www.laka.org | info@laka.org | Ketelhuisplein 43, 1054 RD Amsterdam | 020-6168294

World Information Service on Energy
founded in 1978

NUCLEAR MONITOR

A Publication of World Information Service on Energy (WISE) and the Nuclear Information & Resource Service (NIRS), incorporating the former WISE News Communique

#621 & #622 **February, 2005**

A back-door come-back

Nuclear energy as a solution for climate change?

Contents

Summary

Climate change is widely acknowledged as being one of the most pressing issues for the global community. Climate change affects many aspects of the environment and society, including human health, ecosystems, agriculture and water supplies, local and global economies, sea levels and extreme weather events. Many in the nuclear industry have seen climate change as a *'lever'* by which to revitalise the fortunes of nuclear power.

However, in various stages of the nuclear process huge amounts of energy are needed, much more than for less complex forms of electricity production. Most of this energy comes in the form of fossil fuels, and therefore nuclear power indirectly emits a relatively high amount of greenhouse gases. The emissions from the nuclear industry are strongly dependent on the percentage of uranium in the ores used to fuel the nuclear process, which is expected to decrease dramatic. Recent study estimates that nuclear power production causes the emission of just 3 times fewer greenhouse gases than modern natural gas power stations.

To reduce the emissions of the public energy sector according to the targets of the Kyoto Protocol, 72 new medium sized nuclear plants would be required in the EU-15. These would have to be built before the end of the first commitment period 2008-2012. Leaving aside the huge costs this would involve, it is unlikely that it is technically feasible to build so many new plants in such a short time, given that only 15 new reactors have been built in the last 20 years.

If we would decide to replace all electricity generated by burning fossil fuel with electricity from nuclear power today, there would be enough economically viable uranium to fuel the reactors for between 3 and 4 years. With the use of fast breeder reactors a closed cycle could be reached that would end the dependency on limited uranium resources. But despite huge investments and research over the last decades, breeder reactors have been a technological and economic failure.

Switching the entire world's electricity production to nuclear would still not solve the problem. This is because the production of electricity is only one of many human activities that release greenhouse gases. Others include transport and heating, agriculture, the production of cement and deforestation. The CO_2 released worldwide through electricity production accounts for 9% of total annual human greenhouse gas emissions.

Numerous studies have shown that the single most effective way to reduce emissions is to reduce energy demand. Studies of future energy scenarios show no evident correlation between CO_2 emissions and nuclear power. In fact the scenario with the lowest emissions was not the one with the greatest use of nuclear power, but the one in which the growth in demand was minimised.

There are also a lot of alternative energy sources. The costs of renewable sources are falling rapidly: in the last 10 years the cost per kWh of electricity from wind turbines fell by 50%, and that from photovoltaic cells fell by 30%. The costs of nuclear power are rising, despite the fact that nuclear power has been hugely subsidised over the last half century. Some of the costs of nuclear energy have been excluded from the price. Examples include costs of decommissioning and liability costs.

In the medium term it is possible to supply all of the world's energy needs through renewable sources based on current technology. Renewable energy sources have multiple benefits. They are free from greenhouse gas emissions and can also increase diversity in the energy market. They can provide long-term sustainability of our energy supply and can be used in rural areas of less developed countries that are not connected to gas and electricity networks.

There are many serious problems associated with nuclear power that have existed since its introduction and are still not resolved. For the storage of high radioactive nuclear waste there are still no final repositories in operation. In the last decades researchers have been working on the technology to reduce radioactivity and the decay time of nuclear waste, the so-called *transmutation* process. There is no guarantee that this expensive research will be successful, and these techniques can only be applied for future spent fuel and not for the present amount of nuclear waste.

Although much progress has been made in increasing safety standards reactors are still n ot inherently safe and problems are still common. Apart from possible technical failures, the risk of human error can never be excluded. This risk will grow now that the onset of privatisation and liberalisation of the electricity market has forced nuclear operators to increase their efficiency and reduce costs. The reductions in the size of the workforce have in some cases led to concerns over safety.

One of the by-products of most nuclear reactors is plutonium-239, which can be used in nuclear weapons. Nuclear installations could also become targets for terrorist attacks and radioactive material could be used by terrorists to make "dirty bombs".

In the event of a nuclear disaster the health concerns are obvious. Exposure to radioactive fallout would lead to an increased risk of genetic disorders, cancer and leukaemia. There are also health risks associated with the day-to-day production of nuclear power. Employees working in power plants are exposed to low-level radioactivity.

1 Introduction

The rise and fall of nuclear power

When nuclear power was first introduced to the world in the middle of the twentieth century, it was promoted as a cheap and limitless energy source that could satisfy the world's growing energy needs. In 1954 Lewis Strauss, at that time the head of the US Atomic Energy Commission, promised that nuclear power plants would provide electricity "too cheap to meter". Twenty years later, in 1974, the International Atomic Energy Agency (IAEA) forecast that there would be up to 4,450 reactors of 1,000 Megawatt (MW) in operation in the world by the year 2000. Uranium would rapidly become scarce but plutonium-fuelled fast breeder reactors would provide endless amounts of cheap electricity (WWF, 2000).

The situation today is a far cry from these early predictions. At present there are 442 nuclear reactors in operation around the world: less than 10% the number predicted by the IAEA thirty years ago (Scheer, 2004). These reactors provide approximately 16% of the world's electricity (Slingerland et al, 2004), and just 2.5% of the world's formal energy demand (WWF, 2000; Hodgson & Maignac, 2001). At the end of 2002 only 32 reactors were listed as being under construction (Slingerland et al, 2004). A large number of these have been officially listed as "under construction" for over 15 years and will probably never be completed. (Atom's Amok, 2004). In the United States, there has not been a successful reactor order in more than 30 years. The last one ordered was the Palo Verde reactor, in October 1973.

Climate change: a lifeline for nuclear power?

In recent years the balance of evidence has confirmed that our planet is becoming warmer due to the emission of greenhouse gases by human activities. Approximately half of these greenhouse gases are emitted by the energy sector. In order to avert catastrophic climate change we urgently need to reduce greenhouse gas emissions. However, the energy demands of the world's population are still growing at an alarming rate. The World Energy Outlook estimates that global energy use will have increased by 67% in 2030 compared to levels in 2000 (IEA, 2002), and it is generally accepted that world energy demand will double by 2050 (WNA, 2004a). How to satisfy these energy demands while simultaneously reducing greenhouse gas emissions is one of the most pressing questions of our time.

According to the nuclear power industry the best way to reduce greenhouse gas emissions is to greatly expand the number of nuclear reactors. Their arguments are summed up in the following statement by the World Energy Council (WEC):

"Nuclear power is of fundamental importance for most WEC members because it is the only energy supply which already has a very large and well diversified resource (and potentially unlimited resource if breeders are used), is quasi-indigenous, does not emit greenhouse gases, and has either favourable or at most slightly unfavourable economics. In fact should the climate change threat become a reality, nuclear is the only existing power technology which could replace coal in base load."
(Cited in NEA, 2002)

The industry has engaged in a huge PR campaign based on these arguments. Articles are written and glossy folders are produced to convince the public and decision-makers that nuclear power is the answer to the climate change problem. By promoting itself as the saviour of the environment the failing industry hopes to give itself a new lease. However, their arguments are based on a number of myths, namely that:

- Nuclear power does not emit greenhouse gases;
- There is a plentiful supply of fuel for the nuclear fission process;
- Nuclear power is economically viable;
- There are no viable alternative solutions;
- There are no other major problems associated with nuclear power;
- The fast breeder technology will eventually mature and provide unlimited resources.

This report will examine each of these myths and disprove their validity.

Chapter 2 examines the current knowledge on climate change, the agreements in place to reduce greenhouse gas emissions, and the role that the nuclear industry seeks for itself within these agreements. Chapter 3 assesses how much of a contribution nuclear power can make in the reduction of greenhouse gas emissions. In chapter 4 the myth that plentiful fuel supplies are available for the nuclear fission process is examined. Chapter 5 investigates whether nuclear energy is financially viable. The myth that no viable alternative solutions exist is examined in section 6, and section 7 addresses a few of the other problems associated with nuclear power.

2 Climate change and nuclear power

Climate change

Climate change is widely acknowledged as being one of the most pressing issues for the global community. In 2001 the United Nations Intergovernmental Panel on Climate Change (IPCC) published its most recent overview report on the issue. This report stressed that there is ever more convincing evidence to suggest that most of the warming of the earth must be directly attributed to human activities, namely the emission of greenhouse gases by burning fossil fuels (oil, coal and gas) for energy production.

Greenhouse gases are naturally found in the atmosphere and trap part of the sun's heat in the lower atmosphere. This process keeps our planet warm and makes life on earth possible. If the atmosphere were devoid of these gases the average global temperature would be approximately 33°C lower than it is today (Barry and Chorley, 1992). However, due to human activities, the concentrations of greenhouse gases in the atmosphere are increasing unnaturally. This results in the trapping of too much heat, leading to a rise in global temperature.

Furthermore, the IPCC report suggests that the temperature rise of the 20th century is very likely the cause of the detected sea-level rise over that period (IPCC, 2001a). The warming up of the seas leads to an increase in the water volume, which makes the sea level rise.

What are the effects of climate change?

The history of the earth has known huge variations in average global temperatures. However, the current warming is taking place at a pace unseen for millions of years. According to the most recent findings of the IPCC, global temperatures will rise between 1.4 and 5.8°C, and sea levels by 9 to 88 cm by 2100, compared to 2000 levels (IPCC, 2001b). Whilst such a temperature rise of a few degrees may not sound particularly alarming, it should be noted that the average temperature difference between the coldest part of the last major ice-age and the present is only about 5°C (Houghton, 1994). The problem is that natural and human systems may not be able to adapt to such a pace of warming.

These changes in climate affect many aspects of the environment and society, including human health, ecosystems, agriculture and water supplies, local and global economies, sea levels and extreme weather events. Whilst some positive effects are expected (e.g. longer agricultural growing seasons in some mid-latitude countries), the negative effects will outweigh the positive even with small temperature rises. The more the temperature rises, the more negative the effects will be (IPCC, 2001b; Greenpeace, 2001).

In Europe some of the effects are already being felt. A sea-level rise of 0.8 to 3.0 mm per year over the last century is seriously felt in water management and also influences the fresh water levels. And the increase of extreme weather events (long periods of drought, extreme rains) over the last 30 years is increasingly causing economic damage e.g. in agriculture (EEA, 2004a; VROM, 2004).

Climate change agreements

In 1992 the first major international agreement on climate change, the United Nations Framework Convention on Climate Change (UNFCCC), was adopted. The UNFCCC requires that atmospheric CO_2 concentrations be stabilised at a level that prevents dangerous climate change. Furthermore, this should be achieved quickly enough to allow ecosystems to adapt in a natural way, food production to continue unharmed and economies to develop sustainably. However, the convention lacked enforcement measures and specific commitments (NEA, 2002).

The Kyoto Protocol, adopted in 1997, built on the commitments made in the UNFCCC but went a serious step further. The protocol established concrete emissions targets for most developed countries, requiring them to reduce their collective emissions of the six most important greenhouse gases (CO_2, CH_4, N_2O, HFK, PFK and SF_6) by at least 5.2% by 2008-2012, as compared to 1990 levels. The Kyoto Protocol defines three flexible mechanisms ("flex mechs") that can be used by developed countries to assist them in meeting their emissions targets: the clean development mechanism (CDM), joint implementation (JI) and emissions trading (NEA, 2002). With these mechanisms countries and companies can buy emission rights. The first two mechanisms allow the (co-) financing of emission saving investments. Under the CDM investments are made in countries with no obligations under the Kyoto Protocol (development countries). Under JI investments are made in countries with an obligation under the Kyoto Protocol that have 'spare' emission space (in practice Eastern European countries and Russia). A system for trade in CO_2 emissions is at present developing in the European Union.

With the signature of Russia's president Putin the Kyoto Protocol has become legally binding. Although the United Stated and Australia have not signed the Kyoto Protocol, the Protocol must be considered a major step towards global climate policy.

Nuclear power and climate change mitigation

Many in the nuclear industry have seen climate change as a *'lever'* by which to revitalise the fortunes of nuclear power (IEA, 1998). Ritch III (2002) described nuclear power as being "*environmentally indispensable*" whilst Hodgson describes nuclear power as being "*by far the most effective way to reduce CO_2 emissions*" (Hodgson & Maignac, 2001, p. 22). They assume that nuclear power emits no greenhouse gases and is low cost (NEA, 2001).

At present nuclear power is not included in the 'flex mechs' of the Kyoto Protocol. However these mechanisms, especially the CDM, are seen by the nuclear industry as an opportunity to expand by gaining government grants to subsidise nuclear plants in developing countries (Groenlinks, 2000). Between now and the end of the first commitment period of the Kyoto Treaty (2008-2012), the industry will be lobbying hard to get nuclear power included in all three of the "flex mechs" after 2012 (NEA, 2002). Some countries already see a new commitment period as another chance to make carbon finance available to fund nuclear power. In October 2004, the Japanese Ministry of Economy, Trade and Industry (MITI) published a report on future climate actions that included a recommendation to make nuclear power eligible for the CDM (METI, 2004). In November 2004 the head of the Italian Climate Change office called for the use of nuclear power in the CDM to be "look[ed] at" (Point Carbon, 2004).

In 2002, the then EU Research Commissioner Philippe Busquin stated that nuclear energy could greatly contribute to meeting Kyoto Protocol requirements. In the same year the UK government chief scientific advisor, Prof. D. King, argued strongly that the UK must build new nuclear power stations and that the radioactive waste problem is "*a legacy of the past*" (N-Base, 2002). Earlier this year, British Prime Minister Tony Blair stated that the UK has not ruled out nuclear power as a means of fighting climate change (WNA, 2004b). Growing concerns about climate change seem to make the nuclear energy option appear more attractive to some high level officials.

3 Nuclear power and greenhouse gas emissions

The contribution of electricity production to greenhouse gas emissions

The myth that nuclear power provides a solution to climate change is based on the assumption that the generation of electricity by nuclear fission does not lead to greenhouse gas emissions. However, even if this were the case, switching the entire world's electricity production to nuclear would still not solve the problem. This is because the production of electricity is only one of many human activities that release greenhouse gases. Others include transport and heating, agriculture, the production of cement and deforestation. The CO_2 released worldwide through electricity production accounts for 9% of total annual human greenhouse gas emissions (UIC, 2001b).

Greenhouse gas emissions from nuclear power production

It is true that the actual fission process whereby electricity is generated does not release greenhouse gases. However, in various stages of the nuclear process (e.g. mining, uranium enrichment, building and decommissioning of power plants, processing and storing radioactive waste) huge amounts of energy are needed, much more than for less complex forms of electricity production. Most of this energy comes in the form of fossil fuels, and therefore nuclear power indirectly generates a relatively high amount of greenhouse gas emissions.

In order to establish the magnitude of these emissions compared to emissions from other forms of electricity production, it is necessary to carry out comparative lifecycle assessment of the various energy supply options. In these assessments the total emissions over the whole lifecycle are added together and divided by the total electricity produced over the lifetime of the power plant: the result shows the total greenhouse gas emissions per kWh electricity.

A number of lifecycle assessments for various electricity production processes have been carried out in the past. One of the most comprehensive of these was carried out by the Öko Institute in Germany. It is based on 10 years of research in the GEMIS (Global Emission Model for Integrated Systems) database. A number of the results are shown in the following table.

Generation Method	Greenhouse Gas Emissions (CO_2-eq. /kWh)
Wind	20
Hydroelectric	33
Nuclear	35
Gas Combined Cycle	Ca. 400
Coal	Ca. 1000

Table 1: Greenhouse gas emissions per generation method in Germany (Öko Institute, 1997).

From the data above it can be concluded that nuclear power emits about the same quantity of greenhouse gases as electricity produced from a number of renewable sources, but much less than fossil fuel sources: 12 times less than gas power stations and almost 30 times less than coal power stations. Much of these emissions occur when energy is used for the mining of uranium, during transports and in the enrichment process that makes uranium usable as reactor fuel. The emissions during decommissioning of a nuclear reactor are probably underestimated in these analyses, because in practice these emissions turn out to be much higher than was assumed theoretically.

In a number of other studies similar emissions data are reported, where nuclear power emissions are calculated in the range of 30-60 g CO_2-eq. /kWh (IAE, 1994; CRIEPI, 1995). A more recent study by Storm van Leeuwen & Smith (2004) estimated the difference in emissions between nuclear and gas power plants to be much smaller than the assessments described above. According to their data, nuclear power production causes the emission of just 3 times fewer greenhouse gases than modern natural gas power stations. This figure is based on rich ores with over 0.1% uranium content. Moreover they expect a dramatic decrease of the percentage of uranium content in ores, which will make the extraction of the uranium much more energy consuming. The emissions from the nuclear industry are strongly dependent on the percentage of uranium in the ores used to fuel the nuclear process. The global average uranium content in ores is currently about 0.15% (Canadian Nuclear, 2002, cited in Slingerland et al, 2004).

How many nuclear power plants are needed to reduce emissions?

Can we reduce the emissions of the public energy sector (electricity and combined heat/ electricity) by replacing fossil fuels with nuclear power on a large scale? And if so, how many new power plants would we need? Makhijani (2002) estimates that, in order to produce a noticeable reduction in global CO_2 emissions, it would be necessary to build 2000 large new nuclear reactors of 1000 MW each. The U.S. National Commission on Energy estimates that U.S. reactors would have to double or triple over the next 30-50 years. This means about 300-400 new reactors, including those to replace reactors which will be retiring during that period (National Commission on Energy, 2004).

We have calculated the number of new nuclear power stations that would be needed to reduce the emissions of the public energy sector by 2012 according to the targets of the Kyoto Protocol in the EU-15 (EU prior to the expansion). Although the Protocol does not actually stipulate the sectors in which emissions reductions are to be made, we have made the calculations assuming that each sector contributes according to the levels of its current contribution to total emissions. This means that while this sector accounts for 39% of emissions it should be responsible for 39% of emissions reductions (EarthTrends, 2003).

Assuming that electricity generation from nuclear power plants does indeed cause the indirect emission of 35g CO_2-eq./kWh (Öko, 1997), 72 **new** medium sized plants of 500MW each would be required in the EU-15. (For an explanation of the calculations and assumptions please refer to appendix 1). These would have to be built before the end of the first commitment period 2008-2012. Leaving aside the huge costs this would involve, it is unlikely that it is technically feasible to build so many new plants in such a short time, given that only 15 new reactors have been built in the last 20 years (WISE, 2003). Furthermore, with so many new reactors, the world supply of uranium would be exhausted very quickly (see section 4).

Nuclear power and heat production

Society does not just require energy in the form of electricity: heat is also essential. In the average French household for example, two thirds of the energy used is heat and one-third is electricity (WWF, 2000). When fossil fuels are burnt to produce electricity, a by-product of the process is heat. Traditionally this heat energy has been lost as waste and therefore the efficiency of fossil fuel burning power plants has been low. However, in the last few decades huge advances have been made in fossil fuel cogeneration plants where most of this 'waste heat' is recovered and used in industrial heating or urban heating systems. The efficiency in these plants can reach as high as 90%, compared to 35-55% in conventional plants (Field, 2000; WWF, 2000).

How efficient is a nuclear power plant compared to a modern natural gas fired cogeneration plant? The Öko Institute has calculated the total greenhouse gas emissions of producing 1kWh electricity and 2kWh heat by various energy systems. A natural-gas fired cogeneration plant typically generates about one-third electricity and two-thirds heat, so all of the emissions in this system would stem from the cogeneration plant. In the case of a conventional nuclear plant power, the heat would have to be generated from another source: the Öko study chose an oil-fired central heating system. (Oil was chosen because the associated emissions fall between those of coal and gas.) The total emissions in this case would be as for 1kWh electricity generation in the nuclear plant, and 2 kWh heat production by the oil-fired central heating system. The results reveal that the total emissions from the gas cogeneration plant are of the same order of magnitude as those produced in the nuclear + oil example. Therefore, if we were to replace older fossil-fuel burning power stations with new cogeneration systems, for the same amount of electricity and heat generation the total greenhouse gas emissions would be similar to those in a system based on electricity from nuclear power and heating from fossil fuels.

A number of nuclear cogeneration power plants have been built in Russia, Slovakia, Switzerland and Canada amongst others (Federation of Electric Power Companies of Japan, 2000). However, these are the exception rather than the rule. While nuclear cogeneration is technically feasible, there is much less experience with this method than with fossil-fuel powered cogeneration plants mainly because nuclear power plants are built far from urban areas. Therefore the transport of the heat from the power station to the consumer would lead to a lot of heat loss.

Greenhouse gas emissions in France

In 2003 France generated 75% of its electricity in nuclear power plants. The nuclear industry likes to use France as a shining example of the advantages of nuclear power. However, France's greenhouse gas emissions in 2000 were still increasing, largely because it has lost control of energy consumption in other sectors, e.g. transport.
Furthermore, studies of future energy scenarios carried out by the French Government Central Planning Agency show no evident correlation between CO_2 emissions and nuclear power. In fact the scenario with the lowest emissions was not the one with the greatest use of nuclear power, but the one in which the growth in demand was minimised (Boisson, 1998 & Charpin *et al*., 2000). In another study, a comparison was made between the results of investments in wind energy and the same amount of investment in nuclear energy. The results were clearly favourable for wind energy. With the same investment much more energy could be generated with wind. Moreover, with investments in wind energy more new jobs were generated than with investments in nuclear energy (Bonduelle & Levevre, 2003).

4 Uranium reserves

Just as with fossil fuel, the use of uranium as fuel is limited by its availability. Uranium is a finite resource. Although we are often told by the nuclear industry that uranium is a "*plentiful commodity*" (Ritch III, 2002), an examination of the data reveals that this is not the case.

How large are the planet's uranium reserves?

According to the most recent figures of the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) on global uranium reserves, the total known recoverable reserves amount to 3,5 million tonnes: this refers to reasonably assured reserves and estimated additional reserves which can be extracted at a cost of less than $80/kg (NEA & IAEA, 2004). Given that the current use of uranium is in the order of 67,000 tonnes per year, this would give us enough uranium for about 50 years (WISE, 2003; NEA-IAEA, 2004; WNA, 2004c). Of course, the total reserves of uranium are much greater than this; NEA and IAEA estimate the total of all conventional reserves to be in the order of 14,4 million tonnes. But not only are these reserves very expensive to mine, and therefore not economically viable, the grades of usable uranium are too low for net electricity production. Large parts of the presently quoted reserves (about half) are marginal already. This is the case in Namibia, South Africa, Kazakhstan and with the Olympic Dam mine in Australia.

As pointed out by advocates of nuclear power, there are also vast amounts uranium in unconventional sources. For example uranium is found in ocean water, but at a concentration of 0.0000002% (Storm van Leeuwen & Smith, 2004). The costs of extracting this uranium for use in nuclear power generation would be huge. Furthermore, the extraction and enrichment of this uranium would require more energy than could be produced with it.

If we would decide to replace all electricity generated by burning fossil fuel with electricity from nuclear power today, there would be enough economically viable uranium to fuel the reactors for between 3 and 4 years (O'Rourke, 2004; Storm van Leeuwen & Smith, 2004). Even if we were to double world usage of nuclear energy, the life span of uranium reserves would be just 25 years. Therefore any potential benefits to the climate are extremely temporary.

Fast breeder reactors

For many years the nuclear industry has claimed that fast breeder reactors will vastly extend the life span of nuclear power. Fast breeder reactors use plutonium from spent fuel as a fuel source. Plutonium is one of the most poisonous elements known by mankind; it is not found in nature and can only be produced artificially. With the use and 'breeding' of plutonium, a closed cycle could be reached that would end the dependency on limited uranium resources. But despite huge investments and research over the last decades, breeder reactors have been a technological and economic failure. Breeders in the UK, and the French Super Phoenix, have been permanently closed down due to safety concerns and a serious 1995 accident at the Monju Fast Breeder plant in Japan led to its permanent closure (FOE, 1998). Currently there are no commercial fast breeder reactors in operation in the world and hopes of developing a successful fast breeder programme are fading quickly.

5 The economics of nuclear power

In this section two important questions are addressed: is nuclear power financially viable and can nuclear power help to reduce greenhouse gas emissions in an economically effective manner?

Is nuclear power economically viable?

In the 1970's nuclear power cost half as much as electricity from coal burning: by 1990 nuclear power cost twice as much as electricity from coal burning (Slingerland et al, 2004). Today the costs of nuclear power are estimated to be about $0.05-0.07/kWh making it, on average, between 2 and 4 times more expensive than electricity generated by burning fossil fuels.
Compared with some modern renewable energy sources, nuclear power has mixed fortunes: for example it is more expensive than wind, about the same price as hydroelectric power and cogeneration with gasified wood, and cheaper than solar energy using photovoltaic (PV) cells (Öko Institute, 1997). However, whilst the costs of nuclear power are rising, those associated with renewable energy sources are falling rapidly as they are relatively new and rapid progress is currently being made in reducing costs and increasing efficiency. In the case of nuclear power the costs are rising and are likely to continue rising for the foreseeable future. This is partly because the nuclear industry has been heavily subsidised by governments in the past meaning that some of the costs have been excluded from the price, but have been paid for by the taxpayer. We all pay for the costs of nuclear energy. Examples include:

Decommissioning: so far very few nuclear installations have been decommissioned but in the coming years many plants will reach the end of their lifetimes and will be shut down. Experience in the USA and elsewhere has shown that this is an extremely expensive process. For example, the decommissioning of the Yankee Rowe nuclear reactor in Massachusetts was expected to cost $120 million but actually cost about $450 million. The cost of decommissioning all of the reactors in the US could be as high as $33 billion (GAO, 2003). Costs are this high because a large part of the building is radioactive and can only be demolished by robots. These radioactive materials must also be removed and stored under secured circumstances.

Liability: the *Price-Anderson Act* in the USA limits the nuclear industry's liability in the case of an accident to $9.1 billion, less than 2% of the $560 billion that could be caused in damages by a serious nuclear disaster, according to American federal research into the consequences of the Three Mile Island accident in 1979. The other 98% of the costs will have to be paid for by the government. If the nuclear industry itself had to take full financial responsibility for potential nuclear disasters, the costs of insurance would be huge and the cost of nuclear power would also be much higher (Mechtenberg-Berrigan, 2003). *The Paris Convention on Third Party Liability* sets the maximum economic liability of nuclear operators in 15 European countries. Although the maximum operator liability was revised upwards in 2004 to €700 million (NEA, 2004), this amount would be truly insignificant in the event of a nuclear disaster.

The market itself provides evidence of nuclear power's lack of financially viability. Since the liberalisation and privatisation of the energy markets in the UK, the full costs of nuclear power have been more exposed. Companies have not been eager to invest in this energy source as it cannot exist in a competitive market without government subsidies (FOE, 1998). Even in France, where nuclear power accounts for 75% of total electricity production, it has been admitted that nuclear power is far more expensive than electricity from efficient fossil fuel burning power plants (Makhijani, 2002).

Reducing greenhouse gas emissions in an economically efficient manner

With regards to climate change it is also important to know the cost of reducing greenhouse gas emissions associated with various options, e.g. different energy sources, different levels of end-user efficiency etc. These costs are commonly referred to as the CO_2 abatement costs. These are the costs of reducing greenhouse gas emissions by a given amount (e.g. 1 tonne) in comparison to a given reference option, usually coal.

The Öko Institute has calculated the abatement costs per tonne of CO_2 reduction in relation to a coal-fired power station in Germany. The results are shown in figure 1.

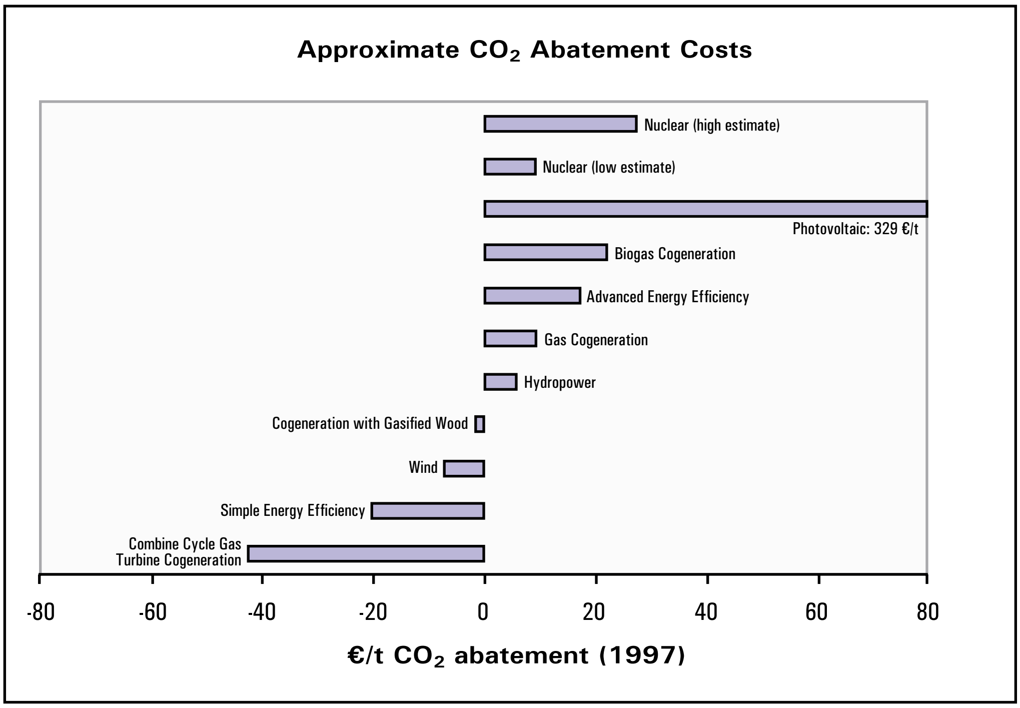

Figure 1: CO_2 abatement costs for various electricity systems (adapted from Öko Institute, 1997)

As can be seen, CO_2 reductions can be made at negative costs by employing combined cycle gas turbine cogeneration, wind, cogeneration with gasified wood and simple energy efficiency. Nuclear power has positive abatement costs, in about the same order of magnitude as new hydropower, gas cogeneration, advanced energy efficiency, and biogas cogeneration.

Hence, a variety of renewable and fossil fuel efficient alternatives are available which are economically more viable than nuclear power in terms of greenhouse gas abatement.

6 Alternative energy options

Electricity generation accounts for just 9% of annual human greenhouse gas emissions. Ways must be found to reduce emissions from the whole of the energy sector. In this section we will briefly outline a few of the alternatives by which the world can satisfy its energy needs in an economically and environmentally sustainable way.

Sustainable is above all efficient

There are hundreds of ways to reduce greenhouse gas emissions within the energy sector. A few examples are listed below but the list is by no means exhaustive:

- Renewable energy (wind, solar, geothermal, hydro, tidal, biomass etc.);
- Cleaner use of fossil fuels;
- Increased taxation on CO_2 emissions;
- CO_2 sequestration (storing CO_2 produced in power stations);
- Increased energy efficiency.

Numerous studies have shown that the single most effective way to reduce emissions is to reduce energy demand (Marignac & Schneider, 2001). A lot of energy could already be saved with the design of smarter consumer electronics, or with less wasteful ways to regulate the temperatures of our building. This may seem obvious but unfortunately it is all too often forgotten in policymaking. Unfortunately this seems to be the case in the largest energy consuming country in the world, the USA. The views of the current administration on energy policy are typified in the following quote from Vice President Dick Cheney:

"Conservation may be a sign of personal virtue, but it is not a sufficient basis for a sound, comprehensive energy policy." (Cited in Cunningham et al, 2003 p. 496)

China is set to overtake the US (at 21%) as the biggest producer of greenhouse gases by 2025 unless current trends are modified (WWF, 2004). Although a major enlargement program for nuclear energy did get underway, this will not provide any solution to China's contribution to climate change. 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 (Schneider & Froggatt, 2004) by shifting towards using renewable energy, such as solar or wind power, and more efficiency in energy consumption.

Can sustainable energy supply our needs?

The whole of society's energy demands amount to less than 0.1% of the energy we receive from the sun each year. So far there are only limited places where we can harness this solar energy in an effective way but this gives an indication of the vast potential of renewable energy sources. Chances for renewable energy will increase substantially in a supportive economic climate and when governments set ambitious but realistic targets. In some countries, such as Germany, the scientific community operates in important studies with an ambitious target of 46% renewable energy sources by 2050 (Johansson et. al, 2004).

Renewable energy sources have multiple benefits. Not only is their use free from greenhouse gas emissions but they can also increase diversity in the energy market. Thereby they will reduce dependence on specific energy sources and so increase security of supply. They can provide long-term sustainability of our energy supply. And because of their small-scale applicability, they can be used in rural areas of less developed countries that are not connected to gas and electricity networks.

In the medium term it is possible to supply all of the world's energy needs through renewable sources based on current technology (i.e. not including the further developments to be made in the future). This scenario has been depicted in three separate studies, compiled by The Union of Concerned Scientists in the USA (1978); The International Institute for Applied Systems Analysis for Europe (1981); Enquete Commission of the German Bundestag (2002). Whilst none of these studies have ever been seriously refuted, they have all been largely ignored by conventional experts (Scheer, 2004).

The technology is available to provide our energy needs through renewable sources and thereby to make huge reductions in our greenhouse gas emissions. However, in the past new energy systems have not been fully implemented due to the supposed high financial costs. It now turns out that these costs are not so high.

The costs of alternative energy options

Despite the commonly heard arguments that alternative energy sources and energy saving technology are not economically viable, the majority of studies show that this is not actually the case. In 1997, a report issued by the United States Department of Energy (DOE) stated that CO_2 emissions in the USA could be brought back to 1990 levels by 2010 at no added cost by increasing energy efficiency and decreasing demand (FOE, 1998). A World Energy Council (WEC) report in the same year confirmed that increased energy efficiency is the biggest, most immediate and cost-effective way to reduce greenhouse gas emission (WWF, 2000).

Furthermore, the costs of renewable energy sources are falling very rapidly: in the last 10 years the cost per kWh of electricity from wind turbines fell by 50%, and that from photovoltaic cells fell by 30% (NEA, 2001). Costs of renewable energy sources are expected to become lower as more research is carried out and more experience is gained with these techniques.

The most interesting point to note here is that the costs of renewable energy sources are falling whilst the costs of nuclear power are rising, despite the fact that nuclear power has been hugely subsidised over the last half century. Estimates show that to date the nuclear industry has received around $1 trillion in state support, compared to just $50 billion for renewable energy (Scheer, 2004). If these huge investments had been made in renewable energy the total energy production from these sources would today be huge. Given the fact that nuclear power can only temporarily, and partially, contribute to reduce greenhouse gas emissions it would be very inefficient to invest huge sums in nuclear development whilst investments in truly sustainable and environmentally friendly energy alternatives are much more rewarding.

7 Other problems associated with nuclear power

So far we have seen that nuclear power can play only a limited role in reducing greenhouse gas emissions, and that in any case the potential savings made would only be temporary. Nuclear power is very expensive and moreover, many alternatives are available which can reduce CO_2 emissions far more effectively, for infinite time periods, and at far lower costs. However, some people argue that climate change is such an important issue that we must employ all available methods to reduce greenhouse gas emissions, no matter what the cost.

There are so many other serious problems associated with nuclear power that any minor and temporary benefits are of tiny significance compared to the problems. These problems have existed since the introduction of nuclear power and are still not resolved. The chance that they will be solved within a reasonable time becomes more and more unlikely. In this section we will highlight the four major problems: storing radioactive waste, safety, weapons proliferation and terrorism, and health.

Storing radioactive waste

One of the most serious and persistent problems of nuclear power is what to do with radioactive waste. Supporters argue that radioactive waste is actually not a major problem since the quantities are small. Whilst this may be true in relation to coal-fired power plants, there are still huge amounts of waste created during the nuclear process. In fact the production of 1,000 tons of uranium fuel typically generates 100,000 tons of tailings and 3.5 million litres of liquid waste (Cunningham *et al*, 2003).
The amount of sludge produced is nearly the same as that of the ore milled. At a grade of 0.1% uranium, 99.9% of the material is left over. As long-lived decay products such as thorium-230 and radium-226 are not removed, the sludge contains 85% of the initial radioactivity of the ore. In addition, the sludge contains heavy metals and other contaminants such as arsenic, as well as chemical reagents used during the milling process.

Still, the volume of waste is not the main problem associated with nuclear waste. The main problem is that high-level waste remains dangerously radioactive for up to 240,000 years (Greenpeace, 2004). After half a century of research there are still no satisfactory solutions to this problem. The most commonly suggested solution is to build underground waste repositories for long-term storage. In 1987, the U.S. Department of Energy announced plans to build such a repository at Yucca Mountain in Nevada. According to the plan, high-level radioactive waste will be buried deep in the ground where it will hopefully remain unexposed to groundwater and unaffected by earthquakes (Cunningham *et al*, 2003). On a timescale of hundreds of thousands of years, however, it is impossible to predict whether an area will remain dry or geologically stable.

Moreover the costs of monitoring and maintenance over such a timescale are unimaginable and generations for hundreds of thousands of years to come would still have to pay the cost for a few years electricity for our generation. The Yucca Mountain scheme has generated huge public outcry and it is likely that the project will never go ahead. Similar problems elsewhere in the world mean that there are currently no final repositories in operation.

In the last decades researchers have been working on the technology to reduce radioactivity and the decay time of nuclear waste, the so-called *transmutation* process. This has often been optimistically heralded as the future solution to the waste problem, however, there is no guarantee that this research will be successful, and if it is the financial costs will be enormous. Nuclear waste contains many different types of radioactive isotopes, which must all be partitioned separately and then transmutated separately. The aim is to decrease the decay time of the radioactivity of these isotopes. This will not be possible for all isotopes and not all isotopes can be partitioned. It will require new processing technologies and plants. At this moment only plutonium and uranium are separated in reprocessing. The application of these new techniques will require a large-scale introduction of fast breeder reactors or other new advanced reactor types, which will take billions of dollars and many decades. And it is obvious that these techniques can only be applied for future spent fuel and not for the present amount of nuclear waste (WISE, 1998). Every attempt to present it as a solution for already present waste is misleading.

Other so-called solutions that have been proposed include: disposing waste in deep ocean trenches, blasting waste into space, and leaving waste by nuclear power plants until a use for it is possibly identified in the future. This last method is now applied on a large scale.

Safety

Despite claims that the nuclear power industry has a "*superb record*" on safety (WNA, 2004a) and an "*impeccable safety practice*" (Ritch III, 2002), historical evidence provides many examples of nuclear disasters and near disasters, for example at Windscale (UK, 1957), Chelyabinsk-40 (Russia, 1957/8), Brown's Ferry (Alabama, USA, 1975), Three Mile Island (Pennsylvania, USA, 1979) and Chernobyl (Ukraine, 1986). Admittedly much progress has been made in increasing safety standards but reactors are still not inherently safe and problems are still common.

In 1995, a natrium leak in the Monju fast-breeder reactor in Japan led to its closure, and once again highlighted safety fears in the nuclear industry. More recently, in 2002, a near disaster was averted at the Davis-Besse reactor in Ohio, USA. The steel in the reactor head was found to be punctured and was within less than a quarter of an inch of causing catastrophic meltdown: in the years preceding this incident the reactor had received a near-perfect safety score (Mechtenberg-Berrigan, 2003). Due to cooling problems in France during the heat wave in the summer of 2003, engineers told the government that they could no longer guarantee the safety of the country's 58 nuclear power plants (Duval Smith, 2003). This is of particular importance as it suggests that nuclear power production will become even less safe as heat waves become more common due to climate change.

Apart from possible technical failures, the risk of human error can never be excluded. This risk will grow now that the onset of privatisation and liberalisation of the electricity market has forced nuclear operators to increase their efficiency and reduce costs. For nuclear energy, it is more difficult to reduce costs because it has high fixed costs: building costs make up about 75% of the total costs (compared, for example, with only 25% for gas). All savings must therefore come from the 25% variable costs of the electricity price, notably from efficiency increases and personnel reductions (Greenpeace & WISE, 2001). In the US significant reductions have been made with an estimated 26,000 workers leaving the industry over the last eight years. The reductions in the size of the workforce have in some cases led to concerns over safety.

Weapons proliferation and terrorism

One of the by-products of most nuclear reactors is plutonium-239, which can be used in nuclear weapons. The international Non Proliferation Treaty (NPT) is supposed to prevent the spread of nuclear weapons but a number of countries with nuclear capabilities, including India, Pakistan and Israel, are not party in the NPT. While most countries claim a strict delineation between nuclear power production and the military use of plutonium, it cannot be ruled out that plutonium could be used in weapons proliferation. According to the UN Climate Panel IPCC, the security threat would be "colossal" if nuclear power was used extensively to tackle climate change. Within the Non Proliferation Treaty, it is completely legal to obtain all necessary technology and material and then to withdraw from the treaty prior to deciding and announcing the wish to make nuclear weapons.

Nuclear installations could also become targets for terrorist attacks: numerous studies since the 2001 attacks on New York have found nuclear plants to be at substantial risk from terrorism (Coeytaux & Margnac, 2003; Oxford Research Group, 2003). Furthermore, radioactive material could be used by terrorists to make "dirty bombs".

Health

In the event of a nuclear disaster the health concerns are obvious. Exposure to radioactive fallout would lead to an increased risk of genetic disorders, cancer and leukaemia. In some areas of Belarus, for example, national reports indicate that incidents of thyroid cancer in children have increased more than a hundred-fold when compared with the period before the Chernobyl accident (UN-IHA, 2004).

However, there are also health risks associated with the day-to-day production of nuclear power. Employees working in power plants are exposed to low-level radioactivity. According to a study by the University of California, based on research at the DOE/Rocketdyne nuclear facility in that American state, the risk of employee exposure to low-level radioactive waste is 6 to 8 times higher than was previously presumed (Mechtenberg-Berrigan, 2003). One should realise that there is no such thing as a safe limit. Each amount of radiation can cause serious health damage.

Conclusions

In the context of international climate change negotiations, the nuclear industry tries to depict nuclear energy as the most effective way to solve the climate problem. This claim has no basis in fact. Nuclear energy is neither effective nor viable, it is not a sustainable source and it causes devastating problems that humanity is not able to handle.

1 - A little less is not enough.
When examining the various stages of the nuclear process it turns out that nuclear energy does - indirectly - generate greenhouse gases. Much less than by energy production using coal and oil, but not much less than gas and significantly more compared with electricity production from sustainable energy sources such as sun or wind. The emission factor of nuclear energy is about to rise because the grades of usable uranium in the ore will decrease in the future. Therefore more energy will be needed to mine, extract and enrich this uranium to make it usable for nuclear power generation.

2 - Electricity is only a small part of the climate problem.
Electricity generation accounts for just 9% of total human greenhouse gas emissions, and only electricity production is possible with nuclear energy. For a solution to the climate problem, as research shows over and over again, we should look at the demand side of energy. Less energy should be wasted and sustainable sources should be developed with the utmost urgency.

3 - Money can be spent only once.
The costs of nuclear energy are huge, although this is not shown in the price because many costs are financed by society in the form of government subsidies. If the nuclear industry itself had to carry the costs for realistic insurance and for decommissioning then nuclear energy would be an even more expensive source of energy. And meanwhile the prices of sustainable energy are decreasing. If we have to choose where to invest our money, then governments and society should provide more means for the development of sustainable energy and energy demand reduction.

4 - Nuclear energy is neither sustainable nor infinite.
Uranium reserves are limited and this fuel problem cannot be solved with fast breeder technology because even after decennia of research, fast breeders are a technical and economical failure. Moreover plutonium, the fuel for fast breeders, is extremely poisonous and dangerous as well as being the basis for nuclear weapons.

5 - Years of failure do not guarantee success in the future.
There is still no feasible idea on how to deal with the extremely dangerous radioactive waste. It is not the volume but the level of (very long-term) danger that is the real problem with this waste. Advocates of nuclear energy point to research into techniques that should reduce the half-life of radioactivity of this waste, but the chances for success are rapidly fading. Moreover these techniques could only provide a solution for new radioactive waste, not for the existing waste. Attempts to find a safe final storage for it have failed to date.

6 - It can be done differently.
Nuclear energy is an inefficient and dangerous way to prevent climate change. Added to this are the problems of nuclear waste, safety risks, health risks to employees, and the risks of nuclear proliferation and terrorism. Moreover there are other possibilities. We have enough technical know-ledge to introduce sustainable energy on a large scale and to prevent the waste of energy. What we lack is the political will to invest in these methods of climate protection. But we will have to make a start with it, and we better do it quick. Climate change is causing too much damage already, financial as well as social and ecological. We cannot afford to ignore it.

	Units	EU-15	Sources
Current Annual CO_2 Emissions from all sectors (2002 data)	g	3.22×10^{15}	EEA (2004)
Base CO_2 Emissions from all sectors (1990)	g	3.23×10^{15}	EEA (2004)
Kyoto Protocol CO_2 Emissions Targets from all sectors*	g	2.97×10^{15}	EEA (2004)
CO_2 Emissions Distance to Target:all sectors (current emissions - target emissions)	g/yr	2.46×10^{14}	
Current CO_2 Emissions from Electricity Sector (based on current fuel mix)	g/kWh	378	WRI (2004) & MIT (2003)
Indirect CO_2 Emissions from Nuclear Power Generation	g/kWh	35	Öko (1997)
Emissions Reductions per kWh by Nuclear Generation (current fuel mix emissions - nuclear emissions)	g/kWh	343	
Contribution of Public Power Generation Sector to Total CO_2 Emissions	%	39	EarthTrends (2003)
Nuclear Generation Needed to Achieve Total CO_2 Reduction Target of Kyoto Protocol: (Distance to target / emissions reductions per kWh from nuclear generation)	kWh/year	7.25×10^{11}	
Nuclear Generation Needed to Reduce CO_2 Emissions from Public Power Generation in line with Kyoto (39% of total in the EU-15)	kWh/year	1.88×10^{11}	
Number of 500 MW Nuclear Power Plants Needed	**units**	**72**	

EU-15 target: 8% reduction on 1990 emissions by 2008-12.

Assumptions
A number of assumptions have been made in order to estimate the number of nuclear power stations needed. Firstly, it is assumed that between present and 2012 emissions per kWh and total electricity consumption would stay constant (i.e. it has been assumed that public energy use will neither increase nor decrease, and that no other emissions reduction technologies will be added). Current emissions data are based on 2002 emissions due to data availability. Secondly, we have assumed that each kWh of electricity generated from the new nuclear plants will replace one kWh generation from other sources based on *pro-rata* reductions according to the current fuel mix. Thirdly, we have assumed that any new power plants will run at 89.6% capacity, as this is the current average capacity of nuclear plants in the USA (NEI, 2004). Therefore the assessment of the number of extra plants needed should be considered indicative.

References

Atom's Amok (2004) http://binky.thinkquest.nl/~ll120/power.php?show=12, cited 05 September 2004.

Boisson, P. (1998) *Energie 2010-2020 - Rapport plénier*. Paris: Commissariat Général du Plan.

Bonduelle & Levevre (2003). *Éole ou Pluton?* Paris, DETENTE.

Charpin, J.M., Dessus, B. & Pellat, R. (2000) *Economic Forecast Study of the Nuclear Power Option*. Paris: Commissariat Général du Plan.

CRIEPI (1995) *Comparison of* CO_2 *Emission Factors between Process Analysis and I/O Analysis*. Working document prepared for IAEA, Tokyo.

Coeytaux & Marignac (2003) *The Unbearable Risk - Proliferation, Terrorist Threats and the Plutonium Industry*. WISE-Paris, 2003.

Cunningham, W.P., Cunningham, M.A. & Saigo, B.W. (2003) *Environmental Science. A Global Concern*. New York: McGraw Hill.

Duval Smith, A. (2003) Over-heated Nukes Fail the Climate Change Test, *The Saskatchewan Environmental Society Newsletter*, Sept/Oct 2003, p.6.

EarthTrends (2003) EarthTrends Country Profiles. Climate and Atmosphere. Netherlands, http://earthtrends.wri.org/pdf_library/country_profiles/Cli_cou_528.pdf, cited 30 January 2005.

ECN (1998) *Mogelijkheden voor* CO_2*-reductie in 2020.* Petten, The Netherlands: ECN.

EEA (2004a) *Impacts of Europe's changing climate. An indicator-based assessment*. EEA report nr. 2/2004.

EEA (2004b) *Annual European community greenhouse gas inventory 1990-2002 and inventory report 2004*. Submission to the UNFCCC Secretariat. EEA technical report.

Export info (2004), cited 18 January 2005.

Federation of Electric Power Companies of Japan (2000) *Comments on the World Wide Fund for Nature's Report, "Climate Change and Nuclear Power"* http://www.japannuclear.com/files/Comments%20on%20the%20World%20Wide%20Fund%20for%20Nature%20Report%20%282000%29.pdf, cited 16 November 2004.

Field, S. (2000) Nuclear Power is No Answer to Global Warming, On the Watch, *The New England Coalition on Nuclear Pollution Newsletter*, 2000/3, pp.3-6.

FOE (1998) Nuclear power is no solution to climate change: exploring the myths, *The Safe Energy Bulletin*, 115, Climate Change Briefing.

GAO (2003) *Nuclear Regulation: NRC Needs More Effective Analysis to Ensure Accumulation of Funds to Decommission Nuclear Power Plants* GAO-04-32 http://www.gao.gov/docdblite/details.php?rptno=GAO-04-32

Greenpeace (2001) *Dangerous Interference with the Climate System: Implications of the IPCC Third Assessment Report for Article 2 of the Climate Convention*. Greenpeace Briefing Paper, Sixth Session (Part 2) of the Conference of the Parties to the United Nations Framework Convention on Climate Change, 16-27 July 2001, Bonn, Germany. Amsterdam: Greenpeace International.

Greenpeace & WISE (2001). World Nuclear Industry Status Report 2001. Unpublished paper.

Greenpeace (2004) *Kernenergie - kernwapens*, www.greenpeace.nl/campaigns/intro?campaign_id=4537#B2 cited 22 October 2004.

Groenlinks (2000) *Schone Schijn. Hoe clean is kernenergie*. Utrecht, The Netherlands: Stichting Groenlinks in de Europese Unie).

Hodgson, P. & Maignac, Y. (2001) Is Nuclear Power a Viable Solution to Climate Change? Debate, *The Ecologist*, 31(7), 20-23.

Houghton, J.T. (1994) *Global Warming: The Complete Briefing*. Oxford: Lion.

IAEA (2000) *Nuclear Power for Greenhouse Gas Mitigation*. Vienna: IAEA.

IEA (1994) *Energy and the Environment, Transport Systems Responses in the OECD - Greenhouse Gas Emissions and Road Transport Technology*. Paris: IEA.

IEA (1998) *Nuclear Power. Sustainability, Climate Change and Competition.* Paris: IEA-OECD.

IEA (2002) *World Energy Outlook.* Paris: IEA.

IPCC (2001a) *Climate Change 2001: The Scientific Basis. Technical Summary.* Geneva: IPCC.

IPCC (2001b) *Climate Change 2001: The Impacts, Adaptation & Vulnerability. Technical Summary.* Geneva: IPCC.

Johansson et.al (2004) *The Potentials of Renewable Energy*. Thematic Background Paper. International Conference for Renewable Energies, Bonn.

Kidd, S. (1998) *Uranium Resources, Sustainability and Environment*. 17th WEC Congress Papers, Houston, USA, 13-18 September 1998, http://worldenergy.org/wecgeis/publications/default/tech_papers/17th_congress/3_2_12.asp#Heading8, cited 22 October 2004.

Makhijani, A. (2002) Nuclear Power: No Answer to Global Climate Change, *Nukewatch Pathfinder*, Autumn 2002, p.6.

Marignac, Y. & Schneider, M. (2001) Towards a World Energy Efficiency Link (WEEL), in Pink, A. (Ed.) *Sustainable Development International*. London: ICG Publishing.

Mechtenberg-Berrigan, M. (2003) Deadly Deceit: Debunking the Myths of Nuclear Power, *Nukewatch Pathfinder*, Spring 2004, pp.4-5.

MIT (2003) *The Future of Nuclear Power. An Interdisciplinary MIT Study. Glossary and Appendices*. Cambridge, USA: MIT cited 18 January 2005.

METI (2004) Ministry of Economy, Trade and Industry of Japan *CDM in the Post-Kyoto Regime* http://www.meti.go.jp/english/policy/c_main_environment.html#2

National Commission on Energy (2004). *Ending the Energy Stalemate*. Washington, NCE.

N-Base (2002) 'Nuclear Needed', *N-Base Briefing*, 316, 9 March 2002.

NEA (2001) *Activities on Climate Technology: Inventory for Nuclear Generation*. http://www.nea.fr/html/ndd/climate/acting.html cited 12 October 2004.

NEA (2002) *Nuclear Energy and the Kyoto Protocol*. Paris: OECD.

NEA (2004) *Revised Nuclear Third Party Liability Conventions improve victims' rights to compensation*. Press communiqué, http://www.nea.fr/html/general/press/2004/2004-01.html, cited 13 February 2004.

NEA-IAEA (2004) *Uranium 2003: Resources, Production and Demand*. Paris: OECD.

NEI (2004) US *Capacity Factors by Fuel Type*, cited 18 January 2005.

Öko-Institute (1997) *Comparing Greenhouse-Gas Emissions and Abatement Costs of Nuclear and Alternative Energy Options from a Life-Cycle Perspective*. Paper presented at the CNIC Conference on Nuclear Energy and Greenhouse-Gas Emissions, Tokyo, November 1997. http://www.oeko.de/service/gemis/files/info/nuke_co2_en.pdf cited 12 October 2004.

O'Rourke, B. (2004) *As Global Warming Accelerates, Is It Time For Nuclear Power To Come In From The Cold?* http://truthnews.com/world/2004070151.htm cited 22 October 2004.

Oxford Research Group (2003) *Nuclear Terrorism in Britain: Risks and Realities*. Current Decisions Reports no.27.

Point Carbon (2004) *Italy calls for use of nuclear to fight global climate change*. www.pointcarbon.com 29.11.04

Ritch III, J. (2002) Nuclear Energy at a Moment of Truth. Six Reasons Behind the Case for Nuclear Power, *IAEA Bulletin*, 44(2), pp. 30-37.

Scheer, H. (2004) *Nuclear Energy Belongs in the Technology Museum*. WRCE Update September 19 2004, http://www.world-council-for-renewable-energy.org/downloads/WCRE_Update_190904.pdf, cited 22 October 2004.

Schneider & Froggatt (2004) *World Nuclear Industry Status Report 2004*, Brussels: Greens/EFA Group in the European Parliament.

Slingerland, S., Bello, Q, Davidson, M., Loo, van, K., Rooijers, F. & Sevenster, M. (2004) *Het nucleaire landschap. Verkenning van feiten en meningen over kernenergie*. Working document 94. The Hague: Rathenau Institute.

Storm van Leeuwen, J.W. & Smith, P. (2004) *Can nuclear power provide energy for the future: would it solve the CO_2 emission problem?* http://beheer.oprit.rug.nl/deenen/Nuclear_sustainability_rev3.doc cited 12 October 2004.

Turkenburg, W.C. (2000) Renewable energy technologies, in UNDP (Ed.) *World Energy Assessment. Energy and the Challenge of Sustainability*. New York: UNDP.

UIC (2001a) Life cycle CO_2 emissions, *UIC Newsletter*, 5 October 2001, p.2.

UIC (2001b) *Sustainable Energy - Uranium, Electricity and Greenhouse*, http://www.uic.com.au/ueg.htm cited 12 October 2004.

UN-IHA 896 *Press release*, 26 April 2004

VROM (2004) *Dutch Climate Policy*. http://www.vrom.nl/international cited 06 September 2004.

WISE (1998) Partitioning and transmutation: a hype. In: *WISE News Communiqué 503*. 4 December 1998.

WISE (2003) *Kernenergie als oplossing voor het klimaatprobleem?* Amsterdam: WISE.

WNA (2004a) *The environment needs nuclear*. http://www.world-nuclear.org/pdf/The_Environment_Needs_Nuclear.pdf cited 12 October 2004.
WNA (2004b) Prime Minister Tony Blair indicated that the government was reconsidering the possible construction of new nuclear power reactors, *WNA News Briefing*, 04.28, p.2.

WNA (2004c) *Supply of Uranium*, http://www.world-nuclear.org/info/inf75.htm, cited 22 October 2004.

WRI (2004) *Indirect CO_2 Emissions from Use of Electricity*, cited 18 January 2005

WWF (2000) *Climate Change and Nuclear Policy*. Gland, Switzerland: WWF.

WWF (2004) *WWF China's climate and energy program*, http://www.wwfchina.org/english/loca.php?loca=205, cited 24 January 2005.

NIRS/WISE offices and relays

WISE Amsterdam
P.O. Box 59636
1040 LC Amsterdam
The Netherlands
Tel: +31 20 612 6368
Fax: +31 20 689 2179
Email: wiseamster@antenna.nl
Web: www.antenna.nl/wise

NIRS
1424 16th Street NW, #404
Washington, DC 20036
USA
Tel: +1 202 328 0002
Fax: +1 202 462 2183
Email: nirsnet@nirs.org
Web: www.nirs.org

NIRS Southeast
P.O. Box 7586
Asheville, NC 28802
USA
Tel: +1 828 675 1792
Email: nirs@main.nc.us

WISE Argentina
c/o Taller Ecologista
CC 441
2000 Rosario
Argentina
Email: wiseros@ciudad.com.ar
Web: www.taller.org.ar

WISE Austria
c/o Plattform gegen Atomgefahr
Mathilde Halla
Landstrasse 31
4020 Linz
Austria
Tel: +43 732 774275; +43 664 2416806
Fax: +43 732 785602
Email: post@atomstopp.at
Web: www.atomstopp.com

WISE Czech Republic
c/o Jan Beranek
Chytalky 24
594 55 Dolni Loucky
Czech Republic
Tel: +420 604 207305
Email: wisebrno@ecn.cz

WISE Japan
P.O. Box 1, Konan Post Office
Hiroshima City 739-1491
Japan
Tel/Fax: +81 82 828 2603
Email: kota-goldencat@kfa.biglobe.ne.jp

WISE Russia
P.O. Box 1477
236000 Kaliningrad
Russia
Tel/fax: +7 95 2784642
Email: ecodefense@online.ru
Web: www.antiatom.ru

WISE Slovakia
c/o SZOPK Sirius
Katarina Bartovicova
Godrova 3/b
811 06 Bratislava
Slovak Republic
Tel: +421 905 935353
Fax: 421 2 5542 4255
Email: wise@wise.sk
Web: www.wise.sk

WISE Sweden
c/o FMKK
Barnängsgatan 23
116 41 Stockholm
Sweden
Tel: +46 8 84 1490
Fax: +46 8 84 5181
Email: info@folkkampanjen.se
Web: www.folkkampanjen.se

WISE Ukraine
P.O. Box 73
Rivne-33023
Ukraine
Tel/fax: +380 362 237024
Email: ecoclub@ukrwest.net
Web: www.atominfo.org.ua

WISE Uranium
Peter Diehl
Am Schwedenteich 4
01477 Arnsdorf
Germany
Tel: +49 35200 20737
Email: uranium@t-online.de
Web: www.antenna.nl/wise/uranium

WISE/NIRS NUCLEAR MONITOR

The Nuclear Information & Resource Service was founded in 1978 and is based in Washington, US. The World Information Service on Energy was set up in the same year and houses in Amsterdam, Netherlands. NIRS and WISE Amsterdam joined forces in 2000, creating a worldwide network of information and resource centers for citizens and environmental organizations concerned about nuclear power, radioactive waste, radiation, and sustainable energy issues.

The *WISE/NIRS Nuclear Monitor* publishes international information in English 20 times a year. A Spanish translation of this newsletter is available on the WISE Amsterdam website (www.antenna.nl/wise/esp). A Russian version is published by WISE Russia and a Ukrainian version is published by WISE Ukraine. The *WISE/NIRS Nuclear Monitor* can be obtained both on paper and in an email version (pdf format). Old issues are (after two months) available through the WISE Amsterdam homepage: www.antenna.nl/wise.

Receiving the WISE/NIRS Nuclear Monitor

US and Canada based readers should contact NIRS for details of how to receive the *Nuclear Monitor* (address see page 23). Others receive the *Nuclear Monitor* through WISE Amsterdam. For individuals and NGOs we ask a minimum annual donation of 50 Euros (20 Euros for the email version). Institutions and industry should contact us for details of subscription prices.

WISE Amsterdam/NIRS
ISSN: 1570-4629

Author Philip Ward.
Editorial team Wendela de Vries/Peer de Rijk (WISE Amsterdam)
Michael Mariotte (NIRS)
Lay-out Steven van Hekelen

This report is publishes as a special issue of the Nuclear Monitor, the bi-weekly newsletter of World Information Service on Energy (WISE) and Nuclear Information & Resource Service (NIRS). It counts for issues #621 and #622.