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EDITORIAL

The Pros and Cons of Nuclear Power

- Piyush Pant

The debate over the feasibility and utility of nuclear power is gaining ground afresh in India, particularly since a nuclear deal between India and US has been concluded.. The opponents of the deal point out that commissioning of nuclear power plants and generation of nuclear power will add little (about 4 percent) to the overall energy needs of the country while extracting a heavier price in terms of financial, environmental and health costs. Whereas the proponents of nuclear deal hail the nuclear power as the clean, safe, carbon-neutral way to produce electricity. Suddenly nuclear has become lesser evil in the minds of these people. In fact, the nuclear power industry and its governmental allies, throughout the developed world, are spending tens of millions of dollars annually to promote atomic power as "clean air" energy source and to encourage the construction of new nuclear reactors. Ratification of Kyoto Protocol by Russia will give further push to these activities of the industry.This increased love for nuclear power has taken place despite reverse opinions expressed by the world bodies like United Nations. For example, in November 2000, the world, by refusing to give nuclear power greenhouse gas credits during the UN climate change talks at the Hague, recognized it as a dirty, dangerous and unnecessary technology. It received a further blow when a UN Sustainable Development Conference in April 2001 refused to label nuclear a sustainable technology. One more development further defeats the sustainability argument. France's claim about the sustainability of nuclear power production is wearing thin. It is now a public knowledge that the company Electricite de France had to raise 33,000 million dollars as loans in the international market and that it has not so far been able to repay anything except the interest, despite its large income from arms sales.

Although operating nuclear plants generate 20 per cent of U.S. electricity, Nuclear Power's economic competitiveness in US has been eroded over the past 15 years during which time utilities have cancelled117 nuclear power plant orders. In 1993 there were 109 licensed reactors in the US. As of October 31, 2005 there are 104 commercial nuclear generating units that are fully licensed by the U.S. Nuclear Regulatory Commission (NRC) to operate in the United States. Although U. S. has the most nuclear capacity of any nation, no new commercial reactor has come on line since May 1996. The last reactor to come on line in America was the Watt's Bar reactor in Tennessee, Owned and operated by the Tennessee Valley Authority, it began commercial service in May 1996. However, US commercial nuclear capacity has increased recently but mainly through uprating of existing reactors. It was only in 2007 that 5 applications were made to the Nuclear Regulatory Commission to construct and operate new nuclear power plants.

In fact, this sudden spurt in nuclear energy promotion is the handiwork of 'nuclear power industry' which is lobbying hard the U.S. and U. K. parliaments for the new generation of nuclear reactors and is also rolling out a multiyear advertising campaign to build public support for a generation of new plants using words like "nuclear renaissance". So much so that in Britain, public money has been used to support a vigorous pro-nuclear campaign called Nuklear 21. The leaflets distributed during the campaign called nuclear power "atoms for peace" and claimed that "nuclear will help save the planet".

If you are not convinced then please read this news item which appeared in the Wall Street Journal on January 26, 2006. It said- as "part of an effort to jump-start the nuclear-power industry ", the Bush administration is proposing "a 250 million dollar initiative to reprocess spent nuclear fuel." The Global Nuclear Energy Partnership proposal would allow General Electric and other US companies to sell developing countries "reactors and nuclear fuel on the condition that the U S would take back the spent fuel for reprocessing."

Herein lies the corporate trap! And Indian government and nation's elite seem to be ready to fall in the trap.

In this issue of *INFOPACK* we are giving the summary of the documents discussing various aspects of the nuclear power.

Nuclear Reactor Hazards

By:

Antony Froggatt

Bird's Eye View

The document summarized here is part of the book titled 'Nuclear Power: Myth and Reality, The Risks and Prospects of Nuclear Power' publish by Heinrich Boll Foundation. This is the second chapter of the book.

In the introduction, the chapter says that this report is based exclusively on Greenpeace International's report "Nuclear Reactors Hazards, Ongoing Dangers of Operating Nuclear Technology in the 21st Century" published in April 2005 (GREENPEACE 2005).

The sections reproduced in the chapter look at the characteristics and inherent flaws of the main reactor designs in operation today; the second part assesses the risks associated with new designs and discusses the "ageing" of operational reactors and the third section looks at the terrorist threat to nuclear power.

Report's main conclusions are:

- All operational reactors have very serious inherent safety flaws which can not be eliminated by safety upgrading.
- A major accident in a light-water reactor can lead to radioactive releases equivalent to several times the release at Chernobyl and about 1000 times that releases by a fission weapon.
- The average age of the world's reactors is around twenty one years and many countries are planning to extend the lifetime of their reactors beyond the original design lifetime. This leads to the degradation of critical components and the increase of severe incidents.
- Deregulation (liberalization) of electricity markets has pushed nuclear utilities to decrease safety-related investments and limit staff. Utilities are also upgrading their reactors by increasing reactor pressure, operational temperature, and the burn-up of the fuel. This accelerates ageing and decreases safety margins.
- Reactors cannot be sufficiently protected against a terrorist threat. There are several scenarios - aside from a crash of an airliner into the reactor building - which could lead to a major accident.

The chapter, under the section titled **"Commercial Reactor Types and their Shortcomings"** says that at the start of 2005 there were 441 nuclear power reactors, operating in 31 countries. But there are only four broad categories for nuclear reactors currently deployed or under development. These are Generation I, Generation II, Generation III, and Generation IV.

Generation I Reactor: The early Soviet designed reactors, the VVER 440-230s, are classified as Generation I reactors. These reactors have significant and serious design flaws. These reactors operating in Central Europe will be closed by end of this decade but others in Russia are likely to continue to operate.

The lack of secondary containment system and adequate emergency core cooling system are of particular concern.

The other Generation I reactor design still in operation is the United Kingdom's Magnox design air-cooled, graphite-moderated natural uranium reactor. The reactor sore is located inside a large pressure vessel. Some of the Magnox fleet have older steel pressure vessels and have suffered from corrosion. Brittle failure of the pressure vessel could lead to loss of the primary coolant, and possibly large radioactive releases. For this and other reasons, many Magnox stations have been shut down. These reactors do not have a secondary containment system - which protect the reactor core from external events and helps to contain radioactivity in the event of core-related accident and thus the reactors have a high potential for large radioactive releases.

The document says that the Generation II Design reactor known as RBMK reactor is the most notorious reactor in the world. It is a graphite-moderated boiling water reactor and used at the Chernobyl Station in Ukraine, which was the site of the world's worst civilian nuclear power accident in 1986.

The document points out that the reactor has some fundamental design problems, some of which have been rectified after the Chernobyl accident but other problems remain unattended due to technical and economic reasons. The RBMK reactors contain more zirconium alloy in the core than any other reactor type. They also contain a large amount of graphite (about 1700 tons). A graphite fire can seriously aggravate an accident situation; it can also react violently with water at higher temperature, producing explosive hydrogen.

The document points out that the fundamental design flaws of these reactors have led to the international community classifying these reactors as "non-upgradable" and to seek their closure.

It says that the most prevalent design in operation is the **Pressurized Water Reactors (PWR)**, with 215 in operation around the world. These reactors can accelerate the corrosion of components; in particular, the steam generators now frequently have to be replaced. Similarly, extensive documentation now exists on the problems of cracking in the vessel head penetrations. In the early 1990s, cracks began to appear in the reactor vessel heads of some reactors in France.

The second most prevalent reactor design is the **Boiling Water Reactor (BWR)** which was developed and modified from PWR. However, modification has failed to improve safety measures. The result is a reactor that still exhibits most of the hazardous features of the PWR, while introducing a number of new problems.

Significant corrosion problems have been observed in many **BWRs**. In the nineties a vast amount of cracking had been detected in a number of **German BWRs**. Another persisting problem in BWRs occurred in 2001: pipes ruptured at Hamaoka-1 (Japan) and at Brunsbuttel (Germany). The cause of both cases was an explosion of a mixture of hydrogen and oxygen, which was produced by hydrolysis in the coolant water. In such cases a severe accident with catastrophic radioactive releases (comparable to those at the Chernobyl accident) will develop.

The document further says that the next most prevalent reactor currently deployed is the **Pressurized Heavy Water Reactor (PHWR)**, of which there are 39 currently in operation in seven countries. The main design is the **Canadian CANDU** reactor, which is fuelled by natural uranium and is heavy water cooled and moderated. The reactor design has some inherent design flaws, most notably that it suffers from positive void coefficient, whereby should the reactor loose coolant, the level of reactivity increases. Secondly, the use of natural uranium significantly increases the volume of uranium in the core, which can lead to instability. The pressure tubes that contain the uranium tubes are subject to significant neutron bombardment. These and other operational problems have caused huge safety and economic problems for the CANDU fleet.

The Advanced Gas Reactor (AGR) is only operated in the United Kingdom and is a modified and updated version of the Magnox reactor. However, some of the inherent problems of the earlier reactors remain, notably, the lack of a secondary containment system and age-related degradation. Most recently cracking of graphite bricks that make up the reactor core was discovered.

However, the document says that the Generation III reactors are so called "Advanced Reactor", three of which are already in operation in Japan, more are under construction or planned. Most of them are "evolutionary" designs that have been developed from Generation II reactor type with some modification.

The document further says that the **European Pressurized Water Reactor (EPR)** is a pressurized water reactor that has developed from the French N4 and the German KONVOI reactor line, the latest Generation III reactors which went into operation in those countries. The goals stated for EPR development are to improve the safety level of the reactor, achieve mitigation of severe accidents by restricting their consequences to the plant itself, and to reduce cost.

It further says that in spite of the changes being envisaged, the EPR appears to be plagued by a problem which is widespread among Generation II PWRs. According to the Finnish regulatory authority, sump strainer clogging is an issue with EPR, which has been identified many years ago but still appears to be a challenge for the EPR. All in all, there is no guarantee that the safety level of the EPR represents a significant improvement compared to N4 and KONVOI; in particular, the reduction of the expected core-melt probability by a factor of ten is not proven.

Furthermore, there are serious doubts as to whether the mitigation and control of a core-melt accident with the "core-catcher" concept will actually work as envisaged.

The document further says that the **Pebble Bed Moduler Reactor (PBMR)**, South Africa, is a high-temperature gas-cooled reactor, which unlike Light-Water Reactor uses water and steam. The **PBMR** design uses pressurized helium heated in the reactor core to drive a series of turbines that attach to an electrical generator. Helium temperature at the core outlet is about 900 degree centigrade, at a pressure of 69 bars. The secondary helium circuit is cooled by water.

Designer claims that there are no accident scenarios that would result in significant fuel damage and catastrophic release of radioactivity.

According to perspective PBMR operator, ESKOM' the reactor is "walk-away-safe", meant to imply that should the plant personnel leave the site, the reactor would not get into a critical condition. It is claimed that fuel temperature will peak at 1600 degree centigrade in any case, whereas fuel damage will not begin below 2000 degree centigrade (ESCOM 2005).

However, the temperature limit 1600 degree C is not guaranteed in reality. Furthermore, fission product releases from the fuel elements already begin at temperature just above 1600degree C. In this context, it is irrelevant that severe fuel damage or melting only occurs above 2000 degree C. Massive radioactive releases can take place well below this temperature.

However, the document points out that Generation IV reactors are heralded as highly economical, incorporate enhanced safety produce minimal amount of waste, and as being impervious to proliferation.

Goals for Generation IV are identified in four broad areas:

a) Sustainability; b) Economics; c) Safety and Reliability; and d) Proliferation Resistance and Physical Protection.

It says that some hundreds different reactor designs were identified as candidates and evaluated by Groups of International Experts. At the end of the process, six concepts were recommended for further development.

To further encourage and strengthen research and development for Generation IV reactors, the United States, Canada, France, Japan, and the United Kingdom signed the International Forum Framework Agreement on February 28, 2005, in Washington. Special emphasis appears to lie in developing systems for the generation of hydrogen as well as electricity.

In 2001, the International Atomic Energy Association (IAEA) had initiated a similar initiative - the International Projects on Innovative Nuclear Reactors and Fuel Cycles (INPRO). As of November 2004, twenty-one countries or entities have become members of INPRO.

The document says that six concepts for Generation IV were selected for further development in the framework of GIF. They are:

- **GFR-Gas-Cooled Fast Reactor System** - This system is a helium-cooled reactor with fast-neutron spectrum and closed fuel cycle. It is primarily envisioned for electricity production and actinide management.

  In spite of large technology gaps, the GFR System is top-ranked in sustainability because of its closed fuel cycle and excellent performance in actinide management. It is rated good in safety, economics, as well as proliferation resistance and physical protection. The GFR is estimated to be employed by 2025.
- **LFR-Lead-Cooled Fast Reactor System** - This reactor is designed for small grids and for developing countries that may not wish to deploy a fuel cycle infrastructure. The LFR system is top-ranked in sustainability because a closed fuel cycle is proliferation resistance and is aimed at physical protection because it employs a long-life over.
- **MSR-Molten Salt Reactor System** - It is primarily envisioned for electricity production and waste burn down. The GIF selected the MSR as the most innovative non-classic concept of all six reactor systems. MSR requires the highest costs for development (US$1000 million). The high development costs and the required time frame could eliminate the MSR system from Generation IV altogether.
- **SCWR-Supercritical Water-Cooled Reactor System** - This is high-temperature, high-pressure water-cooled reactor. Uranium oxide is used as fuel in this system. SCWRs are expected to be more economical than LWRs, due to plant simplification and high thermal efficiency. Almost all GIF members display a high interest in the development of the SCWR.
- **SFR-Sodium-Cooled East Reactor System** - According to GIF, the SFR has the broadest development base of all the Generation IV. The existing know-how, however, is based mainly on old reactors that have already been shut down for various reasons.

  Because of its history, as well as because of the significant hazards of the reactor line, it is hard to understand why the SFR has been selected by GIF.
- **VHTR - Very High-Temperature Reactor System** -The VHTR is regarded as the most promising and efficient system for hydrogen production. It is also intended to generate electricity with high efficiency.

The VHTR is a next step in the evolutionary development of high-temperature gas-cooled reactor. Its technology is based on some decommissioned thermal spectrum HTGR pilot and demonstration projects, all of which had rather short and unsuccessful overall operating times.

In the conclusion the document, while evaluating the Generation IV rectors, says that unanticipated technical problems, accidents, the unsolved nuclear waste problem, as well as high costs of nuclear power, combined with lack of public acceptance, have led to a decline of nuclear power. This is the background for the Generation IV initiative of the USDOE. A label is created which is to sell the illusion to the public that a completely new generation of reactors in records is being developed, which is free from all the problems which are plaguing current nuclear installations.

A primary goal of Generation IV lies in the securing of financial means for nuclear research. Today, nuclear power will receive a large amount of R&D money - half of the money of R&D budget (US$87.6 billion) spent by 26 OECD member states between 1991 and 2001 went to nuclear research; only 8% to renewable. Gradually, however, a shift away from nuclear power is taking place. The Generation IV initiative attempts to reverse that shift by making nuclear energy attractive and presenting it as sustainable and carbon-dioxide-free.

The document further points out that the estimated costs for the development of the six Generation IV concepts are about US$6 billion (DOE 2002). It is more than likely that overruns will occur both for costs and for the time required.

This is to be seen that nuclear energy is currently not cost competitive in the deregulated market, not with coal and natural gas, and also not with wind energy. A recently published study demonstrates that for the same investment, wind generates 2.3 times more electricity than a nuclear reactor. The document also points out that the largest increase in nuclear generation is projected for the developing world, where a potential market for Generation IV is seen.

According to GIF, a closed fuel cycle is celebrated as a major advantage of Generation IV concept. This requires the reprocessing of spent fuel to extract the plutonium and using the plutonium as a fuel. This has significant proliferation implications, in particular if these types of reactors are widely deployed around the world. The reprocessing plutonium has been widely criticized for its negative impact on the environment as well as its costs and security implications. The widespread introduction of the closed fuel cycle requires a reversal of current anti-proliferation policy in a number of countries, including the United States, and a revision of current industry policy in most nuclear countries.

The document also says that the cost of such fuel cycle concepts --- the use of reprocessing - would be very high. The MIT of Massachusetts Study found that the fuel cost with a closed cycle, including waste storage and disposed charges, to be about 4.5 times the cost of a once-through cycle. Therefore it is not realistic to expect that there ever will be new reactor and fuel cycle technology that simultaneously overcome the problems of cost, safe waste disposal, and proliferation.

For thermal reactors, "sustainability" is to be achieved by higher enrichment. This, however, does not solve the waste problem. On the contrary, experts are pointing out that so-called high burn up fuel elements will lead to additional problems not only during operation but also during intermediate storage and final disposal.

All in all, the Generation IV reactors are far away from the goal to successfully minimize and manage their nuclear waste.

It has been also mentioned in the document that the Nuclear Control Institute (NCI) warned that transmutation of spent nuclear fuel is no guarantee against proliferation. Furthermore, the growing concerns about the safe and secure transportation of nuclear materials and the nuclear security of nuclear facilities from terrorist attacks is not adequately taken into account in any of the concepts.

New nuclear power plants should be based on evolutionary, not revolutionary technology, according to an NRC Commissioner. The Commissioner cautioned against "too much innovation" which would lead to new problems with untested designs. Even the Generation IV Strategists themselves do not expect significant improvement regarding proliferation resistance and safety. A closer look at the technical concepts shows that many safety problems are still completely unsolved.

The document further talks about the effects of ageing of nuclear plants. It says that the IAEA defines ageing as a continuous time-dependent loss of quality of materials, caused by the operating conditions. During the "middle-age" of a plant, problems tend to be at a minimum. Later, as ageing processes occur there will be a gradual increase of failure rates.

Reactors with graphite moderator are subject to the specific problems of graphite ageing. Ageing constitutes a particular severe problem for passive components. Not only it is often difficult to detect ageing phenomena. Replacement usually was not expected for components like pipelines or graphite parts, and no provisions were made for it. With increasing age of a plant, the reliability of electronic devices can thus be reduced while at the same time, safety margins in the whole system are decreasing,

It has also been observed in the document that the consequence of ageing can roughly be described as twofold. On the one hand, the number of incidents and reportable events at an NPP (Nuclear Power Plant) - small leakages, short-circuits due to cable failure etc. will increase. In Germany, for example, the ten older plants are responsible for about 64% of all reportable events in the time span from 1999 to 2003. On the other hand, there are effects leading to a gradual weakening of materials which may never have any consequences until the reactor is shut down, but which could also lead to catastrophic failures of components with subsequently sever radioactive releases

The document says that most notable problem of the plant is the embitterment of the reactor pressure vessels, increasing the hazard of vessels bursting. Failure of the pressure vessels of PWR or a BWR constitutes an accident beyond the design basis. Safety systems are not designed to cope with this emergency. Hence, there is no chance that it can be controlled. Further more, pressure vessels can lead to immediate containment failure as well, for example, through the pressure peak after vessels bursting, or the formation of high-energy fragments. And catastrophic radioactive releases are the consequence.

In probability risk management studies (PRAs), which are increasingly used as a tool by nuclear regulators, ageing is usually not taken into account. Thus it is clear that the risk of a nuclear accident grows significantly with each year, once a nuclear plant has been in operation for about two decades.

The document next talks about power uprating. It says that **power uprating** is an economically attractive option for NPP an operator that usually goes largely unnoticed by the public. Power uprating is practiced in most countries where NPPs are operated. There are two options to uprate the electrical power of a nuclear power plant. The options are:

a) At constant reactor power, thermal efficiency of the plant is increased. This is mostly achieved by optimizing the turbines. Operational safety of the plant remains on the same level. Also replacement of steam generators can increase sufficiency if the new heat exchangers have higher efficiency.

b) Thermal power of the reactor is raised, usually by increasing coolant temperature. Thus, more steam is produced and the reactor can produce more electricity via the turbines. An increase in thermal power implies more nuclear fissions and thus increases operational risks. Also higher loads to the reactor materials are unavoidable. There is general consensus that an increase of reactor power reduces operational safety margins and at the same time accelerates ageing process.

The document further says that increasing the thermal power of a reactor is regarded as a particularly cost effective way to increase electricity production.

It says that for PWRs, reactor power is increased by raising the average coolant temperature, accompanied by increasing the temperature rise in the core. This leads to decreasing safety margins. Corrosion of fuel element hulls becomes more likely and primary circuit pressure will reach higher peaks during transients. Furthermore, the radioactive inventory in the reactor core is increased proportionately to the power uprate. Measures to control or mitigate critical situations become more difficult.

Similar problems arise for power up-rates of other reactor types. For example, uprating of Quad City 2 BWR in the United States led to vibrations of the main steam line, which in turn damaged other components and necessitated several shutdowns and repairs.

The document further points out that increasing the fuel burn-up (i.e., getting more energy per ton of fuel) is another way in which NPP operates attempt to improve the economy of their plants. The efforts to increase burn-up have been intensified in recent years. Increasing burn-ups also increases the hazard of fuel hull failure and hence, radioactive contamination of cooling water. The use of high burn-up fuel can also reduce operational safety margins. For example, the hazard of neutron flux oscillations in BWRs is increased.

Increased burn-up reduces the mass of spent fuel produced annually by a power reactor. On the other hand, handling, transport, storage and disposal of spent fuel becomes more difficult and hazardous because of higher radiation intensity, higher heat development, and higher content of long-lived actinide nuclides.

The Terror Threat

The document also talks about "Terror Threat". While talking about the 'Terror threat', it says that long before September 11, 2001, numerous deliberate acts of terrorism had taken place in the 20th century. There are numerous potential targets for terrorist attacks including industrial installations, office buildings, and filled sports stadiums. A Nuclear Power Plant could be selected as target for one of the following reasons, or a combination of these reasons:

- Because of the symbolic nature
- Because of the long term effects
- Because of the immediate effects on the electricity generation in the region affected
- Because of the longer term effects on electricity generation.

Terror attacks against nuclear plants are not purely theoretical. In the past, a number of such attacks have already taken place. Luckily, they have not led to a catastrophic radioactive release so far. A few examples can illustrate the record.

- November 12, 1972: Three hijackers took control of a DC-9 of Southern Airlines and threatened to crash it in the Oak Ridge military nuclear research reactor. The hijacker flew on to Cuba after they obtained two million dollars.
- December 1977: Basque separatists set off bombs, damaging the reactor vessel and a steam generator and killing two workers at the Lemoniz NPP under construction in Spain.
- December 1982: ANC guerrilla fighters set off four bombs inside the Koeberg plant under construction in South Africa, despite tight security.
- May 1986: Three of the four off-site power lines leading to the Palo Verde NPP in Arizona were sabotaged by short-circuiting.
- February 1993: At Three Mile Island NPP (Pennsylvania), a man crashed his station wagon through the security gate and rammed the vehicle under a partly opened door in the turbine building. Security guards found him hiding in that building, four hours later.
- 1993: The terrorist behind the car bombing of the World Trade Centre, belonging to the terrorist networks that claimed to be part of the Islamic jihad, threatened to target nuclear sites in a letter receiver by the New York Times and authenticated by the authorities. In addition, the investigation is said to have revealed that the terrorist group was trained in November 1992 in a camp near Harrisburg, Pennsylvania, just fifteen km. away from the Three Mile Island nuclear power station.
- November 1994: A bomb threat was reported at Ignalina NPP in Lithuania. However, no explosion occurred and no bomb was found in the power plant.

Act of War

Military action against nuclear installations constitutes another danger deserving special attention in the present global situation.

The document says that the reasons for terror attacks mentioned above could in such a war, motivate one of the conflicting parties to attack a nuclear plant. If there are nuclear plants in the countries being attacked, there is the risk that those could be damaged during the fighting. During the war power plants might be attacked to paralyze the electricity supply system.

It is also conceivable that nuclear power plants -which serve military purposes or are feared to serve such purposes - will be deliberately destroyed. In this case, the attacker may accept the release of radioactive materials.

The document points out that in June 1981, a large (40MWth) research reactor under construction at the Tuwaitha research center in Iraq was destroyed by Israeli air force because Israelies feared that the reactor could be used (directly or indirectly) for a nuclear arsenal. During the 1991 Gulf War, two smaller reactors at the same site were destroyed in a night attack by US aircraft.

It is quite obvious that the destruction of a nuclear power plant could significantly increase the radioactive contamination produced by a nuclear fission weapon - the fission product inventory of a commercial nuclear power plant is in the order of magnitude of 1000 times that released by a fission weapon. Of all nuclear plants and other facilities with toxic inventories, such as chemical factories, nuclear power plants are probably the most 'attractive' targets for terrorist or military attacks. They are widespread, contain a considerable radioactive inventory, and are important components of the electricity supply system.

The document further says that the attack on a nuclear power plant would be more effective than an attack with armour or concrete-piercing missiles. If high-explosive shells are used, the reactor building will be partly destroyed. Severe damage will occur inside. Plant personnel will be killed. It will be difficult to implement effective and rapid countermeasures. Within a few hours, core-melt will occur with severe release of radioactivity.

The consequences amount to a catastrophe with effects over a large region: up to 10,000sq.km. would have to be evacuated in the short term. There would be up to 15,000 acute radiation deaths and up to one million cancer deaths, as well as uncounted cases of genetic damage. The area that would be contaminated in the long term to a degree necessitating relocation of the population can measure up to 100,000sq.km. The economic damage has been estimated at about 6,000 billion euro.

Once the fuel is exposed, radiation shielding is completely lost and the intervention becomes impossible because of the prohibitive radiation dose rates.

Freshly discharged fuel would then reach the point where it burns in air (900 dg.C) and very severe radioactive releases would begin within hours.

The Economics of Nuclear Power

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Bird's Eye View

Besides executive summery this document is divided into four parts and also contains three annexes.

In Part-I, the document talks about " The Technology : Status and Prospects", in Part-II - about " Nuclear Economics", in Part-III - about "A Nuclear Survival?", and in Part-IV - about "The Alternatives".

In the Executive Summery, the document says that in country after country nuclear construction has gone massively over-budget. In the United States, an assessment of country's 75 reactors showed predicted costs to have been 45 billion dollars. In India, with the most recent and current construction experience, completion costs of the last 10 reactors have averaged at least 300% over budget.

The document further says that the average construction time for nuclear plants has increased from 66 months for completion in the mid 1970s to 116 months between 1995 and 2000. It also says that demand of constructions of nuclear power plants are falling. According to the report there are currently only 22 reactors under active construction in the world. The majorities are constructed in Asia and 16 of the 22 are being built to Chinese, Indian or Russian designs. None of these designs is likely to be exported to OECD. The construction started on five of the reactors over 20 years ago. There are further 14 reactors on which construction has started but is currently suspended. This low level of nuclear construction provides little relevant experience on which to build confidence in cost forecasting.

The document further points out that the economics of nuclear power have always been questionable. It says that following the introduction of competitive electricity markets in many countries, the risk that the plant would cost more than the forecast price was transferred to the power plant developers, which are constrained by the views of financial organizations such as banks, shareholders and credit rating agencies. Such organizations view investment in any type of power plant as risky, raising the cost of capital to levels at which nuclear plant is less likely to complete.

In recent years numerous studies of the economics of nuclear power been conducted. The values of the key parameters used to generate the forecast cost of nuclear power vary significantly from one study to another. For example, the assumed cost of construction ranges from 725-3600/kw euro while the assumed construction time varies from 60 to 120 months. The resultant price of electricity consequently also varies significantly from 18-76/MWh euro.

The document also points out that the much touted nuclear renaissance has failed which had assumed that new plants will be built cheaper than the alternatives, on time and to cost, that they will operate reliably and that the cost of dealing with long-term liabilities, such as waste disposal and decommissioning will stabilize. However, wishing for an outcome is not sufficient to make it fact. Until nuclear power actually meets all these criteria on a sustained basis, the additional risks of nuclear investment will be large.

It also points out that it is now 29 years since the last order for a new nuclear power plant in the US and 34 years since the last order for a plant that was actually completed. Utilities suffered heavy losses in the 1980s as economic regulators became increasingly unwilling to pass huge cost over-runs from nuclear projects on to consumers, forcing utilities to bear the extra costs. The introduction of power markets has meant that plant owners are now fully exposed not just to the risk of cost over-runs but also to plant reliability. The nuclear provisions of the US Energy Policy Act of 2005 (EPACT 2005) are an effort to reverse these changes and protect investors from that large economic risk.

According to the Act, it is unlikely that any US company would be considering investing in a new nuclear plant.

Government financial and contractual guarantees would effectively take nuclear power out of the market so that it is paid for, as in the past, by electricity consumers and tax payers if nuclear power is to be subsidized in this way.

The document further points out that a contemporary case study of Finland's Olkiluoto Plant demonstrates the key problems of construction delays, cost over-runs and the hidden subsidies related to nuclear power plant projects.

The document also says that an energy efficiency action plan proposed by the European Commission in October 2006 called for 20% increase in energy saving across the European Unions. If fully implemented, this would result in energy consumption in the EU being 1500 Mtoe by 2020, instead of the 1890 Mtoe in the business-as-usual scenario and compared to 1750 Mtoe in 2004.

Some energy efficiency measures will come at little no cost, but others will require significant investment. Already Germany has a highly efficient energy economy, but analysis suggests that the country's energy consumption could be reduced by 27% by 2015 using 69 measures across the industrial, commercial and residential sectors at an average cost of 69/MWh euro. This is an enormous energy saving programme to be introduced within a decade. The price of saving is below the likely cost of nuclear electricity.

The document further talks about the renewable electricity sources. It says that the contribution of renewable is growing rapidly with the annual investment growing from about 7bn dollar in 1995 to 338bn dollar in 2005. During 2005 the total installed capacity of non-large-hydro renewable increased by 22GW, which compares to a 3.3 GW increase in nuclear, much of which relates to increased capacity from existing reactors rather than from the construction of new reactors.

The document also says that hydroelectricity and wind energy are expected to deliver the biggest increase in electricity production by 2020; roughly 2000Twh/year in each case. Both technologies are expected to deliver electricity at around 40-50 MWh euro, which is likely to be competitive with nuclear gas and coal.

The document points out that the last experience indicates that the construction costs of nuclear plants completed during the 1980s and early 1990s in the United States and in most of Europe were very high - and much higher than predicted today by few utilities now building nuclear plants and by the nuclear industry generally. It says that according to the data published by the United Department of Energy (DOE), the total estimated cost of 75 of the reactors currently in operation was 49bn dollar. This 100bn dollar cost over-run was more than 200% above the initial cost estimates.

The document further says that the UK Trade and Industry Committee stated in its 2006 report that even the most optimistic estimates for this (new construction) are in the region of five years; but that experience in the UK to date has shown it can take much longer, with an average construction period for existing nuclear power stations of almost 11 years. The most recent reactor, a OWR at Sizewell B, experienced increases in capital costs from 1,619m dollar to 3,700m dollar, while the construction cost of the Torness AGR nuclear reactor in Scotland increased from 742m dollar to a final cost of 2,500m dollar.

The document further points out that the last decade has been a decline in construction of new nuclear power plants. The European Investment Bank noted that very few nuclear power stations have been built in the last few years and thus cost of recent plants does not seem a good reference to assess future costs. Additionally, any future development of nuclear energy will be based on the new generation of reactors and the cost of the new generation is uncertain at this stage.

The MIT study summarizes the current experiences with new build:

- Construction costs in Europe and North America in the 1980s and 1990s were very high;
- The spectra of high construction costs has been a major factor leading to very credible commercial interest in investments in new nuclear power plants; and
- The historical experience produced higher costs than predicted today by the few utilities now building nuclear power plants and by the nuclear industry in general'

The document further points out whether there is a nuclear revival or decline. It says that the current list of plants under construction is a short one. Sixteen of the 22 units are being supplied by vendors from China, Russia and India. It seems unlikely that any of these vendors would be considered in Western Europe or North America, the markets that would need new orders if a global nuclear revival were to take place. Most of India's plants are based on a Canadian design from the 1960s, long since suspended in Canada. China's plants are also closely modeled on old Western designs. China will probably continue to supply mainly its home market with one or two export to Pakistan.

Of the plants under construction, five were ordered 20years ago. Construction is reported to be still underway. Work on a further 14 units has stopped and while there are frequent reports that work may restart at these sites. It is far from clear if and when this will happen. These 'hangover' plants raise a number of issues:

- The designs on which these orders were originally based are now well out of date, if completion to standards significantly below those currently applied was not acceptable, the cost of upgrading could be large and could counterbalance the benefits of the work already done, as occurred at the Temelin nuclear power plant in Czech Republic;
- Much of the equipment already bought has been in store, untouched, for at least 16 years. If this has not been stored to the highest standards, it could require expensive remedial work or even replacement; and
- There must be issues about the quality of work carried out so far. Demonstrating that existing work upto standard will be expensive and if it proves not to be upto bringing the standard, remedial work could be prohibitively expensive.

In part-II titled "Nuclear Economics", the document talks about the main determinants of nuclear power costs. It says that from commercial nuclear power's beginnings, the promise of cheap power has been one of the main claims of the nuclear industry, but this promise of cheap power has seldom been kept.

The document further says that there are several important determinants of the cost of electricity generated by a nuclear power plant. The usual rule-of'-thumb in the past for nuclear power has always been that about two-thirds of the generation cost is accounted for by fixed cost, that is, cost that will incurred whether or not the plant is operated, and the rest by running costs. There are three main elements to the fixed cost per kilowatt hour: the construction cost, the cost of capital, which determines how much it costs to borrow the money to build the plant. The real cost of capital varies from country to country and from utility to utility, according to the country risk (how financially stable the country is) and the credit-rating of the company. There will also be a large 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, especially for nuclear power.

The document also says that higher utilization improves the economics of nuclear power because the large fixed costs can be spread over more saleable units of output than if utilization is lower. In addition, nuclear power plants are physically inflexible. Frequent shutdowns or variations in output reduce both efficiency and lifetime of components. As a result, nuclear power plants are operated on base-load (continuously at full power) except in the very few countries.

In this section, the document also talks about Insurance and Liability. It says that there are two international legal instruments contributing to an international regime on nuclear liability. The International Atomic Energy Agency on Civil Liberty for Nuclear Damage of 1963 and the OECD's Paris Convention on Third Party Liability in the field of Nuclear Energy, from 1960 and the linked Business Supplementary Convention of 1963.

These Conventions are linked by the Joint Protocol, adopted in 1963. The main purposes of the conventions are to:

- Limit liability to a certain amount and limit the period for making claim;
- Require insurance or other surety by operators;
- Channel liability exclusively to the operator of the nuclear installation;
- Imposed strict liability on the nuclear operator, regardless of fault, but subject to exceptions; and
- Grant exclusive jurisdiction to the courts of one country, normally the country in whose territory the incident occurs.

Not all countries that operate nuclear facilities are party to either of the conventions, for example, non-signatories include the USA, Switzerland, Canada, China and India. Furthermore, the Conventions only act to create a minimum level of insurance and many countries require operators or state cover to exceed the covers proposed.

The scale of costs caused by, for example, the Chernobyl disaster, which may be in the order of hundreds of billions of euro, means that conventional insurance cover would probably not be credible because a major accident would bankrupt the insurance companies.

It has been estimated that if Electricite de France (EdF), the main French Electric Utility, was required to fully insure its power plants with private insurance but using the current internationally agreed limit on liabilities of approximately 420m euro, it would increase EdF's insurance premium from 0.017/MWh euro to .19/MWh euro, thus adding around 8% to the cost of generation. However, if there was no ceiling in place and an operator had to cover the full cost of worst-case scenario accident, it would increase the insurance premiums to 5/MWh euro, thus increasing the cost of generation by around 300%.

The document points out that variable costs and non-fuel operations and maintenance (O&M) costs are seldom given much attention in studies of nuclear economics. The cost of fuel is relatively low and has been reasonably predictable. However, the assumption of low running costs was proved wrong in the late 1980s and early 1990s when a small number of US nuclear power plants were retired because the cost of operating them was found to be greater than cost of building and operating a replacement gas-fired plant. It emerged that non-fuel O & M costs were an average in excess of 22/MWh dollar while costs were then more than 12/MWh dollar. 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 cost, specially 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 24.5-28.0/MWh euro from 1997-2004. However, in the first six months of fiscal year 2006/07, operating costs including fuel were 35.5/MWh euro because of poor performance at some plants.

The document further says that the fuel costs have fallen as the world uranium price has been low since the mid-1970s although in recent years, the price of uranium has risen, more than doubling in 2006. These higher uranium costs have yet to be reflected in fuel costs for reactors, although given that much of the cost of fuel relates to processing, such as enrichment, the effect will be limited.

It also says that fuel costs are a small part of the projected cost of nuclear power. The issue of spent fuel disposal is difficult to evaluate. Reprocessing is expensive and, it does little to help waste disposal. Reprocessing merely splits the spent fuel into different parts and does not reduce the amount of radioactivity to be dealt with or the heat load., indeed, reprocessing creates a large amount of low and intermediate level waste because all the equipment and material used in reprocessing becomes radioactive waste.

In this section, the document further talks about the impact of liberalization of electricity industry. It says that when the electricity industry was invariably a monopoly, utilities were normally guaranteed full recovery of costs found to be used and useful as well as prudent. This made any investment a very low risk to those providing the capital because consumers were bearing most of the risk. The cost of capital varies according to the country and whether the company was publicly or privately owned. Publicly owned companies in OECD countries generally have a high credit rating and often do not have to raise equity capital (which is more expensive than debt) therefore the cost of capital is lower than for a commercial company. The range was 5-8%.

Arguably, this low cost of capital was a distortion and led to utilities building more capital-intensive options than they should have done, because they were not being exposed to the economic risk they were taking. Building a power station of almost any type is a highly risky venture: fuel choice could prove wrong, construction costs could escalate and demand might not grow at the forecast rate. But because consumers or taxpayers usually 'picked up the tab' if things went wrong, this risk was ignored by utilities and financiers. If the risk had been borne by the utilities and if bad technology or fuel choices were directly reflected in their profits, utilities would have been much more cautious in their investment decisions, choosing low capital cost options and options that had a low risk of going seriously wrong.

The document also points out that guarantees on construction time for a nuclear plant will be highly risky. In November 2006, Nuclear Week reported that for the Olkiluoto contract: According to industry sources, the contractual penalty for Avera is 0.2% per week of delay past May, 2009 commercial operation target for the first 26 weeks, and 0.1% beyond that. The contract limits the penalty to 10% of the total contract value, or about 300m euro.

It says that poor performance can be particularly costly for a utility. Experience with the most recent Framatome design, N4, shows that reliability is still not assured, especially for new, untested designs. Until all new plants operate from the start of service at levels of 85-90% load factor, it will be too great a risk for the nuclear vendors to offer a guarantee for performance. A particular problem for nuclear plants is that generally not one company controls the whole of the plant.

The document further points out that if electricity markets are not a sham, long-term power purchase agreements at prices not related to the market will not be feasible unless the cost offered is very low. If the wholesale market for power is efficient, most power will be bought and sold at spot or spot-related prices. If retail markets are effective, consumers will switch regularly to obtain the cheapest available price. A long-term power purchase contract to buy the output of the plant at pre-determined prices will either be a huge risk, or will not be worth the paper it is printed on. If retail markets are well-used, no retailer will know from one year to the next what their market will be and the risk of company failure will be significant.

The document also talks about long-term liabilities. It says that from an economic appraisal perspective, long-term liabilities such as waste disposal and decommissioning should have little impact on the economics of nuclear power. At the start of the life of the plant, decommissioning will be 60 or more years away and the final disposal of spent fuel will also be many decades away. In the type of discounted cash flow calculation used in project appraisal, costs and income are 'discounted' to a 'net present value'. In other words, if there is a cost of, say, 100m euro in 10 years' time, and it was assumed the discount rate was 5%, the discounted value of this cost would 61.3m euro. The rational is that a sum of 661.3m euro was invested today at a real interest rate of 5%, after 10 years, it would have grown to 100m euro. By the same logic, income of 100m euro earned in 10 years would be worth only 61.3m euro today.

While this has an intuitive logic, over longer periods and at higher discount rates, the effect is alarming and seems to trivialize huge long-term liabilities.

In chapter IV, the document talks about renewable energy including resource, economics and prospects. It says that the International Energy Agency has suggested renewable are at crossroads - 'no longer a theoretical possibility, but not yet a major market presence'. Including hydro-electricity the proportion of renewable in global electricity generation was about 18% in 2004. Within this figure, geothermal energy, solar, tidal and wind accounted for 334TWh, or about 2% of global electricity production. In 1990, the corresponding amount was 1%. Since global electricity production has increased by 50% since 1990, electricity production from 'new renewable' increased threefold in that time- a compound annual growth rate of 14%. In practice, the growth rates in wind and solar energy have been higher than this, but lower in geothermal and tidal. Annual investment in renewable energy has grown from about 7bn dollar in 1995 to 38bn dollar in 2005. During 2005 the total installed capacity of non-large hydro renewable increased by 22GW, which compares to an increase of 3.3GW increase in nuclear, much of which relates to increased capacity from existing reactors.

The document further says that there are three principal sources of renewable energy: the sun, the moon, and the earth itself. The sun is the source of solar energy and, indirectly, of hydro energy, wind energy, wave energy and biomass energy. The moon is the source of tidal energy and the earth of geothermal energy.

Broadly speaking, gas provides the cheapest electricity in many parts of the European Union and in some of the United States, but many existing hydro sources are already competitive, as they were installed several years ago. Of the 'new renewable' energy sources, wind is becoming increasingly competitive where wind speeds are high, for example in Germany, Denmark, northern France, Britain, Ireland, southern Spain, Portugal, China, India, and some US states as well as Canada.

The larger scale developments in renewable energy technologies deliver economies of scale and currently have the lowest generation costs and are best able to produce energy in quantities to match the output of thermal plant. In the case of wind energy, for example, not only are installed costs per kilowatt lower with large wind turbines and wind farms but higher energy yields are achieved.

In conclusion, the document says that hydro electricity and wind energy are expected to deliver biggest increases in electricity production by 2020-

roughly 2000TWh in each case, depending on the growth rate in wind. Each of these technologies is expected to deliver electricity at around 40-50/MWh euro, which is likely to be competitive with nuclear, gas and coal. The prospects for solar thermal electric, wave and tidal stream energy are more uncertain but their generation costs may also be competitive with the fossil fuel sources. Although the generation costs for solar photovoltaic appear high, there is enormous world wide potential, particularly for household and off-grid applications where other sources of electricity supply are likely to be expensive.

Nuclear Powr: Exposing the Myths

By:

Nuclear Information and Resource Service

Bird's Eye View

In these papers, the writers have exposed the various myths associated with the positive nature of the Nuclear Power. In the first paper these myths have been systematically exposed. It says that the nuclear industry is hoping that concern over climate change will result in support for nuclear power. However, even solely on the grounds of economic criteria it offers poor value for money in displacing fossil fuel plant. Further, with its high cost, long construction time, high environmental risk and problems resulting from waste management, it is clear that nuclear power does not offer a viable solution to climate change. Rather a mixture of energy efficiency and renewable energy offers a quicker, more realistic and sustainable approach to reducing CO2 emissions.

Now the paper goes on exposing various myths-

Nuclear power is economical and cost effective

The full costs of nuclear power have been seriously underestimated by all countries which have the technology, and it is only recently that the true costs have begun to come to light. The hidden costs of waste disposal, decommissioning and provision for accidents have never been adequately accounted for, resulting in a massive drain upon economies. This drain will continue for many years to come as the expensive and dangerous task of nuclear decommissioning gets underway.

Privatisation and liberalisation of the market in the UK, has led to the true costs of nuclear power being exposed. It has become clear that nuclear power cannot exist in a competitive energy market without significant subsidy from Government. This process is now being followed around the world with investors being unwilling to accept the high cost and risks associated with nuclear power. Moreover, if fully comprehensive insurance was required to cover all of the risks of nuclear accidents, the cost of electricity from nuclear power would increase many times from the present level.

Reactor decommissioning costs also remain a major uncertainty. In the UK, for example, the cost of dealing with the unwanted debris of the nuclear industry is officially estimated at about US$70 billion. Of this, just US$22 billion is covered in secure funding arrangements, with the remaining US$48 billion (almost 70%) likely to be paid for by taxpayers. The nuclear industry's claim that, "In most countries, the full costs of waste management and plant decommissioning will be funded from reserves accumulated from current revenues" is clearly untrue.

Countries, particularly in Central and Eastern Europe, are continuing to build new nuclear plants even though it has been shown that investment in energy efficiency measures is the quickest and safest way to tackle their energy crises. For example, the nuclear power plants proposed to replace the remaining reactors at Chernobyl have consistently been shown not to be the least-cost option.

Also, in terms of cost-effectiveness in reducing CO2 emissions, nuclear power fairs very poorly. In 1995, after a year-long, exhaustive review of the case for nuclear power, the UK Government concluded that nuclear power is one of the least cost-effective ways in which to cut CO2 emissions. In the USA improving electricity efficiency is nearly seven times more cost effective than nuclear power for obtaining emissions reductions.

Nuclear power one of the least effective and most expensive ways in which to tackle climate change.

Table 1: CO2 abatement options, in order of cost-effectiveness (10% discount rate)

1 Fuel switching	10 Industrial motive power
2 Appliance efficiency improvements	11 Domestic space heating
3 Industrial CHP	12 Country-wide CHP
4 Lighting efficiency improvements	13 Renewables
5 Small-scale CHP	14 Process Heat
6 Cooking efficiency improvements	15 Industrial Space Heating
7 Service sector space heating	16 Nuclear
8 Advance Gas Turbines	17 Advanced Coal Technology
9 Water heating	

Nuclear power does not produce CO2

Nuclear power is not greenhouse friendly. While electricity generated from nuclear power entails no direct emissions of CO2, the nuclear fuel cycle does release CO2 during mining, fuel enrichment and plant construction. Uranium mining is one of the most CO2 intensive industrial operations and as demand for uranium grows CO2 emissions are expected to rise as core grades decline.

According to calculations by the Öko-Institute, 34 grams of CO2 are emitted per generated kWh in Germany. The results from other international research studies show much higher figures - up to 60 grams of CO2 per kWh. In total, a nuclear power station of standard size (1,250MW operating at 6,500 hours/annum) indirectly emits between 376,000 million tonnes (Germany) and 1,300,000 million tonnes (other countries) of CO2 per year. In comparison to renewable energy, nuclear power releases 4-5 times more CO2 per unit of energy produced taking account of the whole fuel cycle.

Also, with its long development time a nuclear power programme offers no short-term possibility for reducing CO2 emissions.

Nuclear power is safe

Problems of security, safety and environmental impact have been perennial issues for the nuclear industry. Many countries have decided against the development of nuclear power on these grounds, but radioactive contamination is no respector of national borders and nuclear power plants threaten the health and well-being of all surrounding nations and environments. There is also the very serious problems of nuclear proliferation and trafficking.

The UN Intergovernmental Panel on Climate Change (IPCC) view is that if nuclear power were to be used extensively to tackle climate change, "The security threat ... would be colossal".

Just one month after The Economist, a British magazine, had declared in its lead article that the technology was "as safe as a chocolate factory" (1986), there followed a catastrophic nuclear accident at Chernobyl. The accident caused an immediate threat to the lives of 130,000 people living within a 30 kilometre radius who had to be evacuated (and who have been permanently relocated) and 300-400 million people in 15 nations were put at risk of radiation exposure. Forecasts of additional cancer deaths attributable to the Chernobyl accident range from 5,000 to 75,000 and beyond. The nuclear industry argues that the problems in the former Soviet Union are different to those in developed countries, but the United States itself had a serious accident at Three Mile Island in 1979. Whilst the new European Pressurised Reactor and the fusion programmes are being promoted as offering safer operation, no form of nuclear power technology is totally without risk of a major accident. With public opinion strongly set against nuclear power, it would be far better to invest in renewable forms of energy which have widespread public support. The development of new nuclear technology would mean spending huge amounts of money going down another nuclear road, with the prospect of finding the same type of problems and public opposition.

Recent in-depth studies in the United States challenge the claim that exposure to low-level doses of radiation is safe. The health and safety of employees, local communities and the contamination of the environment are genuine risks. A recent study (completed August 1997) funded by the US National Institute for Occupational Safety and Health of the Centers for Disease Control and Prevention, examined the health and mortality of 14,095 workers from the Oak Ridge National Laboratory. The study found "strong evidence of a positive association between low-level radiation and cancer mortality". As of 1990, 26.9% of deaths were due to cancer.

The exposure risk to workers in the uranium mining industry is also great.

4: Nuclear power is sustainable

Nuclear power plants produce extremely long-lived toxic wastes, for which there is no safe means of disposal. The only independent scrutiny of a Government waste management safety case [NIREX in the UK] led to the cancellation of the proposed test site for nuclear waste disposal. As disposal is not scientifically credible, there is no option other than interim storage of radioactive wastes. This means that the legacy of radioactive wastes will have to be passed on to the next generation. Producing long-lived radioactive wastes, with no solution for their disposal, leaving a deadly legacy for many future generations to come is contrary to the principle of sustainability, as laid out in Agenda 21 at the Earth Summit.

In 1976 the UK Royal Commission on Environmental Pollution warned that it is, "irresponsible and morally wrong to commit future generations to the consequences of fission power on a massive scale unless it has been demonstrated beyond reasonable doubt that at least one method exists for the safe isolation of these wastes for the indefinite future". Over twenty years on, still no such method has been found. Nuclear waste management policies are in disarray and there is growing public opposition to the transport and storage of nuclear waste - as has been demonstrated by the scenes at Gorleben, Germany.

Under no circumstances can nuclear power be considered to be sustainable.

5: Nuclear power can provide an endless source of energy

With the virtual demise of the Fast Breeder research programme and no foreseeable commercial development of fusion reactors, the belief that nuclear power can supply an endless source of energy is fast disappearing. The Japanese Monju Fast Breeder reactor has been inactive since a serious accident in December 1995, whilst the French Superphoenix and the breeder reactor programmes in the UK have been permanently closed.

Diminishing uranium supplies and the failure of the breeder reactor programmes mean that nuclear power will not be able to make a long-term contribution to meeting the world's energy needs.

6: Nuclear power makes a vital contribution to energy supply

The assertion by the nuclear industry that, "It is essential that nuclear generating capacity is maintained if emissions from power generation are to be successfully limited over the next 10 to 15 year and beyond" is fundamentally untrue. Emissions can be cut without building more nuclear power plant. In October 1997, the US Department of Energy released a report in which they concluded that the US could cut CO2 emissions to 1990 levels by 2010 with no net cost to the economy. Shell has forecast that renewables could meet up to 50% of the world's energy demand by 2060. Nuclear power only supplies 17% of world electricity supply at present.

Nuclear power is seeing its role in the world's energy mix diminish. Since 1986, according to the IAEA, only three nuclear power stations have been ordered annually. In Europe fourteen out of fifteen European nations have no plans to develop nuclear power; the majority of the countries within the European Union have, "little desire to launch, or to re-invigorate, nuclear power programs"; and nearly half of the EU countries are nuclear free and others are planning to decrease or phase out nuclear power completely. It is clear that the vast sums of money being spent on research and development and on subsidising the industry are in total disproportion to the contribution nuclear power is likely to make to Europe's energy supply in the coming decades.

With a limited amount of funding available for research and development, reallocation of funds from nuclear power and towards renewable energy and energy efficiency would reduce the costs of these technologies, making them even more competitive. However, funds are still being wasted on nuclear power programmes, which are opposed by most people, are more expensive than other alternatives and require a long development time.

It is a myth that "Nuclear power is the only fully developed non-fossil fuel electricity generating option with the potential for large-scale expansion". Nuclear power plants take 10 years to build. Over the next 12 years the European Union is aiming for 10,000MW of wind power and 10,000MW of biomass to be developed. This is a just part of the solution and is equivalent to about 15 nuclear power plant.

Energy policies post-Kyoto

1. Joint Implementation and the Clean Development Mechanism should not be allowed to be used as a smoke screen for new nuclear power development. Western governments must not be allowed to use nuclear power technology in Eastern Europe and in developing countries to obtain greenhouse credits in return for "reducing" future emissions in those countries. Canada had been proposing a system of credits for low carbon-intensive fuels including uranium and natural gas.

   The World Bank has made a decision not to finance new, or the upgrading of old, nuclear power plants based on the following rationale: i) in almost all cases, nuclear is not the least-cost solution to the power supply problem; ii) environmental risks are high and require specialised agencies for their handling.

2. Governments should not be fooled into believing that nuclear power is acceptable as a technically viable, economically feasible or publicly acceptable solution to climate change. The nuclear industry in the developed world, particularly Western Europe and the United States is on its last legs due to its consistent technical problems (accidents, construction errors, unreliable operation), economic failures (cost overruns, non-competitive with renewables in an era of increased deregulation, rising waste storage costs) and dramatic public disaffection (communities in the US, Western Europe and now even Japan, are vehemently opposing the siting of a new nuclear reactors).
3. Developed nations' governments should not be encouraged to support nuclear power construction abroad under the mask of a climate solution, in order to support their own failing nuclear industry. There are real fears that Central and Eastern Europe will become an electricity generating centre for the rest of Europe, producing cheap electricity based upon lower environmental and safety standards and lower public opposition to highly polluting and dangerous energy infrastructure.

   Further, Western corporations have targeted energy-hungry China, where public awareness of nuclear's environmental, economic and public health disasters is virtually non-existent, as an economic goldmine and saviour of their dying industry. Exploiting public innocence of the Chinese people is cruel and unusual punishment. The health and safety of the Chinese people, as well as the ecosystems and peoples of other nuclear industry targeted countries must not be sacrificed on the altar of a nuclear industry bailout.

   Japanese Government delegates to the preliminary conference for COP-3 climate change negotiations in Bonn proposed that expanded use of nuclear energy should be referred to in the draft policy protocol to be signed at COP-3. The proposal had to be withdrawn almost immediately due to opposing voices.
4. Governments need to increase financial investments and incentives in renewables, conservation and energy efficiency. Such measures will create more jobs per unit of energy than traditional fossil fuel and nuclear power industries. For example, while also being cheaper than nuclear power, wind power provides four times as many direct jobs as nuclear power per unit of energy produced.

Conclusions

Under no circumstances can nuclear power be considered to be a solution to climate change:

- It is one of the most expensive ways to reduce carbon dioxide emissions. The nuclear industry does contribute to carbon dioxide emissions. No proven strategies exist for the permanent safe storage of nuclear waste.
- Nuclear power poses a very real health risk.
- Nuclear power is uneconomic, unsustainable and unsafe.

Climate change is a serious problem which needs to be tackled in a way which safeguards the future for generations to come. Tackling climate change through the development of nuclear power is both expensive and just swaps one serious problem for another. Nuclear power cannot be considered to be a "clean source of electricity".

Deconstructing the Nuclear Power Myths

By:

Peter Bunyard

The nuclear industry is hoping to use the Climate Change negotiations to save itself, because the economics of nuclear power has meant a rapid decline in the industry's fortunes. This is a desperate attempt to generate business from the misfortune of the problems we all now face.

In the paper titled 'Deconstructing the Nuclear Power Myths' the writer Peter Bunyard explains the scenario by showcasing France as example. He says that Nuclear power has an appalling record for long drawn-out construction times. The last reactor to come on line in the United States took 23 years to complete. Fifteen years has been the average time taken in many Eastern European countries using USSR technology. In France, the average time taken for construction to operation is 8 years.

We must also not neglect the considerable and proportionately increasing impact of other greenhouse gases to global warming. The use of nuclear power, even to its best advantage, would not make a jot of difference to the emissions of both methane and nitrous oxide since they are primarily derived from agriculture and in particular from deforestation in the tropics.

France — a test case

There are other costs in running nuclear power plants. Even the nuclear industry now admits that the generation of electricity that originates from nuclear power is not wholly free of greenhouse gas emissions. France provides a useful background to review the efficiency of power generation and consumer preference. In 1999, France generated 375 TWh from its nuclear stations. EdF (Electricité de France) estimates that the cost in CO2 emissions of operating its nuclear plants amounts to 6 g CO2 per kWh.

France's electricity board provides an estimate that includes construction, removing the spent fuel, reprocessing and the storage of wastes. On that basis the total CO2 emissions per year from the operation of its nuclear plants amounts to 2.25 million tonnes. That estimate does not include the mining and preparation of the fuel and hence is not dependent on the quality of the ore.

On the other hand, the Öko-Institute of Germany, taking the full fuel cycle costs into account, comes up with an average figure that is nearly 6 times higher — 35 g/kWh — compared with EdF's, in which case the total CO2 emissions would amount to 13.125 million tonnes of CO2 equivalent.

In 1990, France emitted 144 million tonnes of CO2 equivalent. Therefore, nuclear power's contribution to the total emissions amounted to 1.6 percent on EdF's estimates and 9.1 percent, according to the Öko-Institute, both numbers being significant and far from trivial. Nevertheless, banking on the naivete of the public, the nuclear industry exaggerates the advantages of nuclear power in terms of avoided greenhouse gas emissions by comparing its relatively low emissions compared to a coal-fired plant of the same generating size. On that basis, nuclear power comes out 300 times better than coal.

As Mycle Schneider, director of WISE (World Information on Safe Energy)-Paris, points out, those seemingly low percentages of carbon dioxide emission from nuclear power plants hide an elemental truth, that the use of nuclear power in France has to be augmented, because of consumer preference, by the use in the home of natural gas-based heating systems, both for hot water and space-heating. For home-heating purposes electricity from whatever source is an expensive and inefficient option, and basically the public, let alone industry, prefers to turn away from it.

In an average French household, aside from transport, two-thirds of the energy consumed is for heating and just one-third for electricity. Consequently, if we are going to make any comparisons as to the carbon-economy of nuclear power versus fossil-fuel systems, we should do so only by taking the end-use preferences into account.

- First, the differences of any one system lie in its efficiency to provide end-use energy whether for heating or electricity
- Nuclear power stations are built away from population centres
- They are relatively inefficient from a thermodynamic point of view, losing as much as two-thirds of the energy produced as heat to the immediate environment (a body of water or cooling tower).
- The one-third remainder of electricity must be transmitted into a central grid system, where the losses can amount to as much as 10 per cent
- The net result is that about one quarter of the energy originally released gets to the consumer.

If the consumer were to obtain both electricity and heating from a single co-generation system; the efficiency returns can amount to as much as 90 per cent of the original energy and, therefore, some three to four times better than if nuclear generated electricity were to be the sole source of energy in the home.

A proper evaluation of greenhouse gas emissions therefore demands that the method of production gets taken into account when estimating the total release of greenhouse gases. Both coal and fuel oil used in a co-generation plant are still inferior by a factor of two to a nuclear power/ natural gas combination in terms of greenhouse emissions. But that figure is already far-removed from the 300 times advantage so heralded by the nuclear industry and its supporters.

Meanwhile, a natural gas co-generation system is level-pegging with the nuclear power/natural gas combination again in terms of emissions, while being far cheaper to the consumer simply because of the three fold better efficiency in delivering end-use energy. And what about a co-generation system based on biogas? The Öko-Institute estimates that it emits seven times less greenhouse gases in providing end-use energy compared to a nuclear power/natural gas combination.

Although concern over the consequences of accidents, such as at Chernobyl or Three Mile Island impinges on the issue, the high, uneconomic cost of nuclear power, more than any other factor, has brought about the industry's failure to make its mark as a major source of energy in the world. Increasingly too, local 'embedded' generation, such as from a wind farm, or a co-generation plant, is becoming an important competitor against the notion of single large power plants attached to a central grid. In a world ever more competitive in terms of reducing cost, an inefficient, high capital cost nuclear power plant is increasingly an anachronism.

If nuclear power were the answer to a cheap source of energy, why has there been a massive turning away from nuclear power since the 1970s? In the United States, where nuclear technology originated, all civilian nuclear reactors were ordered in the ten-year period between 1963 and 1973, all with huge subsidies from the federal government, including so-called turn-key contracts. No new ones have been ordered since 1973, six years before the accident at Three Mile Island, and a string of cancellations in the 1970s and 80s plus permanent shutdowns meant that total electricity generated by nuclear power went down rather than up. In 1989, the cancellations and shutdowns exceeded those coming on stream by a considerable margin, 4 GW compared to 10.4 GW.

Nuclear Power: Exploding the Myths

By Gordon Edwards

Similarly, writer Gordon Edwards in his paper 'Nuclear Power: Exploding the Myths' gives the example of Canada and its nuclear programme. He says that Nuclear power was once portrayed as peaceful, clean, safe, cheap and abundant. It was even described as miraculous. Disney's animated documentary film "Our Friend the Atom" promised that nuclear power could end world hunger, eliminate poverty, and bring about an unprecedented era of peace and prosperity. For decades, the Canadian Nuclear Association distributed a public-relations comic book which concluded with these words:

> "NEW BOON TO MANKIND
>
> "The benefits of nuclear radiation that we know today are nothing when compared to what we may reasonably expect in the future.
>
> "Food may be preserved in its original fresh condition for long periods of time. Nuclear-powered ships may ply the oceans; trains may cross continents many times on only a few ounces of nuclear fuel; power reactors may help open up remote areas such as Canada's North....
>
> "In time it is possible that nuclear power may lead to temperature-controlled, germ-free cities, and a better life for all mankind."

Today the rhetoric is more muted, but nuclear power is still touted as a saviour of sorts: it will save us from global warming, help us eliminate nuclear weapons, meet the world's burgeoning energy needs. And Ottawa's nuclear decisions remain as inscrutable and unaccountable as ever.

So far, Ottawa has spent over 13 billion (in 1997 $) of taxpayers' money building dozens of nuclear facilities, paying thousands of salaries, creating entire towns to house workers, and spreading Canadian nuclear technology to India, Pakistan, Taiwan, Korea, Argentina, and Romania. Through all this, Ottawa never resorted to public consultation, parliamentary debate or any form of open democratic process. Public approval was taken for granted. It still is.

Jean Chrétien likes nuclear power. He doesn't mention it during election campaigns. It can't be found in the Liberal Party's red book of promises. But M. Chrétien uses his office to back the Canadian nuclear industry to the hilt:

- At a 1996 G-7 Meeting in Moscow, Chrétien stunned everyone by saying that Canada favours the idea of accepting tonnes of left-over plutonium from dismantled nuclear warheads, to be used as fuel in CANDU reactors. The official rationale? "Canada has to play a role in nuclear disarmament." Samples of weapons plutonium fuel from Russia and the US are now being tested in a reactor at Chalk River, Ontario. If the ambitious scheme goes ahead, Canadians will be responsible for all the high-level radioactive waste and residual plutonium in perpetuity; yet Ottawa has no plans for any form of public consultation on the fundamental policy questions -- just pro-forma environmental hearings on the little details.
- M. Chrétien is an indomitable nuclear salesman. Since the banks won't finance CANDU reactor sales, he ensures that the Treasury of Canada does. China was given one-and-a-half billion dollars of taxpayers' money for buying a CANDU reactor. It was the largest loan in Canadian history, yet there was no procedure to secure taxpayers' permission or parliamentary approval. Turkey was promised an equal amount if it would plant a CANDU in its earthquake-prone soil.
- M. Chrétien was reportedly furious to learn that Canadian law requires a complete environmental assessment for a publicly financed project

like the Chinese CANDU. He and his cabinet ignored the law. The Sierra Club of Canada sued. Government lawyers refused to provide documents on technical and financial aspects of the project, saying they were not relevant, because no cabinet member had ever seen any of them. Apparently, the largest loan in Canadian history was based on nothing more than the say-so of Canada's nuclear industry. Ottawa is now trying to stop the court from obtaining copies of other assessments that China may have done on the CANDU project.

- This fall, Chrétien's cabinet launched a concerted effort to have Canada's overseas sales of nuclear reactors accepted by other G-7 countries as a respectable strategy for combating global warming. In fact, the Chrétien government had done nothing to fulfill its 1997 pledge at Kyoto to reduce carbon emissions in Canada by six percent. Instead of apologizing, Ottawa is now saying that Canada deserves greenhouse gas credits for reducing carbon emissions by selling reactors abroad.

Despite all this, the nuclear industry is moribund. Not a single power reactor has been ordered in North America for the last quarter-century, and there are no prospects at all. In western Europe nuclear expansion has also ground to a halt; Germany, Sweden and Switzerland are phasing out nuclear power, and France's aggressive nuclear program is at a standstill. Only in Eastern Europe and in parts of Asia are there any markets for nuclear reactors, and most of them require heroic financial incentives from the sellers.

I think the clearest indication that this industry will not survive is its dread of open debate, independent scrutiny, or public accountability. For over two decades, Atomic Energy of Canada Limited has had a policy of refusing to debate in public with knowledgeable critics. AECL frequently boycotts public meetings, as well as radio and TV shows where both sides of the issues might be adequately represented, in hopes that the events will be cancelled (which they frequently are). I like to think that such an industry cannot long endure.

Let us now turn to the main myths of nuclear power:

Myth 1. "Atoms for Peace" and "Atoms for War" have nothing in common.

Untrue. The Canadian nuclear program began as part of the World War II Atomic Bomb project. The first reactors at Chalk River were built, in part, to produce plutonium for bombs. Plutonium from Chalk River was used by the Americans, the British, and the Russians in their respective bomb programs. India's first atomic bomb, in 1974, used plutonium produced in a clone of the Canadian NRX reactor. Israel's Dimona reactor, which produces plutonium for that country's nuclear weapons, is also a close copy of the NRX reactor.

Every régime that has purchased a CANDU reactor has had military ambitions of a nuclear nature. India and Pakistan are obvious examples. Korea and Taiwan had clandestine atomic bomb development programs when they first purchased Canadian reactors. The generals in Argentina wanted to make Argentina the first nuclear weapons state in South America, and Ceaucescu in Romania had similar inclinations.

Plutonium is mass-produced inside nuclear reactors. It doesn't occur in nature -- but, once created, it lasts for thousands of years. Operating a nuclear reactor creates a permanent plutonium repository. At any time in the future -- thousands of years from now, or next year -- plutonium can be separated from the spent nuclear fuel and used to make atomic bombs.

Recent reports from US weapons authorities have confirmed that any kind of reactor-produced plutonium is good for making atomic bombs. Indeed, the US Academy of Sciences pointed out in a study in November that CANDU spent fuel can be more easily used by criminals or terrorists to get plutonium for bombs than can spent fuel from other types of nuclear power reactors.

The threat of nuclear warfare, increased by the spread of nuclear explosive materials worldwide, is at least as unsettling as the prospect of climate change.

Myth 2. Plutonium extracted from dismantled warheads can be destroyed by burning it as fuel in civilian reactors.

Untrue. Nuclear warheads are rendered useless when their plutonium cores are removed, but there is no method for destroying the plutonium. This constitutes a serious danger. What's to prevent the plutonium from being put back into the warheads, or stolen by criminals, terrorists, or agents of an aggressive régime, and re-fashioned into new nuclear bombs?

At present, all that can be done is to make the plutonium more difficult to access, and therefore less likely to be used in weapons. The method that is favoured by the peace movement is "immobilization". Plutonium is blended with highly radioactive liquid wastes -- there are millions of gallons left over from the weapons program. The mixture is then solidified into ceramic logs weighing two tonnes each. These radioactive logs are stored securely and guarded under international control.

Nuclear power proponents prefer a different method: the "MOX" option. Small amounts of plutonium are mixed with large amounts of uranium to produce a "mixed oxide" reactor fuel, abbreviated as "MOX". MOX fuel is used in a commercial power reactor to generate electricity, and the irradiated fuel is stored onsite.

But the plutonium is not eliminated. From half to two-thirds of the original amount remains in the spent MOX fuel, still weapons-usable, posing a perpetual security risk. MOX is up to seven times more expensive than regular uranium fuel -- even if the plutonium is free -- so there's no good economic justification either.

The MOX option is particularly dangerous because it packages plutonium as a commercial product instead of banning it as a dangerous material. Countries that have invested heavily in nuclear power -- Russia, France, India, Japan -- hope to use plutonium as the principal nuclear fuel of the future, ushering in a "plutonium economy". In this scenario, tonnes of plutonium will be circulating annually in the world's economy, and it will be easy for a criminal organization to acquire the few kilos needed for an atomic bomb.

Unlike the immobilization option, the MOX option runs the risk of stimulating a global traffic in plutonium that cannot be policed effectively. Plutonium gives off almost no penetrating radiation, even though it is extremely toxic when inhaled or ingested. Fresh MOX fuel is therefore easy to steal and smuggle across borders. A recent report from the US says that three men, working for two weeks with only modest resources, could extract enough plutonium from MOX fuel to make an atomic bomb.

Myth 3. Nuclear Power can significantly reduce greenhouse gas emissions.

Untrue. Nuclear power is too expensive to build and too slow to deploy, and does not address the bulk of energy needs which are non-electrical.

Studies show that each dollar invested in energy efficiency saves from five to seven times as much carbon dioxide as a dollar spent on nuclear.

The Royal Society of Canada's 1993 COGGER Report ("Committee on Greenhouse Gas Emission Reductions") didn't even mention nuclear, which was near the bottom of the list of priorities. Energy efficiency was at the top.

It is true that nuclear reactors do not give off carbon dioxide. Neither does solar, wind, ocean thermal, wave power, micro-hydro, or most other renewable energy technologies. Bio-gas (biologically derived methane), though carbon-based, doesn't add to global warming because burning it recycles carbon that was recently extracted from the atmosphere, whereas burning fossil fuels releases carbon that was locked away millions of years ago.

Studies conducted in the aftermath of the first oil crisis showed that nuclear power has little or no role to play in a rational off-oil energy strategy. "Energy Future", the celebrated 1979 Report of the Harvard Business School Task Force on Energy, concludes that efficiency, coupled with judicious use of solar, is by far the most cost-effective strategy for achieving, swiftly and permanently, major reductions in primary energy use (and in greenhouse gas emissions, though the report didn't have global warming in mind.)

President Carter created the Solar Energy Research Institute (SERI) in 1979 and asked if the sun could satisfy 20 percent of US energy needs by the year 2000. The SERI report, "A New Prosperity", showed the goal was in fact easily achievable, but the key was implementing a thorough cost-effective energy efficiency strategy. With lower consumption levels, solar becomes affordable and effective.

In Canada, Friends of the Earth coordinated an ambitious energy analysis, published in 12 volumes by Environment Canada and EMR, entitled "2025: Soft Energy Futures for Canada". It concluded that Canada could, by 2025, support twice the population while using only half as much primary energy as was used in 1978, yet with three times the GNP. This would require no economic penalty, nor would it require curtailing energy use (much as that might be desirable). Due to efficiency gains, no increase in electrical facilities would be needed despite increased electrical use, and all nuclear plants could be retired.

Building an energy-efficient society goes a long way toward building an environmentally friendly and sustainable future. It is more work than just throwing money at energy megaprojects, but the benefits are enormous. It creates jobs throughout the economy, rather than focussing them in one industry. It sharply reduces our negative impact on the global environment. It makes communities more viable by keeping money in the local economy. It brings back hope in the future and sets a worthy benchmark for future generations and developing countries. The obstacles aren't technical or economic in nature, but political and social. It should be our first priority.

Myth 4. Nuclear Power is Clean and Safe.

Untrue. Canada has 200 million tons of radioactive wastes in the NWT, northern Saskatchewan and Ontario, from uranium mining activities. The Wall Street Journal described such waste as an "ecological and financial time bomb", and a Canadian environmental panel described one Saskatchewan site as potentially the most toxic waste dump in Canada.

Irradiated nuclear fuel remains toxic for millions of years. The nuclear industry estimates that a geologic repository will cost about 17 billion dollars.

Money is now being put aside for the repository project, although a ten-year-long environmental review found unresolved safety and environmental concerns. For example, the radioactivity of the waste will heat up the bedrock, which won't return to original temperatures for more than 50 000 years. Could this "thermal pulse" jeopardize the integrity of the repository?

The Atomic Energy Control Board reported to the Treasury Board in 1989 that catastrophic accidents are possible in CANDU reactors, and that it is impossible to say with any assurance that CANDUs are safer or less safe than other types of reactors. A 1976 British Royal Commission on Nuclear Power and the Environment pointed out that bombing a nuclear reactor with conventional bombs would be as catastrophic as a severe nuclear accident. Large parts of Europe might be uninhabitable today, the report said, if nuclear power had been deployed in Europe before World War II.

It is important for people from across the country to insist that nuclear power be phased out in Canada and that no public money be used to finance any expansion of this industry. The Ottawa-based Campaign for Nuclear Phaseout coordinates such resistance to nuclear development: cnp@web.ca, (613) 789 3634, www.cnp.ca.

The Pros and Cons of the Nuclear Energy Debate

By:

The Natural Edge Project and Other

Bird's Eye View

The Pro-Nuclear Case

Those arguing for expanding the global nuclear energy industry argue that it is needed in order to address three things: 1) the risks of climate change, 2) increasing base load energy demand, and 3) the need for an energy source to produce transport fuels once the world reaches peak oil production. More specifically, those proposing an expansion of the nuclear industry argue that:

1. We are about to witness a nuclear renaissance of both nuclear fission and fusion.
2. Since addressing climate change requires large (60% or more) reductions in greenhouse gas emissions, nuclear energy is going to be a key part of the solution to preventing climate change.
3. An expansion of nuclear power is vital to meet growing energy demand. International Energy Agency forecasts that, 'if policies remain unchanged, world energy demand is projected to increase by over 50% between now and 2030'.
4. Other options to reduce greenhouse gas emissions, such as renewable energy, do not provide reliable base load power. The position is that only nuclear and the burning of fossil fuels provides reliable base load power and hence, unless geo-sequestration rapidly becomes technically and economically possible, we have no choice but to build nuclear power plants in the future to mitigate greenhouse gas emissions.
5. The world's oil production will peak soon and to address this nuclear power plants are a potential way to provide energy to create transport fuels such as biofuels, methanol and hydrogen fuels. Also nuclear power can help supply electricity to battery powered cars in the future.
6. Nuclear energy costs less than renewables.
7. The technology of nuclear power has moved on significantly in the last

couple of decades and a reactor like Chernobyl would never be built today.

8. Nuclear programs like those of Sweden and France have been very safe and delivered a lower carbon footprint than countries like Australia which have burnt coal for most of our electricity.
9. Nuclear power is a green solution.
10. **Little Pollution**

    As demand for electricity soars, the pollution produced from fossil fuel-burning plants is heading towards dangerous levels. Coal, gas and oil burning power plants are already responsible for half of America's air pollution. Burning coal produces carbon dioxide, which depletes the protection of the ozone. The soft coal, which many power plants burn, contains sulfur When the gaseous byproducts are absorbed in clouds, precipitation becomes sulfuric acid.. Coal also contains radioactive material. A coal-fired power plant emits more radiation into the air than a nuclear power plant.

    The world's reserves of fossil fuels are running out. The sulfurous coal which many plants use is more polluting than the coal that was previously used. Most of the anthracite, which plants also burn, has been used up. As more soft coal is used, the amount of pollution will increase. According to estimates, fossil fuels will be burned up within fifty years. There are large reserves of uranium, and new breeder reactors can produce more fuel than they use. Unfortunately this doesn't mean we can have an endless supply of fuel Breeder reactors need a feedstock of uranium and thorium, so when we run out of these two fuels (in about 1000 years), breeder reactors will cease to be useful. This is still a more lengthy solution to the current burning of coal, gas, and oil.
11. **Reliability**

    Nuclear power plants need little fuel, so they are less vulnerable to shortages because of strikes or natural disasters. International relations will have little effect on the supply of fuel to the reactors because uranium is evenly deposited around the globe. One disadvantage of uranium mining is that it leaves the residues from chemical processing of the ore, which leads to radon exposure to the public. These effects do not outweigh the benefits by the fact that mining uranium out of the ground reduces future radon exposures. Coal burning leaves ashes that will increase future radon exposures. The estimates of radon show that it is safer to use nuclear fuel than burn coal. Mining of the fuel required to operate a nuclear plant for one year will avert a few hundred deaths, while the ashes from a coal-burning plant will cause 30 deaths.
12. **Safety**

    Safety is both a pro and con, depending on which way you see it. The results of a compromised reactor core can be disastrous, but the precautions that prevent this from happening prevent it well. Nuclear power is one the safest methods of producing energy. Each year, 10,000 to 50,000 Americans die from respiratory diseases due to the burning of coal, and 300 are killed in mining and transportation accidents. In contrast, no Americans have died or been seriously injured because of a reactor accident or radiation exposure from American nuclear power plants. There are a number of safety mechanisms that make the chances of reactor accidents very low. A series of barriers separates the radiation and heat of the reactor core from the outside.

    The reactor core is contained within a 9-inch thick steel pressure vessel. The pressure vessel is surrounded by a thick concrete wall. This is inside a sealed steel containment structure, which itself is inside a steel-reinforced concrete dome four feet thick. The dome is designed to withstand extremes such as earthquakes or a direct hit by a crashing airliner. There is also a large number of sensors that pick up increases in radiation or humidity. An increase in radiation or humidity could mean there is a leak. There are systems that control and stop the chain reaction if necessary. An Emergency Core Cooling System ensures that in the event of an accident there is enough cooling water to cool the reactor.

The Anti-Nuclear Case

Those arguing against expanding nuclear power point argue that nuclear power is too expensive, too risky, too slow to build enough capacity, and too dangerous in this age of terrorism. More specifically they argue that:

1. There is little evidence to support the notion that there is a nuclear renaissance underway. Rather over the coming decades most forecast a decline of nuclear energy as a percentage of global energy supply. They point out that as of 2003 distributed renewable energy generation provided more energy globally than the world's supply from nuclear energy.
2. Nuclear power is never going to be the answer to climate change. Only 32% of the US 's, and 35% of Australia 's greenhouse emissions come from electricity generation, whereas in countries like Brazil and India over 50% of their greenhouse emissions come from Non-CO 2 sources. A nuclear power station cannot reduce Non-CO 2 emissions. Hence those who argue against nuclear energy point out that it is impossible for nuclear power to be the one big techno fix for climate change as well as the fact that building nuclear plants takes many years.
3. Scientists now argue that humanity has to significantly reduce greenhouse gas emissions quickly to ensure that dangerous climate change is avoided. Nuclear power plants take a significant amount of time to build. Energy efficiency and other forms of renewable energy - geo-thermal, wind, solar, tidal, cogeneration, micro-hydro, biomass, wavepower - can be implemented today. Forty three companies and over fifteen cities have already achieved significant greenhouse gas reductions without using nuclear energy.
4. Policies have, are, and will continue to change, and have the potential to dramatically reduce energy demand both for peak and base load energy. Regulations have been created that provide new incentives, and reward energy utilities for selling less energy, which have been shown to dramatically reduce demand for more energy. Thus there is still significant potential to reduce energy demand cost effectively by implementing energy efficiency through all sectors throughout the global economy.
5. Renewable energy sources can indeed provide base load electricity either directly or by also utilising energy storage. Energy from renewable sources now accounts for a quarter of the installed capacity of California , a third of Sweden 's energy, half of Norway 's and three-quarters of Iceland 's. Six fully costed modelling studies already show that deep cuts to greenhouse emissions can be achieved without needing nuclear power.
6. Nations can reduce oil dependency profitably without needing any nuclear power, as demonstrated by the RMI Winning the Oil End Game Report, co-funded by the Pentagon.

7. Renewables are less expensive than Nuclear Power. On the 17th of June 2003 the Economist magazine, wrote that Nuclear energy does not merit any more investment because it is too expensive compared to alternatives including wind and solar energy sources. RMI's Small is Profitable publication demonstrates that once all the 207 benefits of distributed energy generation are taken into account, distributed renewable energy is more profitable than nuclear power. Historically, nuclear power plants have been not only expensive, they're also financially extremely risky because of their long lead times, cost overruns, and open-ended liabilities. If the same money were invested in efficiency or renewables it would have a greater impact on the emissions of the greenhouse gases.
8. While it is true that the technology has moved on, and if the best technologies were applied to any new reactor it would have less risks than Chernobyl, there are new risks, including indirect risk from terrorism.
9. Nuclear waste has half lives that last 10,000s of years. No civilization has ever lasted that long. Is it ethical to be creating a form of waste that will require careful storage for a timeframe longer than any civilization has lasted? Also managing the waste is expensive. There are expensive ways to dispose of long-lived radioactive waste. Sweden, for instance, has spent $14 billion and rising to manage its radioactive waste and is now decommissioning its reactors.
10. Nuclear power is not green due to all the points made above and also due to the following additional facts; namely that nuclear power plants use a great deal of water, uranium is a non-renewable resource and there is significant energy and resources needed to build nuclear plants.
11. **Meltdowns**

    If there is a loss of coolant water in a fission reactor, the rods would overheat. The rods that contain the uranium fuel pellets would dissolve, leaving the fuel exposed. The temperature would increase with the lack of a cooling source. When the fuel rods heat to 2800°C, the fuel would melt, and a white-hot molten mass would melt its way through the containment vessels to the ground below it. This is a worst case scenario, as there are many precautions taken to avoid this. Emergency water reservoirs are designed to immediately flood the core in the case of sudden loss of coolant. There are normally multiple sources of water to draw from, as the low pressure injection pumps, containment spray system, and refueling pumps are all potentially available, and all draw water from different sources. The disaster at Three Mile Island was classified as a partial meltdown, caused by the failure to supply coolant to the core. Although the core was completely destroyed, the radioactive mass never penetrated the steel outlining the containment structure. Several feet of special concrete, a standard precaution, was capable of preventing leakage for several hours, giving operators enough time to fix the flooding system of the reactor core. The worst case of a nuclear disaster was in 1986 at the Chernobyl facility in the Ukraine. A fire ripped apart the casing of the core, releasing radioactive isotopes into the atmosphere. Thirty-one people died as an immediate result. And estimated 15,000 more died in the surrounding area after exposure to the radiation. Three Mile Island and Chernobyl are just examples of the serious problems that meltdowns can create.
12. **Radiation**

    Radiation doses of about 200 rems cause radiation sickness, but only if this large amount of radiation is received all at once. The average person receives about 200 millirems a year from everyday objects and outer space. This is referred to as background radiation. If all our power came from nuclear plants we would receive an extra 2/10 of a millirem a year. The three major effects of radiation (cancer, radiation sickness and genetic mutation) are nearly untraceable at levels below about 50 rems. In a study of 100,000 survivors of the atomic bombs dropped on Hiroshima and Nagasaki, there have been 400 more cancer deaths than normal, and there is not an above average rate of genetic disease in their children. During the accident at Three Mile Island in America, people living within a 50 mile radius only received an extra 3/10 of one percent of their average annual radiation. This was because of the containment structures, the majority of which were not breached. The containment building and primary pressure vessel remained undamaged, fulfilling their function.

13. **Waste Disposal**

The byproducts of the fissioning of uranium-235 remains radioactive for thousands of years, requiring safe disposal away from society until they lose their significant radiation values. Many underground sites have been constructed, only to be filled within months. Storage facilities are not sufficient to store the world's nuclear waste, which limits the amount of nuclear fuel that can be used per year. Transportation of the waste is risky, as many unknown variables may affect the containment vessels. If one of these vessels were compromised, the results may be deadly.

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