavioural change - is easier to achieve (Mitchell and Woodman, 2006).

Mitchell and Woodman conclude that support for new reactors is more likely to strengthen the momentum of the conventional energy system than enable a decentralised energy system to develop. This is because it would:

- Reduce the pressure for appropriate network infrastructure development;
- Reduce the pressure for policy measures to ensure the removal of barriers within economic regulation for small-scale technologies;
- Reduce the pressure for policy measures to ensure greater links within an energy system between supply and demand reduction, for example a move to a service culture or a push for metering reform, and

- Reduce the pressure for behavioural change.

5.5. Demand side management and renewables vs nuclear power

In 2009, an incident in the German NPP Krümel lead to a breakdown of the traffic lighting system in large parts of the City of Hamburg, showing the problem of dependency on one major central electricity producer.
Picture??
In a similar case, the 2007 Chūetsu earthquake in Japan and the shut-down of the Kashiwazaki-Kariwa Nuclear Power Plant, illustrated that demand side management can help to avoid bigger problems. The Kashiwazaki-Kariwa Nuclear Power Plant is the largest nuclear power plant in the world with seven nuclear reactors and over 8,000 MW of installed capacity. Tokyo has a high energy demand in summer times, largely for cooling, and because of the lacking 8,000 MW, electricity deficits had been expected. An effective demand-side management from the energy companies, requiring major energy consumers to reduce or stop electricity consumption at peak-demand times, meant that blackouts could however be avoided (Thomas et al., 2007).

There are many contrasting examples how the nuclear industry has been very much engaged in increasing electricity demand of households by selling electric night-storage-heaters and thereby creating a infrastructure to keep energy demand artificially high.

Proponents of nuclear power call publicly for a phase out of fossil fuels and for replacing them with a mix of base load nuclear power and intermittent renewable sources of energy. In reality, nuclear power is often a strong barrier for renewable energy sources to come online, as the Finnish example shows (Greenpeace, 2009). Commissioning of four nuclear power plants in 1977-1980 led to stagnation in the development of combined heat and power, and favoured inefficient electric heating. Now, the decision on OL3 is already having a similar impact as the graph shows:

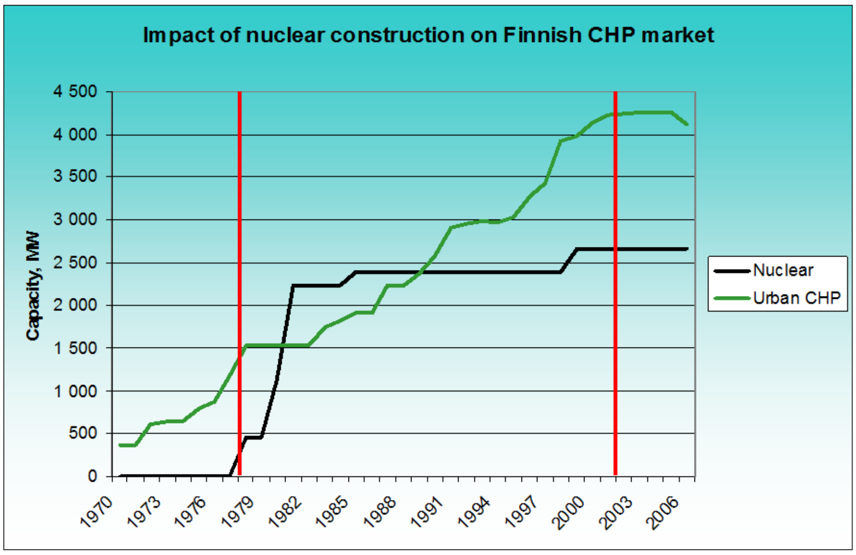

Figure 8: Impact of nuclear construction on Finnish CHP market (Greenpeace, 2009)

The decision on OL3 in Finland was made at a time when new renewable energies, especially wind, had come of age. Significant growth potential was projected. The potentials have not been realized, largely because the market is clogged by OL3 (Greenpeace, 2009).

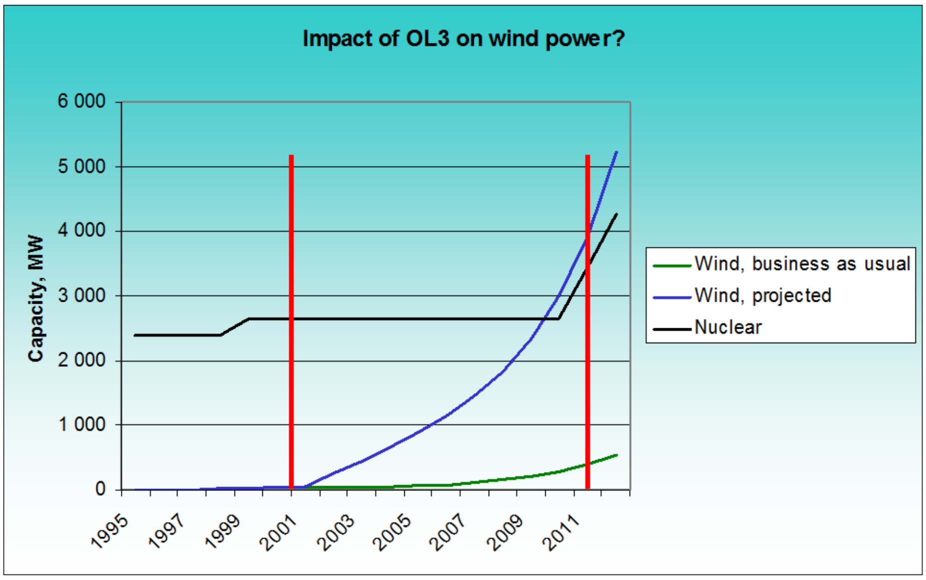

Figure 9: Impact of OL3 on wind power? (Greenpeace, 2009)

A shift in the political framework can change that situation. In Germany, the feed-in tariffs for renewable sources of energy include a priority for renewable energy. That means that if there is electricity from renewable sources, this kWh will be fed in and not the nuclear one. As nuclear power plants are base load plants and economic calculation are based on around 8,000 hours per year of production, this priority is a major problem for nuclear plants. In 2008, German nuclear power plants reached up to only 6,820 hours and 2009 they could end up with only 6,000 hours. Every hour less means 50,000 Euro less per plant. This is mainly due to wind power having access to the grid. There are around 21,000 MW of installed nuclear power in Germany, but 24,000 MW wind power, and even if wind power reaches only 2,000 working hours per year, this is sufficient for a significant reduction of nuclear production. In Great Britain, EdF and Eon have said that they will not build new nuclear power plants if the governments would give strong support for renewables (taz, 2009).

If governments and industry now push nuclear investments, they are creating an infrastructure which disadvantages renewables. The grid layout for a renewable, decentralised energy system is, for example, completely different to that of a nuclear centralised grid. In most cases, local renewable energy plants have only an installed capacity of a few megawatts or less. Each new nuclear power plant makes connecting renewable units less attractive. In the Netherlands, for example, farmers could not sell their wind energy for a long time because the high voltage lines were already reserved by a big production unit in another region.

Nuclear power is neither sustainable nor economic. In fact, investments in nuclear power are increasing costs for renewable energies and energy efficiency now and in the future. These opportunity costs have to be added to nuclear power costs.

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