UNDERSTANDING THE ANTI-NUCLEAR ENVIRONMENTAL MOVEMENT

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This publication was prepared for the International Youth Nuclear Congress by Lubomir Mitev, editor of the bulletin at IYNC and journalist at the independent nuclear news agency NucNet. The report represents neither the organisation's nor the author's view of the international nuclear industry or the anti-nuclear and environmental movements. All views and opinions portrayed in this publication are cited in an academic style in order to credit the relevant authors and publications. The IYNC does not guarantee the accuracy of the data or qualitative information included in this study. Neither IYNC nor anyone affiliated with the organization or the author may be held responsible for the use which may be made of the information contained therein.

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EXECUTIVE SUMMARY

UNDERSTANDING THE ANTI-NUCLEAR ENVIRONMENTAL MOVEMENT

The report Understanding the Anti-nuclear Environmental Movement aims to outline the main arguments against nuclear power as used by anti-nuclear activist organisations and to present them to professionals in the nuclear industry. Using this as a basis, nuclear professionals should be able to understand and, further down the road, learn to communicate with anti-nuclear activists.

The report addresses an issue young nuclear professionals are faced with – they experience difficulty in understanding the reasons why anti-nuclear activism exists. Using several reports produced by anti-nuclear organisations and publications distributed by environmental activists, this report sets out to produce a non-scientific collection of arguments against the nuclear energy industry. It is a first attempt to categorise and structure the arguments and give an explanation about the issues behind them.

For this reason, the report is organized around 5 main ideas:

1. The history of the anti-nuclear environmental movement.

2. The main arguments against the nuclear industry under four main categories:

a. *"Nuclear energy is expensive"* (the economic argument)

b. *"Nuclear energy is dangerous"* (the safety argument)

c. *"There is no solution to nuclear waste"* (the waste argument)

d. *"Nuclear energy technology can result in the creation of nuclear weapons"* (the non-proliferation argument)

3. The way anti-nuclear activists use these arguments. Three interviewees, representatives of anti-nuclear organisations – one each from the USA, Europe and Japan – who were asked the same questions in order to find out how they would respond.

4. Understanding that not all environmental activists are anti-nuclear, we have included an interview with Mr. Bruno Comby, founder of the organization *Environmentalists For Nuclear.*

5. Nuclear energy and climate change. We use nuclear energy and its effect on climate change as an example of how anti-nuclear activists use arguments against nuclear as well as portray how previously anti-nuclear people can change their minds on the issue.

The report concludes that the rise of anti-nuclear activism from the age of nuclear weapons testing, and the general association of nuclear weapons and energy, are detrimental to the further development of the civilian uses of nuclear technology. Several accidents during weapons testing, most notably in the Pacific Ocean, bring about negative emotions which are directly associated with operational nuclear power stations. Anti-nuclear activism also takes different forms depending on the political, social and economic context in which it is manifested.

Anti-nuclear activists and environmental organisations manage to capture the attention of both politicians and the public with passionate arguments on the scale of the threat that nuclear energy poses. One of the main advantages the environmentalist movement has over the nuclear industry is its use of passionate, emotional arguments when attacking nuclear energy. This report has laid the groundwork for young nuclear professionals to use pro-nuclear arguments in a similar way by evoking passion and emotion.

INTRODUCTION

UNDERSTANDING THE ANTI-NUCLEAR ENVIRONMENTAL MOVEMENT

The report *Understanding the Anti-nuclear Environmental Movement* began as an educational project. It aimed to bring forward the main argument against nuclear power as used by anti-nuclear activist organisations and to present them to young professionals working in the nuclear industry. It has grown to become a first step in the framework of a larger project in nuclear communications which aims to create a tool for young professionals to not only understand but also learn to communicate with anti-nuclear activists.

The reason the International Youth Nuclear Congress organization (IYNC) decided to commission the report is that young nuclear professionals noticeably have a hard time understanding why so many people are arguing against their field of work. For a nuclear engineer, physicist or researcher, it is hard to comprehend why this technology, which could be explained through mathematical equations and models, is so hated by certain social groups. Therefore, using several reports produced by anti-nuclear organisations and publications distributed by environmental activists, this report sets out to produce a non-scientific collection of arguments against the nuclear energy industry.

For this reason, the report is organized around three main ideas:

1. Young nuclear professionals need to understand the birth and history of the anti-nuclear environmental movement. In the second decade of the twenty-first century, many of us look at organisations such as *Greenpeace* or *Friends of the Earth* as pro-environment. However, *Greenpeace* was founded on a strong anti-nuclear sentiment which still resonates in its activities.

2. Young nuclear professionals need to understand the four main arguments against the nuclear industry and why they exist. The nuclear industry often repeats that its technology is safe. In practice, however, numerous scandals, leaks and several accidents are being used as proof that this is not so. The report lays out the arguments against nuclear energy divided into the four main categories that they are found:

a. *"Nuclear energy is expensive"* (the economic argument)

b. *"Nuclear energy is dangerous"* (the safety argument)

c. *"There is no solution to nuclear waste*" (the waste argument)

d. *"Nuclear energy technology can result in the creation of nuclear weapons"* (the non-proliferation argument)

For each argument, we describe the technical aspects which the industry often uses to explain the issue and then we go on to describe the counter-arguments used by anti-nuclear groups. These contra-arguments have been collected from numerous reports and publications and do not aim to insult or challenge any particular person, organization, government or country. The views presented here are not of the IYNC and the sources for each argument are clearly indicated.

The conclusions presented at the end of each sub-chapter point out the problem within the industry's activities or in their communication strategies. These conclusions should be viewed with caution because they aim to provoke a defensive response from the nuclear industry. The IYNC and the author of this report intentionally want to use these arguments as starting points in a debate and therefore use somewhat provocative language to initiate a critical viewpoint on the issue being discussed.

3. Young nuclear professionals need to understand the way anti-nuclear activists use these arguments. For this reason, we conducted three interviews with representatives of anti-nuclear organisations – one each from the USA, Europe and Japan. We asked the same questions to all of them (with some minor differences) in order to find out how they would respond. We want to see whether geographical distance makes a difference to the arguments against nuclear energy. The interviews are with: Mr. Hideyuki Ban, Secretary General of *Citizen`s Nuclear Information Center* in Japan, Mr. Jan Haverkamp, expert consultant on nuclear energy and energy policy for Greenpeace Central and Eastern Europe, and Mr. Paul Gunter, founder of *Beyond Nuclear* in the United States.

In order to bring a measure of balance to this report, the author also decided to include one additional interview with a 'rare commodity' in the nuclear energy world – a pro-nuclear environmentalist. In order for **young nuclear professionals to understand that not all environmental activists are anti-nuclear,** we have included an interview with Mr. Bruno Comby, founder of the organization *Environmentalists For Nuclear.* His answers can be viewed in contrast to the three other interviewees.

The three features of this report – the history of the environmental movement, the anti-nuclear arguments and the way they are used, should lead to a better understanding of the anti-nuclear environmental movement in general. We hope that this report will be viewed as the educational and informative tool it is intended to be. We also hope it will be the beginning of a balanced relationship between young nuclear professionals and anti-nuclear environmental organisations.

HISTORY OF ANTI-NUCLEAR ENVIRONMENTALISM

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Wrecked framework of the Museum of Science and Industry in Hiroshima, Japan, as it was shortly after the first atomic bomb on August 6, 1945 (Source: Everett Historical)

The roots of the anti-nuclear environmental movement can be found in the nuclear weapons testing conducted in the mid-1940s, culminating in the detonation of two nuclear devices in Japan by the US army, according to Jerry Brown and Rinaldo Brutuco in their book *Profiles in Power: The Antinuclear Movement and the Dawn of the Solar Age*. The *Little Boy* device, dropped on Hiroshima in August 1945, destroyed 50,000 buildings and killed 70,000 people. The *Fat Man* device, dropped on Nagasaki three days later, destroyed 60 percent of the city and resulted in the deaths of about 35,000 people. This demonstration of the power of nuclear weapons resulted in a growth of stockpiles during the Cold War period, which required nuclear reactors to produce fissile material for warheads. It also demonstrated what the result could be if a nuclear reactor was to have an uncontrolled accident[1].

Nuclear weapons testing continued after the end of World War II. In *Operation Crossroads*, the US conducted a series of controlled explosions at Bikini Atoll in the summer of 1946. According to reports, the residents of the islands had to be re-settled to uninhabited islands where they were unable to sustain themselves. The resettlement caused a limited public backlash against the testing[2].

Yet, it was only in 1954 that fallout from a nuclear weapons test caught the public's attention. A hydrogen bomb test in the Pacific Ocean contaminated the crew of a Japanese fishing boat and one of the fishermen died seven months later. According to Wolfgang Rudig, a UK professor of social science, the incident "provided decisive impetus for the emergence of the anti-nuclear weapons movement in many countries"[3].

Meanwhile, scientists began investigating the effects of radiation on the human body. In 1961, preliminary results of a study conducted by the Greater St. Louis Citizens' Committee for Nuclear Information, the Saint Louis University and the Washington University School of Dental Medicine, known as the *Baby Tooth Survey*, were published[4]. The study aimed to determine the effects of nuclear fallout in the human anatomy by examining the levels of radioactive material absorbed by baby teeth. More specifically, it examined the presence of strontium-90 in the teeth of children who had absorbed it as a result of contaminated water and dairy products from above-ground atomic tests[5].

The results showed children born after the start of large-scale atomic tests had a concentration of Sr-90 in their baby teeth which was 50 times higher than those born earlier. The *Baby Tooth Survey* helped convince US President John F. Kennedy to impose a moratorium on above-ground nuclear weapons testing, followed by the signing of the Partial Test Ban Treaty in 1963 with the USSR[6].

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Reactor pressure vessel at the construction site of the Shippingport nuclear power plant, 10 October 1956 (Source: US Department of Energy)

Opposition to Commercial Nuclear Power in the USA

Commercial nuclear power plants faced opposition in the US from the 1950s. The first US commercial nuclear power plant, the Shippingport atomic power station, was opened in 1958 by President Dwight D. Eisenhower as part of the *Atoms for Peace* initiative. The first nuclear power station to meet public opposition was Fermi-1, a 200-megawatt (thermal) sodium-cooled fast reactor located 30 miles (about 48 kilometers) south of Detroit, Michigan. Christopher Hartz, a professor at California Polytechnic University, says the station's safety was challenged by the public as well as the United Auto Workers union, which enjoys a lot of political influence in Detroit[7]. In October 1966, two fuel assemblies melted and forced Fermi-1 to shut down for nearly four years, feeding fuel to the fire of anti-nuclear sentiment in the area. The reactor was permanently shut down in 1972[8].

However, historian Thomas Wellock attributed the birth of the anti-nuclear movement to events on the West Coast. One of the first commercial nuclear power plants in the US was planned to be built at Bodega Bay, north of San Francisco. Plans for the plant surfaced in 1958 but were met with strong opposition from local citizens due to the site's proximity to the San Andreas Fault, as well as the region's fishing and dairy industries. The plans for Bodega Bay were abandoned in 1964, together with four other reactors planned for California, as well as three in New Jersey and two in New York[9].

The development of nuclear power reactors in other parts of the country did not help calm the anti-nuclear sentiment. An accident at the Stationary Low-Power Reactor Number One (SL-1), a US Army experimental reactor in Idaho, during which three operators were killed in 1961, fueled anti-nuclear movements. J. Samuel Walker, a historian, says environmentalists saw the advantages of nuclear energy regarding reduction of air pollution but were critical of the technology on other issues: safety and accidents, nuclear materials proliferation, high costs, nuclear terrorism and radioactive waste disposal[10]. These issues still form the basis of anti-nuclear movements today and are explored in-depth in this report.

Herbert Kitschelt, professor at Duke University, says the political system in the US created conditions allowing anti-nuclear groups to influence, both directly and indirectly, legislatures and election processes. There was a tendency for anti-nuclear groups in the US to lobby Congressional committees and attempt to influence key sets of actors in the executive branch of government. On the state level, these groups succeeded in forcing several referendums on nuclear energy development. Thus, Maine became the first state to prohibit "generation of electric power by nuclear fission thermal power plants" in September 1980[11]. In other parts of the world, anti-nuclear movements had to resort to other methods because they lacked political influence.

The Anti-Nuclear Movement in Western Europe

The nuclear power program in Europe developed similarly to that in the US. In the United Kingdom, the first wave of anti-nuclear sentiment was brought about by the Campaign for Nuclear Disarmament (CND) in 1957. Protests and marches (some of which lasted for days) took place in England throughout the 1960s. In fact, London saw one of the largest protests against nuclear weapons in October 1983 when more than 300,000 people gathered in Hyde Park[12]. However, most anti-nuclear protests at the time were against the British nuclear weapons program while the environmentalist movement has only developed to organize actions against commercial power plants since the mid-2000s.

Marco Giugni, professor at the University of Geneva, says the early days of the nuclear industry benefitted from a favorable political and social climate in most countries. In the

Anti-nuclear weapons protest march in Oxford, England, 1980 (Source: Kim Taylor)

1960s, nuclear energy plans in Switzerland were adopted with virtually no opposition and three plants entered operation between 1969 and 1972 without significant anti-nuclear activism[13].

The more significant actions in Switzerland were organized against the plans to build a nuclear power station near the village of Kaiseraugst, about 15 kilometers east of Basel. According to professor Giugni, between 1960 and 1973, the anti-nuclear movement used existing institutional opportunities and channels to block the Kaiseraugst nuclear project and then, until 1979, shifted to direct action. For example, a major occupation took place at Kaiseraugst in 1975 after construction work had started. It lasted 10 weeks and 15,000 people took part[14].

In France, the first nuclear power plant site was at Bugey, about 30 kilometers northeast of Lyon. In 1971, 15,000 people demonstrated against the plant, but the reactor became commercially operational in that year. Between 1975 and 1977, approximately 175,000 people participated in 10 anti-nuclear demonstrations in the country[15]. Dr. Kitschelt says the anti-nuclear movement turned to public protest because the French state was relatively effective in preventing political intervention in the regulatory process, unlike in the US. Thus, they could not lobby for a change in policy but rather had to take a confrontational position. In the end, the anti-nuclear movement in France saw a large mobilization when considering the number of participants and activities to the size of the country, but the nuclear program experienced little disruption, Dr. Kitschelt says[16].

Around the same time as the Bugey reactor was coming online in 1971, protests erupted in the West German town of Wyhl, a proposed site for a nuclear power station. The protests culminated in 1975 when an administrative court withdrew the construction license for the Wyhl plant after broad television coverage showed police dragging away protestors which caused social backlash. Between 1975 and 1979, about 280,000 people participated in seven demonstrations. The West German political parties were in favor of the development of nuclear energy and so were the German labor unions. Therefore, the anti-nuclear movement could not gain representation on a political level, resulting in no anti-nuclear positions being taken during parliamentary debates. Just like in France but contrary to the US, anti-nuclear voices in West Germany fell on deaf ears[17].

Dr. Kitschelt argues that the rise of the anti-nuclear movement in Europe was due to political opportunity. He says that in countries like the US, where the political system is open to input from the public and responsive to demonstrations, a search for alternative policies was triggered as a result of anti-nuclear activism. In France and West Germany on the other hand, the governments insisted more intransigently on the predetermined policy course to develop nuclear power[18]. For example, Helmuth Böck, president of the Austrian Nuclear Society, explained in an interview in 2013 that Austria's nuclear power program failed for political reasons. He said: "*at the time [1978] the Chancellor was from the Socialist Party and he said that if the Zwentendorf [nuclear station] referendum failed, he would resign. So, the opposition party, the Christian-Democrats, wanted to use this promise to vote against nuclear power.*"[19] The referendum on Zwentendorf failed by a few thousand votes, but the Chancellor did not keep his promise and he stayed in power[20].

In more recent history, the German coalition government's decision to extend the lifetime of its nuclear power plants passed through a parliamentary vote in October 2010 by 308 votes to 289. However, just seven months later (and two months after the Fukushima-Daiichi accident in Japan), the


Bugey nuclear power plant (Source: EDF)

same coalition government pledged to shut down all nuclear plants by 2022, initiating a phase-out policy. In a statement, the government said, “Germany has enough suitable alternatives to nuclear power with wind, solar, hydropower, geothermal power and biomass”[21]. Policy reversals from pro- to anti-nuclear do not take a long time.

The Chernobyl Factor and Nuclear Opposition in the USSR

In Soviet Russia and after the fall of the USSR, the anti-nuclear movement was loosely connected to the environmental movement. Jane Dawson, Director of the Goodwin-Niering Center for the Environment in Connecticut, says that anti-nuclear movements were organized according to the regions of the USSR where nuclear power plants were being built such as Lithuania, Ukraine and Armenia. None of these movements turned violent but relied on petitions and mass actions. Dr. Dawson says many governmental officials saw the anti-nuclear movement as a “safe outlet for popular frustrations” and thus found little reason to suppress the activism. This led to anti-nuclear movements gaining access to resources for public mobilization in contrast to national and ethnic minority movements. Therefore, suppressed minorities in the Soviet republics found it easier to mobilize under the umbrella of an anti-nuclear movement. In Dr. Dawson’s research, most anti-nuclear movements in the USSR based their arguments on nationalist, territorial or ethnic ideology, although a small number did adhere to environmental principles[22].

In the aftermath of the Chernobyl accident, the tendency changed, Dr. Dawson says. In January 1988, after a change in censorship laws, anti-nuclear publicists began portraying nuclear power stations as “horrifying” and “real threats to people’s health”. Plans for new nuclear stations were equated with policies of genocide. Between 1988 and 1990, over 50 planned nuclear reactors were frozen or cancelled. Dr. Dawson attributes this success to the weakening of the Communist party rather than the resources and organizational strength of the anti-nuclear movement[23].

Anti-nuclear demonstration in Berlin on 10 May 2014 (Source: 360b/Shutterstock.com)

In 1990-91, there was an extreme reversal in the movement’s policy. Dr. Dawson’s research shows that as the USSR broke up in December 1991, the newly independent states such as Ukraine, Lithuania and Armenia struggled to establish themselves as functioning economies and experienced energy crises. The anti-nuclear movements quickly disappeared and previously anti-nuclear political elites began to advocate the re-initiation of nuclear power programs to provide a reliable source of energy. As the nationalist sentiment could no longer be linked to anti-nuclear actions, the movement lost momentum.

Japan Before Fukushima

Anti-nuclear movements existed in Japan long before the Fukushima accident. In fact, two of the first anti-nuclear groups are Japan’s Gensuikyo and Gensuikin movements, which emerged from the previously mentioned 1954 incident where the fishing crew was contaminated by the fallout of a US hydrogen bomb test. The two organizations continue to hold rallies and disseminate information on anti-nuclear issues[24].

The destroyed Chernobyl-4 nuclear reactor in Ukraine with the commemoration monument in the foreground, April 2015 (Source: Tijuana2014/Shutterstock.com)

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Daniel Aldrich, associate professor at Purdue University, argues that the Japanese government developed an extensive array of policy instruments and soft social control techniques designed to bring public opinion in line with its pro-nuclear energy goals. Professor Aldrich cites documents from the Japan Atomic Industrial Forum (JAIF), an industry group, which show that plans for construction of nuclear stations in the 1960s and 70s included actions to minimize the potential influence of well-organized associations, including fisherman's cooperatives. The sites for the stations were chosen where the local population was least likely to mount anti-nuclear campaigns[25].

Prof. Aldrich's arguments show how the Japanese nuclear industry side-stepped the pitfalls which existed in the US. By locating nuclear sites at places of least resistance and making sure that local unions and cooperatives remain in favour of the technology, the industry eliminated most potential opposition. As a result, many Japanese politicians and social organisations feel they were lied to and have since become anti-nuclear[26].

In fact, some Japanese communities did protest against planned nuclear power infrastructure. Fishermen at the Tokaimura nuclear complex expressed their opposition through boat rallies and marches. Others stopped a planned research reactor at Kansai University. Professor Aldrich argues that policy instruments designed for manipulation of public opinion did not guarantee the pro-nuclear policy's success. According to reports, only 54 out of 95 attempts to construct nuclear power plants were successful, giving the Japanese government and nuclear industry's policy and tactics a 57 percent success rate[27].

Examples of the soft social control techniques used in Japan can be seen after the incidents at Three Mile Island in 1979 and Chernobyl in 1986. The Japanese government reassured its citizens that such accidents would not happen in Japan due to its "strong engineering credentials, in-depth safety controls, and highly educated and motivated staff," Professor Aldrich's research says. However, several cover-ups have fueled anti-nuclear sentiments since the 1990s. For example, in December 1995, a sodium-cooled experimental reactor known as Monju experienced a large sodium leak. The agency in charge suppressed the details of the accident causing local residents to fight against the reopening of the reactor[28].

According to Professor Aldrich, the Tokyo Electric Power Company (TEPCO), operator of Fukushima-Daiichi nuclear station, covered up numerous accidents, leaks and cracks since the 1980s. Engineer-whistleblowers reported over 30 incidents which had been covered up by the company. This led to the shutdown of all TEPCO-operated reactors in 2002[29]. Nowadays, Hirohiko Izumida, governor of Niigata prefecture where TEPCO's Kashiwazaki-Kariwa nuclear station is located, has repeatedly refused to consider the restart of reactors at the station[30]. "There has not been a sufficient investigation into the causes of the (Fukushima) accident nor in-house disciplinary actions, so we cannot stand at the starting line of discussions on safety," the governor said in January 2015[31].

In an article in the *New York Times*, Robert Jay Lifton, a lecturer in psychiatry at Harvard Medical School, says there was a pattern of denial, cover-up and cozy bureaucratic collusion between industry and government in Japan. "Even then, pro-nuclear power forces could prevail only by managing to instill in the minds of Japanese people a dichotomy between the physics of nuclear power and that of nuclear weapons, an illusory distinction made not only in Japan but throughout the world," he says. Mr. Lifton concludes that we have to overcome our denial and dissociation and accept that the combination of nature and human fallibility makes no technology completely safe[32].

Tokaimura nuclear power plant (Source: Penn State University)

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INTERVIEW WITH MR. HIDEYUKI BAN

Secretary General of Citizen`s Nuclear Information Center (CNIC), Japan

Mr. Hideyuki Ban:

We are so far unable to perfectly control nuclear energy

What is your opinion of nuclear energy?

Mankind has to abandon the use of nuclear technology not only for military but also for commercial purposes because of the risk of nuclear war, severe accidents such as the one at Fukushima-Daiichi and the insoluble radioactive waste which is the byproduct of these activities.

What do you think is the biggest risk/threat associated with nuclear?

Hereunder I will focus on the commercial use of nuclear power.

- It can cause an accumulation of radionuclides in our environment. A massive amount of radioactive materials were released by the Chernobyl and Fukushima accidents. There remains a potential risk for a severe accident in any nuclear power plant in the world.
- Some radioactive materials such as tritium and iodine are released during the daily operation of a nuclear power plant.
- Radioactive materials will leak out from disposed radioactive wastes. The accumulation of radioactive materials will bring negative influence to our health.

Regarding the risk of a severe accident, it is unexpectedly high. Based on our experience and the calculations of a subcommittee of the Japan Atomic Energy Commission in 2012, it is 2.1×10^{-3} accidents per year for Japan. I do not think the risk can be as low as some experts insist: about 1×10^{-7} accidents per year. This is because experts have so far hardly come to understand very few details of the Fukushima accident through the little amount of data obtained by robots. No one can enter into the containment vessel due to the extremely high radiation levels. This means that few lessons for the design-basis of nuclear plants are reflected in the new regulations.

The successor of the Japan Atomic Energy Commission, the reformed Nuclear Regulation Authority (NRA), at last adopted counter-measures against phases of severe accidents, which is the fourth stage of the defense-in-depth principles, in its revised regulations (but not for emergency preparedness, the fifth stage of the defense-in-depth regulations). This means that Japan's regulations have been brought closer to the world level.

What is nuclear energy's biggest advantage?

Nuclear energy's biggest advantage is its high energy density. But we are so far unable to perfectly control nuclear energy.

Do you think nuclear energy can contribute to fight against climate change?

No, I don't. I see this as a political insistence for supporting nuclear power. Even if nuclear power does not theoretically emit carbon dioxide during its operation phase, statistical data shows that increasing nuclear power and increasing CO_2 emission are in direct proportion in Japan. The data also shows that during the so-called Oil Shock of the 1970s, carbon dioxide emissions were stable. From this evidence I conclude that only energy savings and efficiency can contribute to a reduction of carbon dioxide emissions.

Utilities say they use nuclear power because of national policy and yet cannot maintain nuclear power without support by the Government. On the other hand, they use a lot of coal thermal power because of its lower cost. This is a problem of commercial activities and business, not an issue of theory.

The good period for nuclear power in Japan finished with the Fukushima accident. Now we see the decline of nuclear

To what extent do you think nuclear technology can be safe?

The state-of-the-art technology will make nuclear power safer if it is free in terms of cost. However, nuclear power cannot be free in an economically competitive society. For example, utilities prioritize the lifetime extension of old nuclear plants due to economics.

What do you think is the best way to dispose of nuclear waste?

Domestic geological disposal (DGD) is the final solution. I do not accept the current plan of DGD because it is going too fast and I have questions on some safety issues of the plan. I prefer promoting research and development in a deep borehole-style, because of the possibility to have more stable isolation and address the non-proliferation problem. The most difficult problem is acceptance by residents.

It will take several decades to reach an agreement for a final repository. During the procedure, nuclear waste should be stored safely in interim storage facilities. Negotiations with the governor of Aomori prefecture, where the interim storage and reprocessing facilities are located, on the topic of storing vitrified waste beyond 50 years is necessary. Also, a negotiation with local governors for interim on-site storage of spent fuel is needed.

Is there any other message you would like to share about the peaceful use of nuclear technology?

The good period for nuclear power in Japan finished with the Fukushima accident. Now we see the decline of nuclear. In this situation, safe decommissioning and safe dismantling have become more important. The problem is how to maintain this as a motivation for future activities.

The geopolitical risk of nuclear technology becomes increasingly higher nowadays. As a result, I think the boundary between military and peaceful uses of nuclear technology is blurred even though many nuclear experts endeavour to keep it strictly peaceful. If governments change their current policy to develop a nuclear warhead, can the experts stand against it?

INTERVIEW WITH JAN HAVERKAMP

Expert consultant on nuclear energy and energy policy for Greenpeace Central and Eastern Europe

Jan Haverkamp:

Closed fuel cycle is a fairy tale

What is your opinion of nuclear as an energy source?

In principle, I am not against any technology, nuclear or any other. However, after 30 years of working with nuclear energy, I have noticed that there are too many questions left unanswered to make this technology acceptable. This can be seen on the level of competition – there is a reason why nuclear power is so expensive at the moment. The reason is that there are a large set of drawbacks to the technology.

One issue is that of non-proliferation of nuclear weapons. The forecast by the Nuclear Energy Agency of the OECD of quadrupling nuclear energy capacity is a nightmare scenario for me. I know the complexities of trying to get a grip on the case of nuclear technology in Iran and North Korea. I have seen the problems with Pakistan and India. I also know how Israel, South Africa, Brazil, Argentina, Sweden have been able to wiggle out of International Atomic Energy Agency (IAEA) regulations for long periods of time. People that underestimate the proliferation problem are simply irresponsible.

There is also the drawback of safety. The fact that nuclear power stations are so expensive nowadays is because the industry acknowledges the issues related to safety and has done everything it is willing to do to try to reduce the risk. Despite these efforts, qualitatively speaking the risk remains and due to this the technology is being priced out of the market. This risk derives from the idea that every time you have a strong concentration of toxic substances, be it radioactive or other types of toxicity, you have to be certain that they are not released into the environment.

Radioactive substances are not different and whatever engineering solution you wrap these substances in, it remains impossible to guarantee that they remain inside this dynamic system called a power plant. One reason for this is because dynamic systems – ones that have interaction with the environment – are prone to human activity and therefore to human error. Human activity can also be active attacks and for me, the case of the Krško nuclear power station in Slovenia during the war in 1991 is an eye-opener. In the summer of 1991, Krško found itself in an area of military operations and was threatened by an attack by fighter jets. This made people aware that humans can be really stupid. The fact that Hungary sent a load of spent fuel by train through Ukraine in August 2014 does not give me the impression such issues are taken seriously. In a war situation, it is difficult to protect a nuclear installation and bunker buster weapons can pierce the containment of any reactor or container.

The conclusions of the German Ethics Commission on a safe energy future adopted after the Fukushima-Daiichi disaster speak clearly – if you have a viable alternative to generate clean energy, you have the moral obligation to use that alternative. So, for me it is a moral obligation to phase out nuclear energy.

Do you think nuclear power technology can be safe?

Even if we go beyond the issue of technical safety, there is always the threat of malevolent attack or sabotage. Every time a company comes up with a new design, we at Greenpeace assess it for a malevolent attack and it always fails. Not every threat can be excluded – you can reduce risks to levels that, at least on paper, look interesting.

After 30 years of working with nuclear energy, I have noticed that there are too many questions left unanswered

However, designers can never take all variables into account. Take the Fukushima-Daiichi nuclear power station in Japan for example – the sea wall was not sufficient to stop the incoming tsunami. At the Temelín nuclear station in the Czech Republic there was an unauthorized repair on faulty welding in the primary circuit, which was never documented and so does not appear on record anywhere. Every nuclear power station has a few issues which are not recorded in the system. There is always a risk and people need to be aware of that.

In addition, take into account that nuclear stations need uranium fuel. If you take a look at uranium mining and where it takes place, you will immediately recognize that it causes the same amount of environmental damage as open-cast mining for lignite or copper mining in some places of the world. The uranium mining industry is a destructive industry and thorium mining will not be any better. But also fuel production, reprocessing and waste management need to be taken into account. The entire fuel chain is a chain of unacceptable emissions and risks.

Every nuclear power station has a few issues which are not recorded in the system

What do you think is the biggest risk/threat associated with nuclear energy production?

For me, the nuclear waste issue is a very big problem. To illustrate this, I would like to point out that I worked on the Czech Republic's nuclear waste programme and the first time that the target date of 2065 began circulating for the first final storage in the country, I calculated the age of my son at that time. He would be 73 years old. For me this is a problem because this is two generations away from me and with a lot of uncertainties included.

There is a lot of discussion nowadays about interim storage of spent nuclear fuel. Look at Fukushima unit 4 – I am happy that the fuel has been removed from the fuel pool and put into interim storage. But is this sufficiently safe? And we still have three pools which are half-full with fuel at Fukushima. We have hundreds of stations all over the world whose fuel pools are also half-full with spent fuel and whose interim storage wouldn't survive terrorist attack.

What do you think about the technical side for the management of nuclear waste?

Nuclear waste is problematic. We are looking for some technical solutions, but they are having their difficulties and challenges. I do not think that engineering can solve everything – I think there are some things which are beyond our possibilities for resolution – think about the dilemma of human interference, of retrievability. I do not know whether deep geological disposal will finally make it into commercial operation. It is a chance, but we cannot be certain. I am very upset by the fact that there are no other options being seriously investigated any longer. The nuclear waste issue is a problem that has been on the agenda for over 70 years. I think that after so much time we should be grown up about it and say that this is a problem which we should take seriously and not dismiss as "technically solved, only political" when that is clearly not the case.

We have to take into account that there is no such thing as a closed fuel cycle – it is a fairy tale. Even if we would get Generation IV reactors running for an affordable cost with fewer problems associated with previous generation designs, it is still not a completely closed fuel cycle. The amount of the problem may be

reduced per kWh, but the total volume continues to grow and the qualitative problem remains on the table. We will still have waste with a lifetime of over 100 years that we will have to keep it out of the environment. Even 100 years is already a difficult horizon to plan for. We can at least talk to the people who will be alive at that time, even though with a bit of trouble. If you think back 100 years and remember that we had two World Wars during that time, you start to realise the gravity of the problem. Anything beyond that horizon is crystal ball gazing.

The question is whether we can develop deep geological disposal. The idea behind this technology is to keep the radiotoxic material out of the way for hundreds of thousands of years. I am skeptical about this. Look at the Onkalo project in Finland for example – it depends on the Swedish system for containers to store the waste in. The development of this system is stuck and it is standing still. If we do not resolve the problem with the container system, then having granite rock and humid surroundings for the containers is no longer optimal.

The issues of storing nuclear waste in salt formations can be seen at the Asse II and Morsleben former salt mines in Germany which were used as a deep geological repository for radioactive waste. I know it is not an optimal example, but it has taught us certain lessons about types of underground and what they

We have to take into account that there is no such thing as a closed fuel cycle – it is a fairy tale.

mean for a storage facility and that the incursion of water in such a facility is an important factor; or that the plasticity may be a liability rather than an asset. I cannot predict where all of these lessons will lead us, no-one can.

What do you think of the Yucca Mountain project in the US?

This is a case where nuclear proponents often say that the abandonment of the site was just a political decision. It was a political decision but with major geological research to back it up – it is simply not a suitable site.

This does not mean that I do not want to go forward with deep geological disposal research. My fear is, however, that it might prove a no-go. There are alternative directions to investigate – very deep boreholes, dry geological storage and 100 percent engineered solutions for example. I have expressed my skepticism about the 100 percent safe reactor and I have my reservations about such engineered solutions but we still need to take such ideas into consideration. If deep geological disposal does not work, we need a viable Plan B.

I think the biggest problem with finding a solution – even if it is the least-worst solution – is that a lot of research has been stopped due to lack of financing. This cannot be justified. From a commercial and financial point of view, I can understand why this happens, but this is a cost which is inherent to nuclear power. This is the consequence of concentrating an amount of a toxic substance and the need to store it safely.

As Greenpeace, we think that a solution has to be found. However, we also think that it would help a lot if we 'close the tap' on the production of nuclear

waste. We need to stop increasing the problem. The industry's argument that once you have a final solution, it will no longer matter how much waste is produced is invalid. And anyway – we are not there yet. We do not have a solution in sight. The industry should be honest and accept that there is no repository that will be operational within the next 20 years. That question remains on the agenda and I think it is better to prevent the problem rather than have to steadily expand the end-of-pipe risk reduction.

It would help a lot if we 'close the tap' on the production of nuclear waste. We need to stop increasing the problem

What is your opinion about the development of Generation IV reactors?

The interesting point is that Generation I and II reactors had development cycles which lasted 20 to 30 years from first design to first operational large-scale model. We are now working on Generation IV reactors, the designs for which were on the table 30 to 40 years ago. They still do not exist in commercial operation. I do not believe that we can achieve what is claimed with this technology – I am very skeptical about it.

The 600 megawatt (MW) test reactor at Beloyarsk in Russia has its glitches regularly and I hope people have learned from that. The 800 MW unit which recently achieved first criticality likely will show improvements because of this learning curve. But they are still test reactors.

The use of sodium is complicated. We have this problem of keeping the radioactivity contained within the plant because the concentrated radioactivity is a form of toxic material. In order to deal with that, they have encased it in another toxic substance – sodium in liquid form, which is highly reactive and needs to be contained as well. That is an extra engineering challenge. So, why would we go further and further in complexity if there is no reason to do so, if clean and safe alternatives exist?

It is also difficult to judge the Russian Generation IV reactor development programme because the transparency around it is, to say the least, sub-optimal. It is very difficult to find out how successful it really is and whether it is actually better than the experiences the French had with the Phenix and Superphenix test reactors.

What does the future of energy generation look like?

For the future of energy generation, you have to take into account that nuclear power does not have only one problem and if you deal with it, then everything is going to be fine. You have to remember the issues of cost, proliferation, risk, security, waste, etc. The conclusion is then very easy – why do we not use technologies which have been proven, are on the market and are a lot easier to expand from an engineering point of view? Everything we see the nuclear industry doing is a fight to maintain a niche in the market which is being overtaken by energy efficiency measures and renewable energy sources. The future of the generation market is 100% renewables in 2050, at least for Europe.

Do you think nuclear energy can contribute to the fight against climate change?

If we talk about climate change and reducing carbon dioxide emissions starting this year and we calculate what effect nuclear power could have, we obtain an interesting result. At Greenpeace, we did this estimation 14 years ago for the first time. We decided to park for the exercise the issues of nuclear waste and proliferation and analysed the benefits it could have in the fight against climate change.

Nuclear power does not have only one problem and if you deal with it, then everything is going to be fine

Our findings were the same as what the Organisation for Economic Cooperation and Development (OECD) discovered eight years ago. Technologically, it is impossible to go beyond quadrupling the existing nuclear capacity until 2050. If we do that and compare it to the business-as-usual scenario where we only take the already politically adopted action, the result is a five percent reduction in greenhouse gas emissions.

This means a more qualitative discussion of whether we want to take these risks with nuclear energy for such a small achievement when the total challenge is so much bigger. We need to reduce by about 50 percent and five percent is marginal. Greenpeace's Energy [R]evolution Scenarios and others have shown we can face the challenges without nuclear – and faster and cheaper. For me, nuclear is not a solution – it only diverts our attention and investment capacity. Even so, one should not underestimate the amount of development that renewable energy still needs but the development and learning curves are completely different from those of Generation IV, or even Generation III+, nuclear reactors.

What is the biggest advantage of nuclear power?

Nuclear power is a complex Rubik's cube – that should make you think. Many people from the industry accuse me of not seeing anything positive about nuclear. I do not see anything positive or negative in any technology in particular – it is the technology itself which interests me. Still, I cannot think of any reason at this moment to continue developing nuclear technology for power generation. In the last five years I have also come to change my opinion about nuclear medical research – cyclotrons and linear accelerators are currently producing medical isotopes in a cheaper and less risky way.

I think nuclear reactor technology is like coal fired steam engines technology – it is moving out of sight. That does not make me against steam engines – I like them. But neither steam nor nuclear are the technologies we need today.

I think nuclear reactor technology is like coal fired steam engines technology – it is moving out of sight

ECONOMIC ARGUMENTS AGAINST NUCLEAR POWER

Environmental and anti-nuclear movements have many arguments against the use and promotion of nuclear energy. One of the most wide-spread arguments is that nuclear energy is expensive and not economically viable. This chapter examines the arguments put forward regarding the economics of nuclear energy.

a. Economic aspects of nuclear plants[33]

Firstly, a general overview of costs associated with nuclear energy is needed in order to understand the arguments used by environmental groups.

There are four main elements to take into account when calculating the total cost of a nuclear power plant:

- **Investment cost**: the capital required for the construction of the plant;
- **Operation and maintenance costs**: the costs related to the operation of the power plant;
- **Fuel costs**: front-end and back-end fuel-related costs (fuel assembly production, transport, treatment, storage and disposal of residual waste);
- **Decommissioning costs:** the costs related to a decommissioning fund.

These are known as the *private costs* for the power station. As a part of the final cost profile, they occupy the following ranges:

- Investment: **60% to 85%;**
- Operation and maintenance: **10% to 25%;**
- Fuel: **7% to 15%;**
- Decommissioning: **negligible (up to 1%).**

The most important element for the final cost of a nuclear plant is the *investment* or so-called *capital cost.*

The *capital cost* depends on the type of investor in the project. Typically, **public investors** (governments or government-owned enterprises*) have access to cheap capital because they can borrow money through government bond issued at interest rates typically lower than those applied to financial loans for private investors. **Private investors** typically finance a project through a combination of debt and equity. When they operate in a regulated market (some states in the US for example) there is relatively little risk for the investment, which keeps the interest rates down. If they operate in a liberalised market such as the EU, they have to deal with a high level of uncertainty, which results in high interest rates calculated depending on the credit rating of the company and the type of project**.

Investment cost

- **The total investment cost of a nuclear power plant** equals the overnight construction cost plus interest during construction.
- **Overnight construction cost** equals owner's costs plus engineering, procurement and construction costs plus contingency provision. The overnight construction cost is so-called because it is calculated using the cost as if the full amount was spent 'overnight', or at one specific moment in time. This excludes interest on the capital during the period of construction.
- **Owner's costs** are difficult to determine exactly, but they include elements such as general administration, spare parts, site selection and land acquisition, taxes, and preliminary feasibility studies.
- **Engineering, procurement and construction** costs are related to site preparation, materials, equipment, manpower aspects, as well as the construction, engineering and supervision services and licensing fees.
- **Interest during construction** is the so-called *financing cost* and refers to the interest paid on debt during the period of construction as well as the rate of return to equity investors (for private investments).

Operation and maintenance costs

Usually, operation and maintenance costs include a fixed and variable element. Different countries have different methods of calculating these costs because they include different aspects. For example, in some countries the fuel costs are included in the operation costs, while in others they are not. Therefore, for any general overview, these costs can have a large margin of uncertainty.

Fuel costs

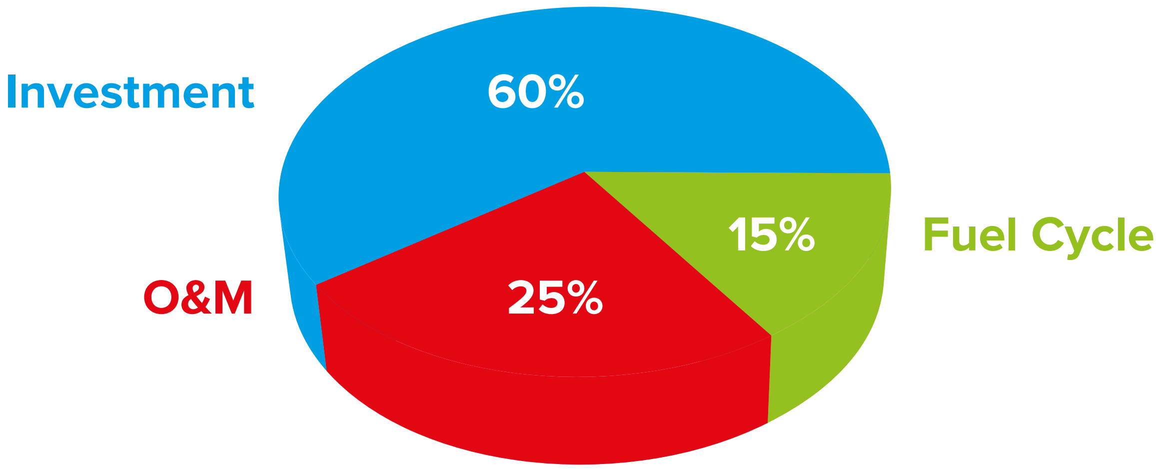
Fuel costs are divided into two: front-end and back-end. The front-end cost is related to actions from the mining of uranium to the loading of the fuel assemblies. The back-end is related to the unloading of the assemblies, intermediate storage, transport, treatment and long-term storage of the residuals. It is estimated that between 7% and 15% of the electricity generation cost of nuclear energy is related to fuel costs.

Research shows that the costs of a fuel cycle where used fuel assemblies are not recycled and one where they are reprocessed and reused are roughly the same. This is because the extra reprocessing cost is regained from a lower price for the front-end supply, since about half of the front-end cost is related to the mining and supply of uranium. However, the fuel cycle where reprocessing is

* Examples of government owned enterprises in Europe who could invest in new nuclear power generation: Vattenfall (Sweden), Electricité de France (France).

** Note that the example of Finland – where large power consumers act as co-investors – is an individual and special case. For example, Fennovoima, which is planning to build the Hanhikivi-1 nuclear station, is composed of 46 companies, which creates a set of circumstances that bring interest rates down.

Cost Structure of Nuclear Electricity Generation (OECD/NEA Nuclear Energy Outlook 2008)



used benefits from not having to store used fuel assemblies and address the issue of nuclear waste.

Factors having an impact on the cost of electricity production

- **Load factor** has been identified as one of the most important factors because it determines how much electricity is being produced by the plant in comparison with the amount of electricity it would produce at its full power when online permanently. A decrease in the load factor leads to less electricity production resulting in less revenue. A typical load factor for a nuclear unit is 85%.
- **Duration of construction** is important for the levelised cost because a prolonged period of construction means an investor would have to pay interest for longer and the period before revenue is generated from the sale of electricity is increased. A typical construction time for a single nuclear reactor unit is five years and for a twin-unit nuclear plant it is six years.
- **Discount rate** is the so-called *opportunity cost of capital*. It refers to the expected rate of return foregone by bypassing other potential investments. In other words, it is the rate of return investors could potentially earn in financial markets. This includes the value that the capital would have at a moment in time in the future if it were to receive interest, as well as accounting for inflation. The discount rate provides justification for investors to provide capital for a project by establishing how much their capital will be worth once the project is completed.

b. Economic Arguments Against Nuclear

According to environmental and anti-nuclear groups' reports on the economics of nuclear, there are two main arguments against the general determinants of nuclear economics – unreliable data for cost prediction and the lack of economies of scale. There are also several more specific arguments against the economic aspects of nuclear plants which will be presented below.

Unreliable Data & Cost Prediction

Environmentalists say that **data on construction and operation costs is unreliable**. A 2005 report by Heinrich Böll Stiftung, a green political foundation based in Germany, says construction cost forecasts should be "treated with scepticism". Forecasts have been "notoriously inaccurate" and there has been a frequent "underestimation" of actual costs. The report argues that predictions of future costs take past costs as a basis but most utilities are not required to publish properly audited reports on construction costs. Therefore, no sound basis for cost predictions exists[34].

The report also says prices quoted by industry members who have a vested interest in the technology (including pro-nuclear utilities and vendors) "clearly must be viewed with scepticism". Costs quoted by international organisations (such as the OECD/NEA) should also be "treated with care" because the data is generally provided by national governments "who may have their own reasons to show nuclear power in a good light"[35].

Environmentalists argue that any price for a nuclear plant quoted as being on 'turnkey' terms should be "regarded with considerable scepticism," according to the Heinrich Böll Stiftung report, a position which is supported by Greenpeace[36]. Historically, four major US nuclear vendors sold a total of 12 plants under contracts which were with 'turnkey' terms – at an agreed price that the vendor guarantees will not increase. Basically, under such contracts, the vendor would have to bear any additional cost incurred for any reason. The four US vendors lost "massive amounts of money" because they were unable to control costs. The report suggests that although some components or construction operations could be sub-contracted under contracts with 'turnkey' terms, a full nuclear plant should not[37].

'Turnkey' contracts: The case of Olkiluoto-3

It has been reported that the **Olkiluoto-3** nuclear power unit was agreed to between buyer TVO and vendor Areva-Siemens under 'turnkey' conditions. Greenpeace says in a report published in 2007 that the contract even included provisions for fines to be charged to the vendor if the plant

Olkiluoto-3 nuclear reactor in Finland (Source: TVO)

was delayed beyond the 48-month construction time. The overall project cost was estimated at €3 billion and first criticality was scheduled for 2009[38].

In 2006, the Finnish nuclear regulator published a report on delays at the Olkiluoto-3 construction site. The report said: "the time and amount of work needed for the detailed design of the unit was clearly underestimated when the overall schedule was agreed on".

In 2007, Areva's representative for Olkiluoto-3, Philippe Knoche, said: *"Areva-Siemens cannot accept 100% compensation responsibility, because the project is one of vast co-operation. The building site is joint so we absolutely deny 100% compensation principle"*[39].

In October 2014, the Finnish utility TVO updated a claim it had filed for arbitration proceedings at the International Chamber of Commerce, for Areva to cover losses amounting to €2.3 billion. The claim is based on estimated costs and losses up to the end of 2018, which is when commercial operation is scheduled to start at Olkiluoto-3, around nine years later than originally planned[40]. Later that same month, Areva updated its own claim for TVO to pay €3.5 billion for "additional work, disruption and prolongation of the project"[41]. Therefore, according to this latest information, the cost of the Olkiluoto-3 project amounts to between €5.3 billion and €6.5 billion.

'BOO contracts': The case of Belene

The Russian state nuclear corporation Rosatom has a special contract it offers to buyers of its nuclear power plant designs called BOO – Build, Own, Operate. Under this type of contract, the vendor would be responsible for the construction, ownership and operation of the nuclear station. After negotiating, but never signing, a construction contract with the Bulgarian government, Rosatom proposed a BOO arrangement for the Belene nuclear power plant. This contract included the construction of a twin-unit plant on the Belene site in Bulgaria[42].

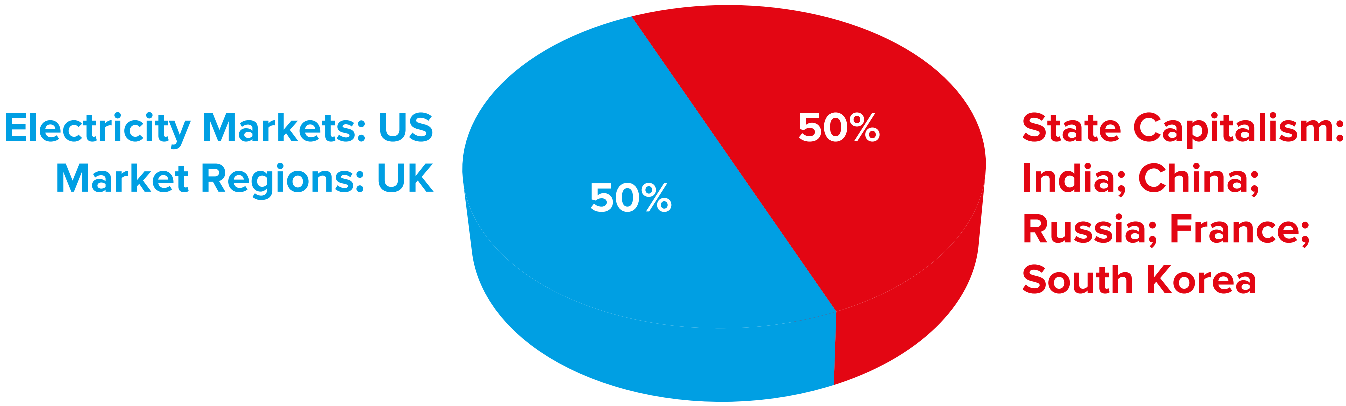
When the Socialist Party lost power to the right wing Citizens for European Development of Bulgaria (GERB) in 2009, the new government set out policy measures to restrict Rosatom's influence over the project. The GERB government demanded a full cost estimate from Rosatom. It finally hired HSBC Holdings, one of the largest banking and financial services institutions in the world, to provide such a cost analysis due to its lack of trust in Rosatom to provide accurate information[43].

In January 2008, the contract price for the Belene plant quoted by Rosatom was reported to be around €4 billion. In 2010, HSBC concluded their investigation into the project and said that the total cost of the plant could actually reach €10 billion. The Bulgarian government cancelled the contract due to the large gap in the cost estimates[44]. However, Rosatom has signed a BOO contract for the construction, ownership and operation of the Akkuyu nuclear power plant in Turkey[45].

Economies of Scale

According to economic theory and experience with most technologies, after successive generations of design and construction, a learning curve is observed which brings costs down and results in improvements. This is because vendors can learn from mistakes and problems encountered during construction of a first specimen of a specific design and apply those lessons directly to the second, third etc. An OECD/NEA report from 2000 says construction of a twin-unit nuclear power station, where the second unit begins construction about a year after the first, would benefit the second unit with an approximately

The Role of Government Versus Private Investors (from Edward Kee, "Future of Nuclear Energy")



20% lower cost. However, the construction of further units of the same type would not lead to any more significant cost savings because the standardisation effect is said to be negligibly low[46].

The Heinrich Böll Stiftung report says the extent to which nuclear power has improved through time "is a moot point" but costs have clearly not fallen. Environmentalists argue that an increase in regulatory standards and the measures needed to meet those standards have pushed costs up[47]. They also argue that major vendors have received very few orders in the past two decades which has led to the closing of production lines and cut-backs on skilled workers. Due to the low level of orders, major components would have to be sub-contracted and manufactured on a one-off basis, which is usually at higher costs than in assembly-line type manufacturing[48].

Cost of Capital

Environmentalists argue that nuclear energy is not economically viable and it is too expensive[49]. The cost of capital is one of the major variables which can have an impact on the price of a nuclear power station. There are two contexts to be considered here.

First, in regulated or monopoly markets, utilities are guaranteed a full recovery of costs, making their investments very low-risk because any risk is transferred to consumers. The reported cost of capital in this situation ranges between 5% and 8%[50].

Second, in unregulated or liberalised markets, utilities are directly liable for the investments they make and cannot transfer the risk to the consumer. In this circumstance, the real cost of capital can reach 15%[51]. However, this can be brought down significantly if the government issues guarantees or provides any other state aid measure. In the European Union, such measures have to be accepted by the European Commission before they can come into force.

This point is reinforced by an International Energy Agency report entitled "World Energy Outlook Special Report 2015: Energy and Climate Change," which says that the largest share of growth in nuclear power has been in regulated markets[52]. The report says China continued to lead in new capacity, with 28 gigawatts of nuclear under construction at the end of 2014, while plants with a combined capacity of 46 GW were under construction in Russia, India, South Korea, the regulated markets of the US as well as several other countries[53].

Maintenance and Fuel Costs

In general, maintenance costs can range between 10% and 25% of the costs of a nuclear power plant, and fuel costs range between 7% and 15%. Environmentalists argue that the idea of low running costs for nuclear plants has been proven wrong because in the late 1980s and early 1990s a small number of US nuclear plants were shut down due to the cost of operating them[54]. At the time, it was calculated that the operating costs of a nuclear plant was higher than that of constructing and operating a gas-fired power plant. In the mid-1990s, significant improvements were made in the reliability (and efficiency) of nuclear plants, which brought down operation and fuel costs[55]. However, due to short- and medium-term changes in fuel prices for fossil-fuelled power plants and the lack of fuel costs for renewable energy sources, nuclear power can be more expensive to operate in some parts of the world[56].

Performance and Lifetime

Environmentalists argue that nuclear power plants are "physically inflexible" according to the Heinrich Böll Stiftung report – they cannot be started up and shut down to vary the output level[57]. However, the main concern is the planned and design performance of the plant. The report argues that planned load factors for most new plants were predicted to be 85% to 90% but in the 1980s the average was around 60%. The issue here is that the lower the load factor, the lower the revenue received for a fixed operational cost. Also, in a liberalised market, a utility which commits to deliver a certain amount of power and fails to do so is forced to find a replacement, usually at a higher cost[58].

Environmentalists do concede that there have been improvements in performance and load factors, with many plants now operating at 85% to 90%. However, they argue that performance decreases near the end of the design lifetime, which then pushes maintenance costs up should the owner decide to renovate or extend the lifetime of the plant[59].

Decommissioning Costs

According to environmentalist organisations, it is difficult to estimate the cost of decommissioning and spent fuel management because there is very little experience with these issues[60]. There are schemes in place for the build-up of funds for the decommissioning of power plants, but anti-nuclear groups argue that the projected costs could be underestimated, the funds could be lost, or the company might collapse before the plant completes its expected lifetime. For example, in the UK, the collapse of British Energy in 2002 means that a significant portion of their decommissioning costs will have to be covered by the state (i.e. by taxpayers)[61].

c. Conclusion

Environmental organisations have numerous arguments against the economics of nuclear energy and most of them are based on the *unreliability of data* or the fact that *underestimations of cost* and *overestimation of reliability* have often occurred in the past. "The economics of nuclear have always been questionable," says a Greenpeace report.

An argument seen to be in favour of nuclear energy is that it does not produce carbon dioxide. However, Greenpeace argues that in terms of economics this does not matter. The European Emissions Trading Scheme introduced a price on the generation of carbon dioxide, aimed at reducing the number of polluting power-generation technologies such as coal. While Greenpeace concedes that this may have a beneficial effect on the economics of nuclear in the medium- and long-term, they continue to take a negative stance[62]. They cite a study from the Massachusetts Institute of Technology, which concludes that carbon prices in excess of $100 (around €90 at current exchange rates) per tonne of carbon would be necessary for nuclear power plants to break even. The price of carbon in the beginning of 2015 in the EU was around €5[63].

Environmentalists also argue that nuclear energy cannot survive without subsidies. In 2005, the US Energy Policy Act outlined subsidies that could amount to between $2 and $20 per megawatt-hour for new nuclear power plant construction. Greenpeace argues that without these subsidies, "it is unlikely that any US company would be considering investing in a new nuclear plant"[64].

In 1999, Vaclav Havel, President of the Czech Republic, said: "*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 the few utilities now building nuclear plants and by the nuclear industry generally [...] I have been lied to nine times. I do not know why I should believe them in the 10th case*"[65].

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THE SAFETY OF NUCLEAR INSTALLATIONS

One of the first questions asked regarding nuclear technology is: "Is it safe?". The position of environmental and anti-nuclear groups is that "nuclear is inherently dangerous". No matter how much money is spent on nuclear safety or how many safety checks are performed by experts and regulatory authorities, environmental groups continue to argue that nuclear energy should be discontinued due to the danger that it poses to the population at large and the environment. This chapter introduces some of the concepts used within the nuclear industry for the safety of nuclear installations and then examines the arguments put forward by environmentalists against the use of nuclear power due to its lack of safety.

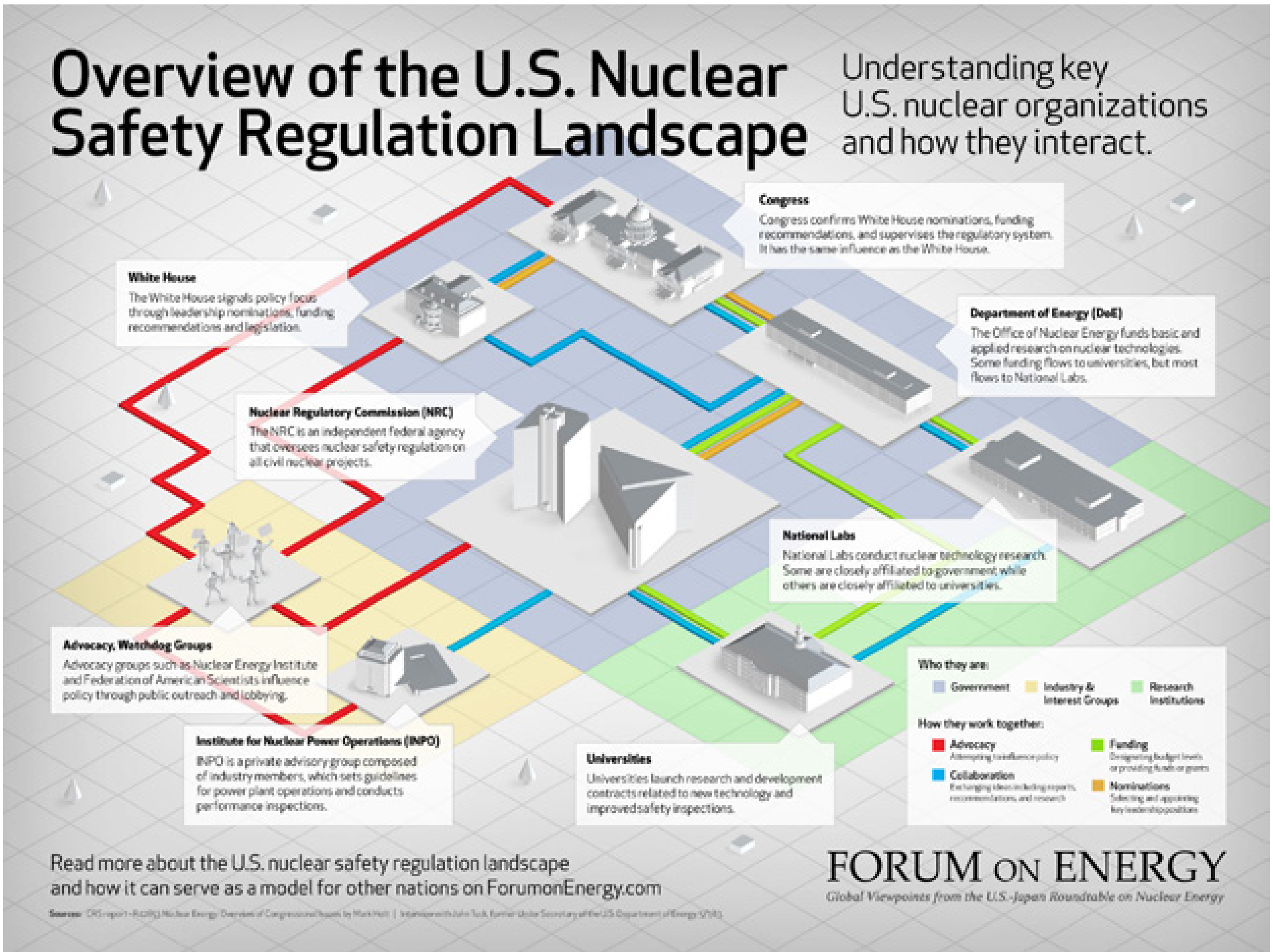
a. Defense-in-depth

The World Nuclear Association (WNA) argues that from the very beginning of development of nuclear energy technology, there has been a "strong awareness of the potential hazard of both nuclear criticality and release of radioactive materials from generating electricity with nuclear power". WNA says that there have been three major accidents in the history of civil nuclear power – Three Mile Island, Chernobyl and Fukushima – which have occurred over 15,000 cumulative reactor-years of commercial nuclear power operation. This is evidence that "nuclear power is safe" and, in addition, the risk of nuclear accidents is "low and declining"[66].

WNA also says to achieve optimum safety, nuclear plants in the western world operate using a 'defence-in-depth' approach, with multiple safety systems supplementing the natural features of the reactor core. Key aspects of the approach are[67]:

- high-quality design and construction,
- equipment which prevents operational disturbances or human failures and errors developing into problems,
- comprehensive monitoring and regular testing to detect equipment or operator failures,
- redundant and diverse systems to control damage to the fuel and prevent significant radioactive releases,
- provisions to confine the effects of severe fuel damage (or any other problem) to the plant itself.

A 2009 US Department of Energy (DOE) Human Performance Improvement Handbook notes that "The aviation industry, medicine, the commercial nuclear power industry, the US Navy, DOE and its contractors, and other high-risk, technologically complex industries have adopted human performance principles, concepts, and practices to consciously reduce human error and bolster defenses in order to reduce accidents and mishaps"[68]. As such, the nuclear industry's focus on safety becomes evident.



UNDERSTANDING THE ANTI-NUCLEAR ENVIRONMENTAL MOVEMENT

Krško nuclear power plant in Slovenia (Source: Krško)

Also in 2007, the US Nuclear Regulatory Commission (NRC) launched a programme to assess the possible consequences of a serious reactor accident. The State-of-the-Art Reactor Consequences Analysis (SOARCA) showed that a severe accident at a US nuclear power plant (PWR or BWR) would not be likely to cause any immediate deaths, and the risks of fatal cancers would be vastly less than the general risks of cancer. The principal conclusion is that existing resources and procedures can stop an accident, slow it down or reduce its impact before it can affect the public[69]. Even if accidents proceed without such mitigation they take much longer to happen and release much less radioactive material than earlier analyses suggested.

In 2011, in the aftermath of the Fukushima accident, the European Union decided to conduct comprehensive and transparent nuclear risk and safety assessments, or "stress-tests"[70]. The Western European Nuclear Regulators' Association (WENRA), a network of Chief Regulators of EU countries with nuclear power plants, proposed these in response to a call from the European Council, and developed specifications. The EU process was completed at the end of September 2012, with the EU Energy Commissioner announcing that the stress tests had showed that the safety of European power reactors was generally satisfactory[71].

With all of this in mind, why do environmentalists keep on challenging nuclear technology on its safety record? The following sections will examine several arguments put forward by environmental organisations in this respect.

b. General Arguments of 'Too Little Safety'

The anti-nuclear publication *Nuclear Monitor* argued in October 2014 that nuclear energy has too little safety. "The odds of a major nuclear disaster are said to be on the order of 1 in 10,000 reactor-years, but experience shows accidents occur even more frequently," it says[72]. Furthermore, over 250,000 people were displaced because of the Chernobyl accident and over 150,000 people due to the Fukushima accident, the publication says[73].

In addition, an expert from Fukushima university said in an interview that:

"*the government encountered a phenomenon it labelled "disaster-related death". This is the number of people who died from physical and mental fatigue, and those who were driven to suicide, related to the disaster, but not as a direct result of it. In Fukushima prefecture, the number of such "disaster-related deaths" was 1,656, as of March 2014. To put this into perspective, the number of people in Fukushima who died as a direct result of the tsunami and earthquake – in other words, those who were killed in the initial calamity – has been put at 1,607. So there have been more indirect deaths than direct deaths. In Fukushima, 80 percent of the deaths categorised as "disaster-related deaths" were people living in 11 municipalities in the evacuated areas*"[74].

Greenpeace argues on its website that the nuclear industry has demonstrated that safety and nuclear power is a contradiction in terms. "Safe reactors are a myth," Greenpeace says, and adds that an accident can occur in any nuclear reactor, causing the release of large quantities of deadly radiation into the environment[75]. The aging of nuclear reactors, in particular the effect of prolonged operation on materials and large components, is endemic throughout the world's nuclear industry. At the same time nuclear operators are continually trying to reduce costs due to both greater competition in the electricity market and the need to meet shareholder expectations[76].

Greenpeace provides several examples of industrial nuclear incidents to highlight the danger which the technology poses[77]:

- In 1999 in Japan, two workers received lethal doses of radiation at the Tokai-mura nuclear fuel plant; later, it was revealed that safety data and inspections had been manipulated at many of the country's reactors to avoid 'expensive' repairs and lengthy closure;
- In 2002 in the US, a catastrophic accident was "only just avoided" at the David-Besse reactor, when it was discovered that corrosion had come very close to penetrating the reactor pressure vessel. After two-years of repairs were conducted, the reactor received a licence to operate until 2017.
- In 2003 in France, torrential rainfall caused the emergency shutdown of Cruas-3 and -4 due to flood-affected damage.
- In 2004 in Japan, a steam explosion at the Mihama reactor killed five workers.

Greenpeace also argues that nuclear plants are highly vulnerable to deliberate acts of sabotage and terrorist attack. They quote the International Atomic Energy Agency (IAEA), which admits that "Most nuclear power plants were built during the 1960s and 1970s, and like the World Trade Center, they were designed to withstand only accidental impacts from the small 'Cessna' type sports aircraft. If you postulate the risk of a jumbo jet full of fuel, it is clear that their design was not conceived to withstand such an impact."[78]

Perhaps one of the worst cases where the safety and security of a nuclear plant were threatened was in the summer of 1991 when the single-unit Krško nuclear power plant in Slovenia found itself in an area of military operations[79]. According to a publication in *Nuclear Technology*, "this was probably the first commercial nuclear power plant to have been threatened by an attack by fighter jets"[80]. A number of never-before-asked questions had to be answered by the operating staff and supporting organizations. The best operating mode to which the plant should be brought before the attack is cold shutdown, and radiological consequences to the environment after the spent fuel is damaged and the water in the pit is lost are not very high[81].

Similar concerns are being raised with the political crisis and military actions in Ukraine in 2014 and 2015, with the South Ukraine and Zaporozhye nuclear power stations located close to the conflict zone. Operator Energoatom said in its 2014 annual report that it has carried out vulnerability assessments and implemented communications strategies for on-site staff in the event of a crisis[82].

Michèle Rivasi, a French member of the European Parliament and founder of Nuclear Transparency Watch, an environmentalist network promoting nuclear safety and transparency, commented in December 2014 that "missile attacks are common in the region [of Zaporozhye nuclear station] and could hit – voluntarily or unintentionally – a nuclear plant"[83].

Therefore, the arguments against nuclear power plants can take many forms when it comes to safety. Environmentalists argue that any reactor can, at any moment, have an accident resulting in the general devastation of the surrounding area, innumerable deaths, injuries and displaced persons, and an expensive cleanup process. If these arguments are not used, then the threat of a terrorist attack or general act of war is always present in the argumentation.

c. Institutionalised Safety and Regulatory Standards

Jim Green, an activist for Friends of the Earth, says one of the major reasons why the public remains skeptical about the safety on nuclear reactors in Japan is the re-emergence of the government/corporate collusion that was a central feature of the pre-Fukushima 'nuclear village'. The 'nuclear village' refers to a group of government officials, industries and academia notorious for being strongly pro-nuclear[84].

Junko Edahiro, chief executive of Japan for Sustainability, explained in November 2014 how he was a member of an energy committee - an advisory body for the government - charged with providing input on energy policies of Japan until 2030. The committee had 25 members, eight of whom were not in favour of nuclear power. "The new administration [of Prime Minister Shinzo Abe], however, restructured the committee, eliminating anyone against nuclear power [...] and the regulatory committee to oversee nuclear policies and operations is currently headed by a well-known nuclear proponent," Mr Edahiro said[85].

The case of the Tokyo Electric Power Company (TEPCO), the operator of the Fukushima-Daiichi nuclear power station, wanting to restart units 6 and 7 at its Kashiwazaki-Kariwa nuclear plant is also fueling anti-nuclear arguments about safety. TEPCO's plan is not being accepted by the governor of Niigata province, Hirohiko Izamuda, who says the company must address its "institutionalized lying" before it can restart the reactors. Also, government prosecutors have refused to bring charges against TEPCO officials for "negligence" which led to the Fukushima-Daiichi accident - one of the governor's demands[86].

In the case of Japan, and in many other cases such as in Austria, the pro- or anti-nuclear stance of government officials has either won them popularity or brought them down from power. Depending on the country, being pro-nuclear can be political suicide for a politician, while being anti-nuclear could muster significant support.

Jim Green also warns of safety issues with China's nuclear programme. "Numerous insiders have warned about inadequate nuclear safety and regulatory standards in China," he wrote in December 2014[87].

One such 'insider' is He Zuoxiu, a former state nuclear physicist, who said in March 2013 that a nuclear disaster in China is "highly probable"[88]. He argues that the world's 443 operational reactors (in 2013) operated for a total of 14,767 reactor-years during which time 23 accidents involving a reactor core meltdown or partial meltdown were observed. Taking into account that China plans to have 71 reactors by 2020, then the country will "most probably suffer a major accident within the next 69 years"[89].

He Zuoxiu continues to say that the "risks rocket" due to the inexperience of reactor operators and technicians in China. Using only the examples of Three Mile Island, Chernobyl and Fukushima as a reference is not enough to anticipate a possible accident at a Generation III-type reactor. The fact that China is building, and planning to build, many reactors of the Generation III type without any operational experience increases the risk of an accident, he says[90].

Such arguments by environmentalists often attempt to use mathematical or logical processes to introduce fear into the mind of their audience. At the basis of such arguments is the idea that nuclear energy production should be a 100% safe process – an unachievable goal due to the simple fact that nothing is completely safe. Risks always exist, but the anti-nuclear groups do not wish to recognize the developments in safety of nuclear power station designs.

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Kalinin nuclear power plant in Russia (Source: A.Savin, Wikimedia Commons)

In their minds, these stations are inherently unsafe, no matter what technology is used.

Furthermore, a 2011 cable released by WikiLeaks also highlighted the secrecy of bidding processes for new nuclear power plant contracts in China, the influence of government lobbying, and potential weaknesses in management and regulatory oversight, Jim Green says in the *Nuclear Monitor*[91]. A Westinghouse representative in China is quoted by the cables as saying: “the biggest potential bottleneck is human resources – coming up with enough trained personnel to build and operate all of these new plants, as well as regulate the industry”[92]. This confirms He Zuoxiu’s statements.

In addition, Greenpeace’s 2014 report *Rosatom Risks* criticizes several safety-related incidents at Russia’s nuclear power plants. The Kalinin nuclear power station’s unit 4 was a highlight of safety issues with domestic new-build reactors. The unit achieved first criticality in October 2011, and suffered 11 incidents between 15 November 2011 and 15 January 2012, according to data taken from Russia’s nuclear regulator Rostechnadzor. Issues observed in this time-period included several failures of the main circulation pumps, which ensure the circulation of coolant through the reactor core, and instances where pressure levels in the primary circuit decreased due to failures in the pressuriser[93].

Greenpeace says the worst failure at Kalinin-4 was on 26 November 2011 when a hydrogen explosion inside the unit led to a leak of possible radioactive gasses to the reactor containment building. Although the incident was reported by Rostechnadzor, the extent of the damage was not publicly disclosed. The reactor experienced five more technical failures in 2013, one of which resulted in a two-month maintenance outage. Greenpeace criticizes not only the safety record of the unit, but also the lack of transparency by the operator and regulator[94].

Greenpeace’s report also cites the construction of the second Leningrad nuclear power station’s unit 1 as an example of the lack of safety at nuclear installations even in the construction phase. In June 2011, after a visit to the site, the director-general of the Finnish nuclear safety regulator STUK commented that the construction and design of the reactors were of the highest quality. A month later, a reinforcement cage of the containment building collapsed on its concrete frame, resulting in a one-year delay for the project at a high cost, but luckily there were no casualties. STUK’s director-general left his position after his flawed review of the safety at Leningrad 2, and soon after became the vice president of Rosatom’s international sales unit Rusatom Overseas[95].

Furthermore, in March 2015, M.V. Ramana, a physicist at Princeton University, and Suvrat Raju, a physicist at India’s International Centre for Theoretical Sciences, wrote that concerns have recently been raised about India and its plan to build more nuclear reactors. “While multinational nuclear suppliers, such as G.E. and Westinghouse publicly insist that their products are extraordinarily safe, they are adamant that they will not accept any liability should an accident occur at one of their reactors,” they wrote[96]. Indeed, a major question raised by anti-nuclear activists that has not yet been answered is whether the supplier of the Fukushima-Daiichi plant (General Electric) should be held liable for the March 2011 accident[97].

The 2014 Greenpeace report *Lifetime extension of ageing nuclear power plants: Entering a new era of risk* argues that ageing reactors pose a greater risk than ones which have

The destroyed Fukushima nuclear power plant unit 3 (Source: TEPCO)

operated for less time but they remain under the same rules for insurance and liability. The report says that suppliers would most likely claim that the accident was caused by companies involved in the initial design and construction of the plant and not by the maintenance work carried out on the plant. “Even if it were possible to hold contractors and suppliers liable, victims would still face serious difficulties in proving who caused an accident,” the report says[98]. The issue of nuclear liability continues to be debated politically.

There are numerous other examples which environmental groups cite as indicative of safety issues at nuclear power stations and potential “cover-ups” by authorities and industry representatives. Plenty of failures, small accidents, preventive shutdowns and corruption cases related to low-quality material delivery create skepticism and generate attacks by anti-nuclear activists. Due to the general lack of transparency in some of the biggest pro-nuclear countries, the global reputation of nuclear energy suffers.

To exemplify this, consider the case of the Fukushima-Daiichi accident. The station suffered an earthquake and was hit by a tsunami – a scenario which it was prepared for but not to the sufficient extent. The lessons learned from the accident have produced numerous safety measures which have been implemented at nuclear stations around the world. For example, hydrogen venting systems have been installed in almost all nuclear units which did not already have them in order to avoid the build-up of hydrogen inside the containment. This will prevent an explosion such as the one that happened at unit 3 of the Fukushima station[99].

However, other measures such as the impact of a tsunami hitting a station can be seen as rather unnecessary for some stations located inland. Still, these costly studies have been conducted to fulfill regulatory requirements aimed at ensuring the safety of the station. As improbable as it may be for a station located in central France or Canada to be hit by a tsunami, the impact assessment had to be conducted[100]. These measures, as far-reaching as they are, do not dispel the anti-nuclear arguments against the safety of nuclear installations.

d. Conclusions

When considering the question of nuclear safety, there are numerous aspects which need to be covered. There are several organisations, both regional and global, which deal with improvements and promotion of nuclear safety. The World Association of Nuclear Operators (WANO), which aims to promote the exchange of operating experience and conducts peer-reviews is one example. The International Atomic Energy Agency’s (IAEA) Convention on Nuclear Safety (CNS) aims to legally commit participating States operating land-based nuclear power plants to maintain a high level of safety by setting international benchmarks to which States would subscribe.

However, the numerous international treaties, agreements and guidelines have not done much to dispel claims by anti-nuclear activists that the technology is inherently unsafe. This is mainly due to failure by the industry to maintain a high level of professionalism towards the technology they are handling. The numerous corruption cases, automatic shutdowns due to human error and accidents (both severe and not severe) do not help the industry to prove environmentalists wrong.

Overall, the safety of nuclear reactors has been questioned in numerous instances with different arguments. The main dilemma is that with a lack of transparency, the anti-nuclear movement cries out against being ill-informed on the safety of nuclear installations. On the other hand, with full transparency, the industry has not been able to explain small mistakes, which cause further questions and protests against nuclear energy. In fact, with full transparency, there has been widespread panic among the general public in the event of a non-safety related shutdown due to a lack of understanding. A study published in the *Conservation Biology* journal by Barry W. Brook and Corey J. A. Bradshaw, researchers at the University of Adelaide, recently argued that “to demand zero incidents and no waste is to ask the impossible of any energy technology”[101]. Public engagement is only one way to address these issues, but the main goal is to build trust between the industry and environmental organisations – something that may never happen.

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NUCLEAR FUEL
AND
RADIOACTIVE WASTE

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Dry cask storage of nuclear waste (Source: US Nuclear Regulatory Commission)

Nuclear waste management is one of the most highly contested issues for environmentalists and anti-nuclear activists. The waste generated by a nuclear energy reactor has to be managed in a safe and secure way to protect the population and the environment. Unlike other industrial wastes, the level of hazard of all nuclear waste - its radioactivity - diminishes with time. However, radioactive waste is often portrayed as an extremely dangerous product. This chapter examines the arguments environmentalists put forward for the total shut down of nuclear energy due to the waste generated.

a. Waste Management

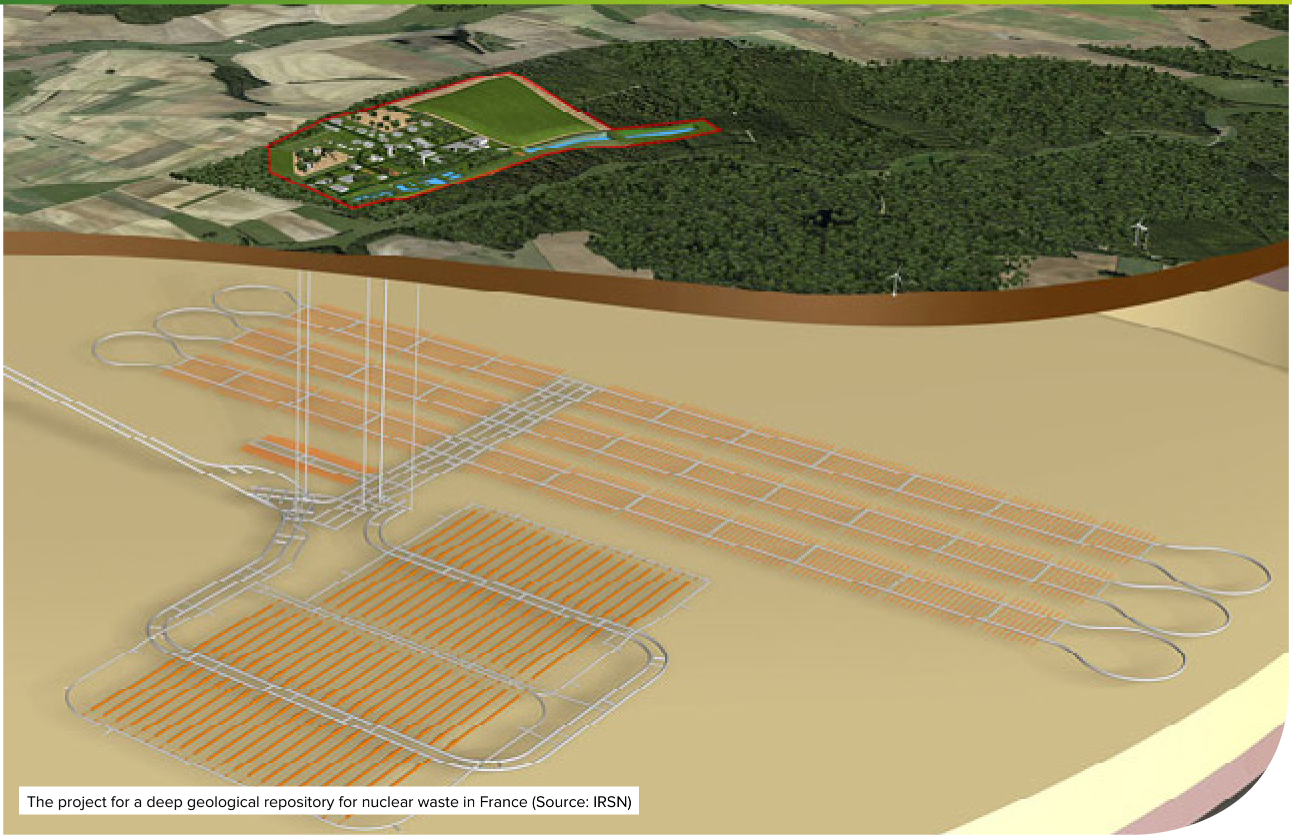
The World Nuclear Association (WNA) explains that at each stage of the fuel cycle there are proven technologies to safely dispose of the radioactive wastes generated by a reactor. For low- and intermediate-level wastes, storage facilities and reprocessing plants are implemented. For high-level wastes some countries await the accumulation of enough of it to warrant building geological repositories; others, such as the USA, have encountered political delays[102].

Environmentalists rarely distinguish between different categories of waste. Often, when they argue against the generation of nuclear waste, they refer directly to high-level waste (HLW) because it is the most dangerous and has the longest lifetime. In fact, research shows that HLW includes only the spent nuclear fuel and accounts for only about 3% of the total waste produced by a typical nuclear power station. However, it also accounts for about 95% of the radioactivity associated with nuclear waste[103].

Spent nuclear fuel first has to be stored in temporary storage ponds filled with water in order to cool down after they have been removed from the reactor core. Then, it is transferred to so-called intermediate storage for a period of about 40-50 years, after which the radioactivity of the fuel is about 0.1% of the original level. Much of the spent fuel existing today is at this stage of storage. The WNA argues that this delay means that final disposal is not urgent in any logistical sense. In fact, currently operational nuclear reactors have a lifetime of between 40 and 60 years[104]. By the time the last fuel assembly is removed from the reactor, it will have to spend a further 40 to 50 years in interim storage, justifying the lack of urgency.

According to the WNA, there are about 270,000 tonnes of used nuclear fuel in storage, much of it at reactor sites. About 90% of this is in storage ponds and the remaining 10% are in dry storage[105]. If used reactor fuel is not reprocessed, it will still contain all the highly radioactive isotopes, and then the entire fuel assembly is treated as HLW for direct disposal. However, if it is reprocessed, then the highly-radioactive fission products and transuranic elements with long-lived radioactivity are separated. The transuranics are disposed of and the fission products can be re-used for new nuclear fuel (e.g. mixed-oxide fuel or MOX)[106].

The reprocessing of spent nuclear fuel can introduce the "partially closed cycle", which has already been practiced on an industrial scale for a few decades, spent fuel is reprocessed for the extraction of uranium and plutonium, and only spent recycled fuel (MOX fuel or fuel containing recycled uranium) is stored for later disposal. The process usually involves interim storage of the spent fuel to cool it down before it is transferred to a reprocessing plant where uranium and plutonium are separated from the residual



The project for a deep geological repository for nuclear waste in France (Source: IRSN)

waste products. After separation, the re-usable components are used for fabrication of recycled fuel such as MOX, and the residual waste products are conditioned and transferred to an interim storage facility pending final disposal in a deep geological repository[107].

With a "fully closed cycle", the recycling process is repeated until the re-usable components have been completely consumed. This remains "only a long-term prospect" and is in principle only feasible with the use of Fast Neutron Reactors (FNRs)[108]. However, several countries are pushing ahead with research and development programmes for FNRs specifically because they would like to reprocess the stockpiles of spent nuclear fuel.

The following sections will examine the argument used by environmentalists regarding two proposals for a solution to nuclear waste – the deep geological repository and the use of fast neutron reactors for re-usage of recycled nuclear fuel.

b. Deep Geological Disposal

Rebecca Lunn, Professor of engineering geosciences at the University of Strathclyde, is quoted by *The Guardian* as saying: "Geological disposal of nuclear waste involves the construction of a precision-engineered facility deep below the ground into which waste canisters are carefully manoeuvred"[109]. The only operational deep geological radioactive waste repository in the world is the Waste Isolation Pilot Plant (WIPP), located in the New Mexico desert in the US. It is a site which stores long-lived intermediate-level waste left over from the US nuclear weapons programme, with more than 171,000 containers in 2013[110].

In February 2014, an accident involving a chemical reaction led to a radioactive release inside the repository and 22 workers received low-level internal radiation exposure[111]. It is believed that a unique chemical reaction caused the release[112]. Joseph Trento, an investigative journalist, quotes a former WIPP official saying: "If a canister contained a large enough amount of certain elements, there could be the threat of fire or explosion. The DOE sites that sent in the waste got careless in documenting what was being shipped in"[113].

Furthermore, environmentalists argue that safety analyses for installations such as a repository can be incorrect. The safety analysis conducted before WIPP began construction concluded that accidents such as the one in 2014 have a probability to happen once every 200,000 years. Jim Green, activist for Friends of the Earth, argues that since WIPP began operation in 1999, it is on track for over 13,000 accidents involving a release of radiation over a 200,000 year period[114].

Another issue which gave birth to an anti-nuclear argument related to the WIPP incident is based on a US Environmental Protection Agency review of air testing at the plant. Discrepancies were found in the testing and recording of results. Some records showed air samples contained no detectable levels of radiation when measurable levels were present. Such discrepancies give cause for alarm by anti-nuclear groups and add to the feelings of suspicion towards the industry[115].

Storage of radioactive waste in an underground repository in New Mexico, USA (Source: US Department of Energy)

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Vie from Yucca Mountain, Nevada, 7 June 2005 (Source: Wikipedia)

Also in the US, at the proposed site for a deep geological repository for spent nuclear fuel called Yucca Mountain, political opposition has basically ground the project to a halt. However, this is not a case of anti-nuclear politics. Rather it is a purely political maneuver. Scott Peterson, senior vice-president for communications at the Washington DC-based Nuclear Energy Institute (NEI) explained the case as follows:

"One of the reasons the project has stalled so badly is that when Barack Obama went to Nevada for his first presidential campaign in 2009, Democratic Senator Harry Reid – the then Senate majority leader – essentially extracted a promise from him that he would not proceed with the project. When Mr. Obama was elected, he shut down the programme by withdrawing its funding and the DOE has not been doing any additional work at the site itself or on the licensing process"[116].

The US Nuclear Regulatory Commission (NRC), on the other hand, continues to work on the licensing of the Yucca Mountain facility through a court order. In 2013, a US Court of Appeals ruled that the NRC had "acted improperly" when it stopped the licensing process. "Unless and until Congress authoritatively says otherwise, or there are no appropriated funds remaining, the NRC must promptly continue with the legally mandated licensing process," the Court said[117].

For the US nuclear industry, Yucca Mountain is of huge importance because it is the only repository site under consideration since 1987. The amount spent by the industry and relevant authorities involved about US$ 10 billion in site studies. "There is support from both parties in Congress," Mr. Peterson said[118]. In opposition, Nevada Senator Reid introduced a Bill to Congress in the beginning of 2015 to allow state governments to have veto power over the Yucca Mountain project. He said: "For decades the federal government wasted billions of dollars attempting to recklessly move America's deadly high-level nuclear waste to a dump at Yucca Mountain, despite the overwhelming objections of Nevadans"[119]. Public opinion polling on Yucca Mountain has always been difficult to carry out and as a result polls from both the pro- and anti-camp are often distorted by the way the questions are formulated.

Other deep-geological disposal repositories being considered in France, the UK and Finland are still in the early stages of development and have faced significant political and public opposition. In the UK, the industry spent a lot of time informing the local population what hosting a storage facility would mean before they asked the local councils for permission to begin exploration.

In Germany, where a government commission is in charge of selecting a suitable site for a deep geological repository, the process has also stalled. Ralf Güldner, president of the German Atomic Forum, said in an interview:

"The industry has contributed €1.6 billion for the exploration of the Gorleben salt dome since 1979. The utilities have prepared their spent fuel and other radioactive waste, placed it in dry storage near the Gorleben site and made it ready for permanent disposal in that facility. This is the process on which the industry has based its analyses and cost estimates for final disposal. However, the government keeps changing the process and this might result in the postponement of the whole procedure by up to 50 years."[120]

Therefore, there are numerous political and economic problems in countries where nuclear reactors were built in the 1960s and '70s, where nuclear waste is reaching its time of disposal. The only operational storage facility in the US has encountered an accident which will keep it inoperative indefinitely (the latest estimates are until the Spring of 2016)[121]. In other countries, the political process for developing a spent nuclear fuel repository has either stalled or met with public opposition.

In China, where the China National Nuclear Corporation (CNNC) is building a reprocessing plant, security problems

The Superphénix nuclear reactor at Creys-Malville, France, in 2007 (Source: Yann Forget)

have been identified. In 2010, a hot test of the facility was conducted and Hui Zhang, a physicist at Harvard University, says many problems, including safety and security issues, were encountered and identified. "These included both a very high amount of waste produced and a very high measure of material unaccounted for," he said[122].

Mr. Zhang also said: "China has no convincing rationale for rushing to build commercial-scale reprocessing facilities or plutonium breeder reactors in the next couple of decades, and a move toward breeders and reprocessing would be a move away from more secure consolidation of nuclear materials"[123].

c. Generation IV Fast Neutron Reactors

A study published in the *Conservation Biology* journal by Barry W. Brook and Corey J. A. Bradshaw, researchers at the University of Adelaide, recently argued that integral fast reactor technology can potentially use 99% of the nuclear fuel loaded into the reactor and leave only a small amount of waste that decays into background levels of radiation within 300 years[124].

Furthermore, a report by the European Commission's Joint Research Centre published in October 2014, entitled *Management of spent nuclear fuel and its waste*, says Europe needs to find robust technical solutions covering the whole nuclear fuel cycle, while at the same time keeping alternatives available to accommodate changes in future policies and plans. It says the development of FNRs should continue because of the potential improvement they offer in using uranium and other fissionable elements that result from recycling. It also says further work on national or regional solutions for deep geological disposal is "essential and urgent" to ensure that spent fuel or high-level waste can be safely disposed of at the appropriate time[125].

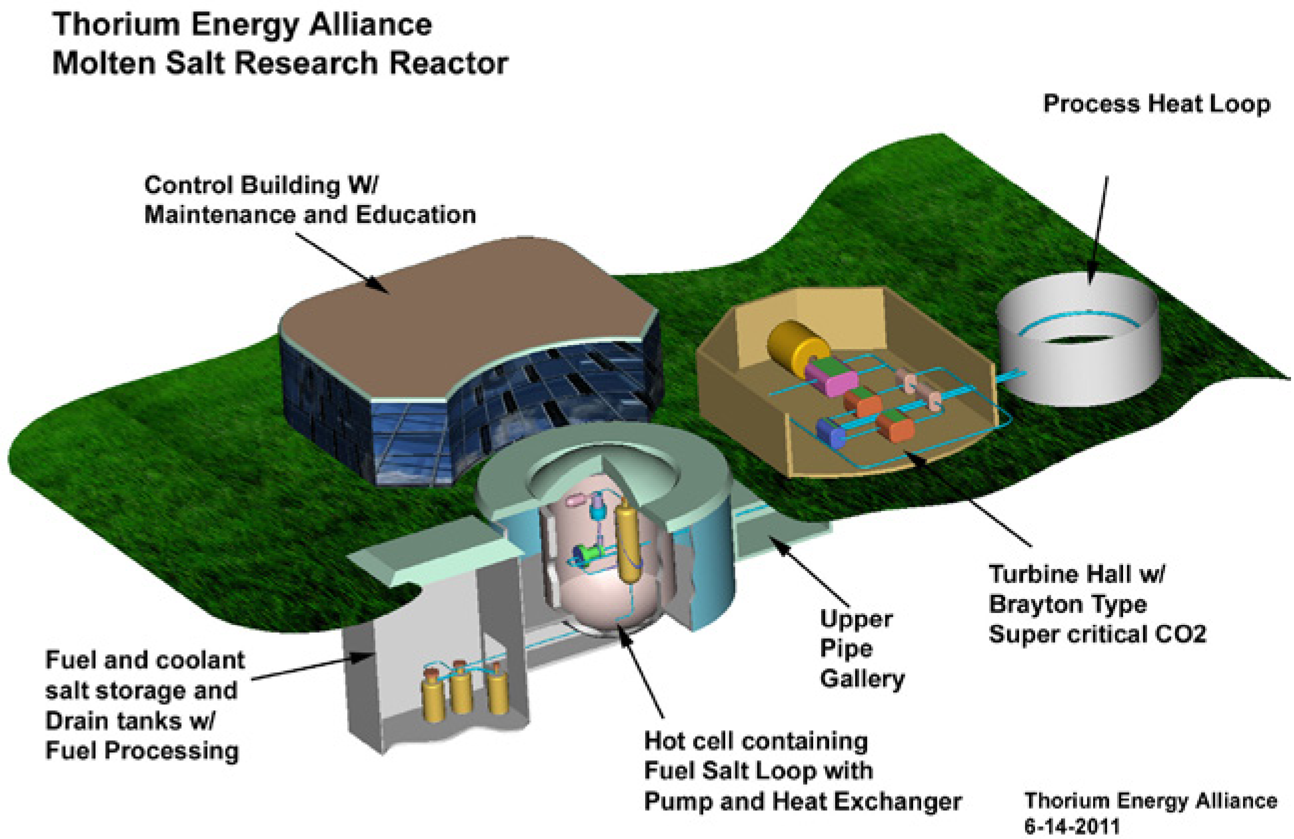
On the other hand, researchers have argued that there is no urgency in finding a solution to the spent nuclear fuel issue for two main reasons. Firstly, the average price of uranium on the global market has been steady at between US$40 and US$50 per ounce for a long time[126]. Secondly, the three biggest global producers of uranium are Canada, Kazakhstan and Australia – all located far from any volatile regional conflict area. For these reasons new uranium is readily available at a cheap price which discourages the development of recycling and reprocessing technology[127].

In 2012, Robert Hargreaves's book *Thorium: energy cheaper than coal* also argued that reactor designs which move beyond uranium and use thorium as a fuel offer a realistic future for nuclear power as a major source of energy with sufficient fuel resources for millions of years. India, which sits on the largest thorium resources in the world, is committed to developing a thorium-fueled reactor in order to use its indigenous resources[128].

Conventional and fast reactors are different in several ways. Conventional thermal nuclear reactors bombard atoms of uranium fuel with slow or thermal neutrons. The problem is that this process uses only around one percent of the potential energy in the uranium fuel is turned into electricity. The rest remains locked up in the fuel, much of it in the form of plutonium, the chief by-product of the 'once-through cycle'. The idea of FNRs is to grab more of this energy from the spent fuel of the conventional reactor and it can do this by repeatedly recycling the fuel through the reactor[129].

The second difference is that in a conventional thermal reactor, the speed of the neutrons has to be slowed down or moderated to ensure chain reactions occur. In a typical pressurised water reactor, the cooling water itself acts as this moderator. But in an FNR, as the name suggests, the best results for generating energy from the plutonium fuel are achieved by bombarding it with fast neutrons. This is done by substituting the cooling water with a liquid metal such as sodium, which does not slow down the neutrons[130].

Proponents of FNRs point to another advantage. The American Nuclear Society says that although FNRs do not eliminate the need for international proliferation safeguards, they make the task easier by segregating and consuming the plutonium as it is created. The use of onsite reprocessing makes the threat of losing or misplacing plutonium during the process highly impractical[131].



Anti-nuclear groups argue that the development of FNRs has an "Alice in Wonderland flavor" to it, according to Jim Green. The promotion of "non-existent" reactor types is "an implicit acknowledgement that conventional uranium-fuelled reactors aren't all they're cracked up to be," Mr. Green says[132].

In the UK, designs for FNRs which could potentially burn the stockpile of plutonium stored at Sellafield have been promoted in recent years. Anti-nuclear groups say that the UK government has found that the facilities have not been industrially demonstrated and that waste disposal issues remain unresolved and could be further complicated if it is deemed necessary to remove sodium from spent fuel to facilitate disposal[133].

A recent report, entitled *Feasibility of Developing a Pilot Scale Molten Salt Reactor in the UK,* found that funding for research, development and construction of a prototype experimental reactor is one of the biggest hurdles to the development of a molten-salt FNR in the UK. The report argues that direct government funding would enable a faster route to the development of MSRs and even with extensive private investment, government support would be necessary. In addition, the inexperience of the regulatory authorities with such 'innovative designs' would make it even more difficult to develop the technology[134].

In the US, the government has considered using Advanced Disposition Reactors (ADRs) for the same purpose – to manage the growing stockpiles of plutonium produced by conventional light-water reactors. The US government concluded there is "significant technical risk" in constructing an ADR. They found that it would take approximately 18 years to complete, and that it would be around twice as expensive as all other available options[135]. Dave Lochbaum, a nuclear engineer from the Union of Concerned Scientists, a non-profit advocacy group in the US, says FNRs look good in theory but not in practice[136].

A report by the US Department of Energy (DOE) published in August 2015 compared two approaches for plutonium disposal: the construction and operation of a MOX fuel facility and the dilution or down-blending of plutonium using chemicals before storing it in a deep geological repository (the 'dilute and dispose option'). The team did not consider alternatives such as use in the framework of a fast reactor programme in the United States due to its lack of potential to be used as a solution in the short term. The report concluded that the 'MOX approach', which includes the construction and operation of a MOX fuel fabrication facility, and other necessary activities such as support fuel licensing and reactor modifications, would require a budget increase from the current $400 million (about €360 million) per year to about $700 to $800 million per year for 15 to 18 years. The 'dilute and dispose option' could be executed within roughly the same timeframe but at the current funding level of $400 million per year[137].

Therefore, the US DOE has argued that the recycling of plutonium into MOX fuel, which can be re-used in commercial reactors, is more expensive than simply disposing of it in a repository. However, the report assumes that the 'dilute and dispose' option will be able to depend on the availability of national processing and storage facilities for its execution, namely the Waste Isolation Pilot Plant (WIPP) in New Mexico, the Savannah River site in South Carolina and Los Alamos National Laboratory in New Mexico[138]. The problems related to the WIPP facility have been discussed above.

Jim Green and other anti-nuclear activists say the claim that FNRs could burn up the existing stockpiles of plutonium is false. "An infinitely more likely outcome would be some fast reactors consuming waste and weapons-useable material while other fast reactors and conventional uranium reactors continue to produce such materials," he says[139]. The argument put forward by many environmentalists is that it will be unnecessary to develop FNRs as a solution to

Contamination warning sign on the river Techa in Russia in 2007 (Source: Ecodefense, Heinrich Boell Stiftung Russia, Alla Slapovskaya, Alisa Nikulina)

nuclear waste if the production of nuclear waste is ceased all together.

Mr. Green also attacks the paper by professors Brook and Bradshaw. To their statement that nuclear power expansion would not lead to a large increase in the number of countries with access to nuclear resources and expertise, he responds: "one wonders how such jiggery-pockery could find its way into a peer-reviewed journal"[140]. Furthermore, he argues that there is no demand for the uranium or plutonium separated at reprocessing plants and no repositories for the HLW. "It's a problem that needs to be solved; it's a problem that *can* be solved," he says without proposing a solution[141].

Anna Kireeva, a writer for the Bellona Foundation, a climate NGO, says Russia is also struggling with its nuclear waste. In 2013, Russia had 24,000 tonnes of spent nuclear fuel, with 13,000 tonnes being stored on-site at the graphite-moderated RBMK-type stations. Russia's RBMK reactors produce significantly more waste than the typical Generation II reactors operational around Western Europe and the US. Russia has a reprocessing facility at the Mayak Chemical Combine and an operational FNR (the BN-600) at Beloyarsk, but it still has a spent fuel problem[142].

According to a 2014 Greenpeace report, entitled *Rosatom Risks,* the Mayak Chemical Combine has suffered from technical failures that have not been disclosed to the public. In 1957, a large storage tank filled with radioactive waste exploded in the facility, contaminating a large area of about 20,000 square kilometres and leading to the evacuation of about 10,000 people. Rosatom has justified the continued reprocessing of spent fuel at the Mayak plant on the basis that plutonium will be used as fuel in its FNR reactor programme, but Greenpeace labels this programme a failure[143].

Greenpeace also argues that Rosatom is wrongfully promoting reprocessing as an environmentally friendly alternative to disposal. "Reprocessing has yielded Russia one of the largest stockpiles of reactor-grade plutonium in the world, and it has come at terrible environmental and social costs," the report says. In fact, in 2011, Swiss nuclear operator Axpo suspended its contract with Rosatom for the import of fuel due to a lack of transparency at the Mayak facility. Rosatom's "forbidding the Swiss authorities and Axpo officials from inspecting the site," was a major reason for this decision, Greenpeace says[144]. In 2014, the deal for reprocessing Axpo's spent fuel at Mayak was officially cancelled by the Swiss company[145].

Furthermore, Rosatom's experimental FNR programme has suffered from problems despite generous funds. "Russia says that its demonstration BN-600 reactor has achieved a greater capacity factor than any other fast reactor globally. However, nuclear experts and physicists have pointed out, this is 'only because of the willingness of its operators to keep it operating despite multiple sodium fires'," Greenpeace's report says[146]. These risks are due to the fact that the sodium in FNRs which use it as a coolant is highly reactive with both air and water and has to be contained within an atmosphere of 100% nitrogen if it is not to explode or catch fire[147].

Therefore, the problems associated with new technologies such as FNRs are typical of any technology in the development stages. However, anti-nuclear groups propose that the inherently dangerous nuclear technology should not be developed at all. It is worth mentioning that, despite the issues with sodium-cooled reactors, Russia is developing the plans for the construction of a 1,200-megawatt commercial sodium-cooled reactor and China is developing a 600-megawatt pilot reactor of the same design. Research is ongoing into other FNR types, such as ones using lead-bismuth coolant[148].

NUCLEAR INDUSTRY WASTE

Producing a very small quantity of waste

*These figures were calculated by dividing the total amount of waste produced globally by the world population (7.35 billion, July 2015, UN estimation).
**It only includes radioactive waste from nuclear power plants and their fuel cycle support facilities (excluding mining and extraction wastes).

**short-lived waste: its radioactivity will decrease by a factor of 2 every 30 years; long-lived waste: its radioactivity will decrease but over a much longer duration*

Source: OECD/NEA

d. Conclusions

In OECD countries, about 300 million tonnes of toxic waste is produced each year but after conditioning it amounts to only 81,000 cubic metres. The WNA says a typical 1,000 megawatt light-water reactor will generate about 200 to 350 cubic metres of low- and intermediate-level waste per year as well as about 75 cubic metres of used fuel. This compares with an average 400,000 tonnes of ash produced from a coal-fired plant of the same power capacity every year[149].

However, anti-nuclear groups and environmentalists do not always argue against the production of nuclear waste as much as against the industrial practices regarding the possible disposal solutions. The example of the accident and subsequent investigation at the WIPP facility shows why many might be skeptical about the possibility to store waste safely underground. Yet again, problems regarding safety culture, following protocol and respect towards the technology being used have caused embarrassment for the industry.

In January 2015, the French nuclear regulator (ASN) criticized Areva over its La Hague reprocessing facility in northern France. The ASN said in a statement that waste which has "significant nuclear safety and radiation protection implications" resulting from the activities of a spent fuel reprocessing plant between 1966 and 1998 had been delayed for reprocessing[150]. Because of its physicochemical and radiological nature and the current storage conditions, retrieval and packaging operations for the waste must be carried out according to a rigid timetable. "These delays… lead to the continued storage of legacy waste in unsatisfactory conditions of safety," ASN said[151].

A lack of transparency about nuclear waste breeds lack of trust while full transparency shows mistakes being made. If political and environmental opposition to nuclear waste management is to stop, then the industry has to show that it is capable of managing this by-product in a safe way which will not threaten the public or the environment. However, they also have to take a final decision on how the existing nuclear waste is to be disposed or treated. Even if every nuclear reactor shut down at this very moment and never started up again, there would still be close to 300,000 tonnes of highly-radioactive spent nuclear fuel which cannot be ignored[152].

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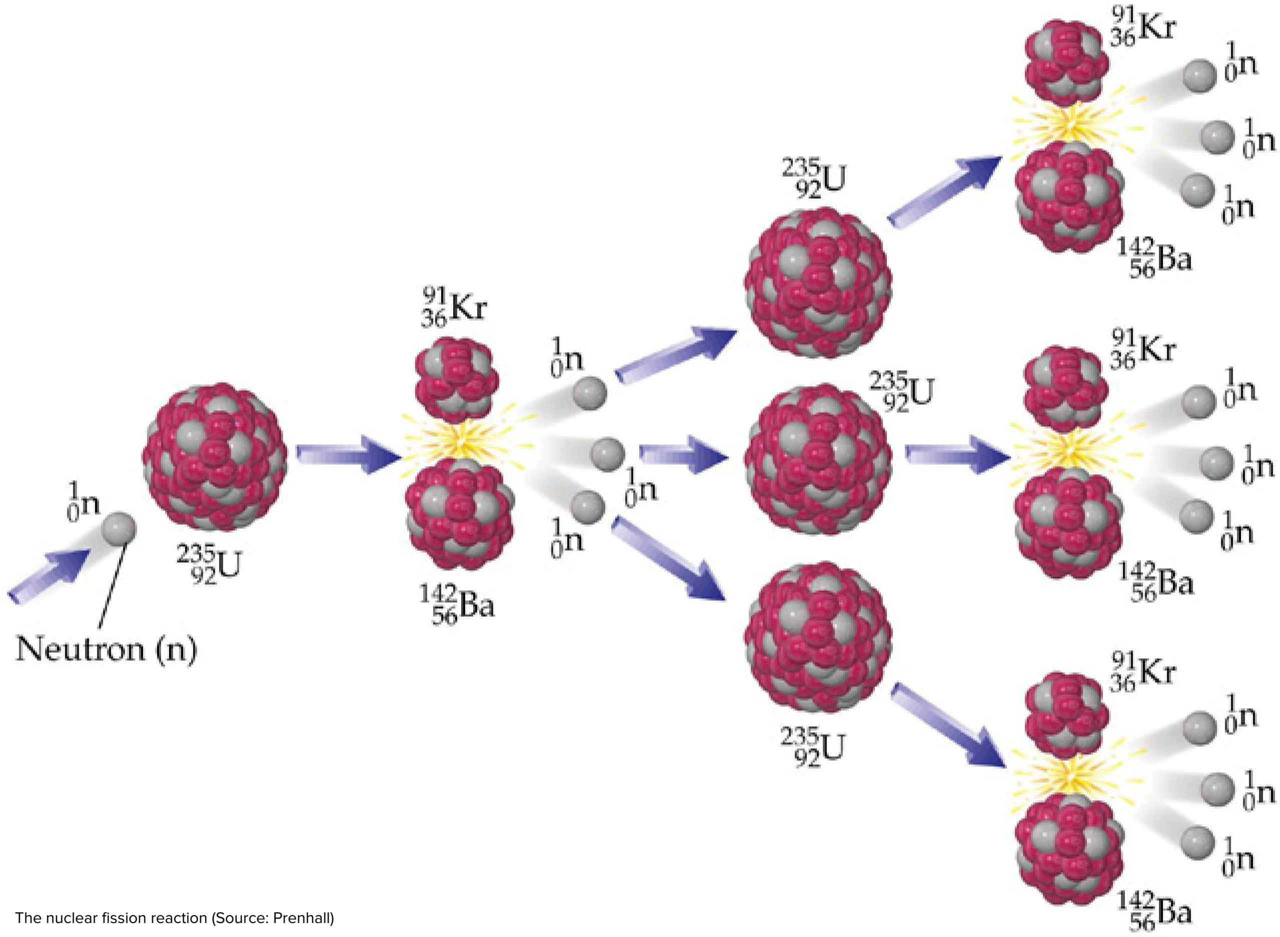
NUCLEAR POWER AND PROLIFERATION OF NUCLEAR WEAPONS



The nuclear fission reaction (Source: Prenhall)

Anti-nuclear groups often say that nuclear energy is dangerous because it produces material which can be used to make atomic weapons. This chapter examines the arguments put forward related to the issue of nuclear proliferation and nuclear energy.

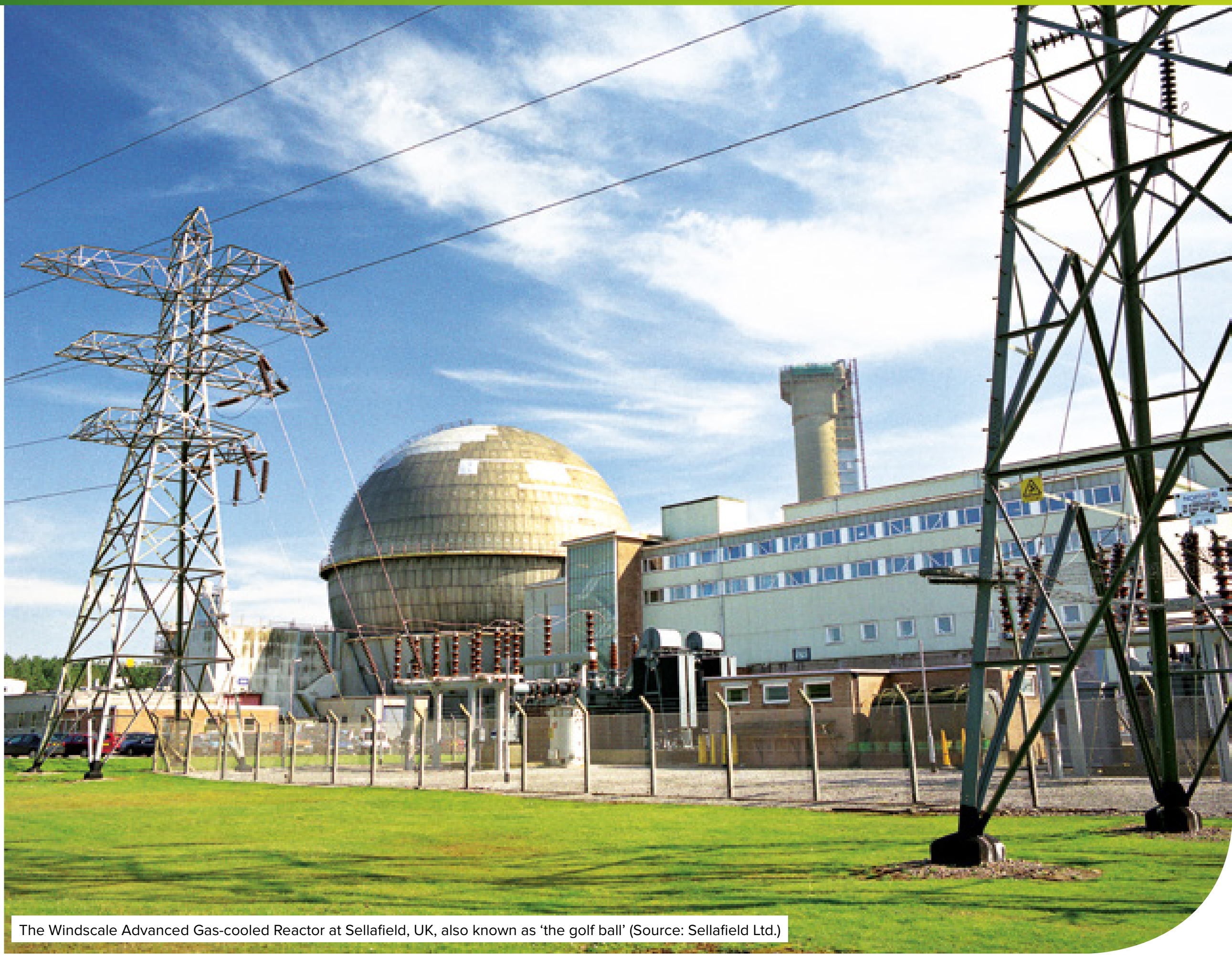
a. Uranium and Plutonium

The World Nuclear Association (WNA) explains that in every nuclear reactor there is both fission of isotopes such as uranium-235, and the formation of new, heavier isotopes due to neutron capture, primarily by U-238. Most of the fuel mass in a reactor is U-238 which can become plutonium-239 and, by successive neutron capture, Pu-240, Pu-241 and Pu-242 as well as other transuranic isotopes. Pu-239 and Pu-241 are fissile materials, like U-235[153].

There are two different kinds of plutonium, the WNA says: reactor-grade and weapons-grade. Reactor-grade plutonium is recovered as a by-product of typical used fuel from a nuclear energy reactor, after the fuel has been irradiated ('burned') for about three years. Weapons-grade plutonium is made especially for the purpose of usage in the military and is recovered from used uranium fuel that has been irradiated for only 2-3 months in a plutonium production reactor. Both types must be regarded as a potential proliferation risk, and managed accordingly[154].

WNA also explains that it takes about 10 kilograms of nearly pure Pu-239 to make an atomic bomb. In a commercial power reactor, producing this quantity requires 30 megawatt-years of reactor operation, with frequent fuel changes and reprocessing of the 'hot' fuel. Hence 'weapons-grade' plutonium is made in special production reactors by burning natural uranium fuel for only about three months instead of the three years typical of light-water power reactors[155].

According to the Federation of American Scientists (FAS), plutonium has assumed a position of importance because of its successful use as an explosive ingredient in nuclear weapons. One kilogram of plutonium is equivalent to about 22 million kilowatt-hours of heat energy. In weapons terms, the complete detonation of a kilogram of plutonium can produce an explosion equal to about 20,000 tonnes of chemical explosive. The world's nuclear energy reactors are now producing about 20,000 kg of plutonium every year[156].



The Windscale Advanced Gas-cooled Reactor at Sellafield, UK, also known as 'the golf ball' (Source: Sellafield Ltd.)

b. "Too much bomb-making material"

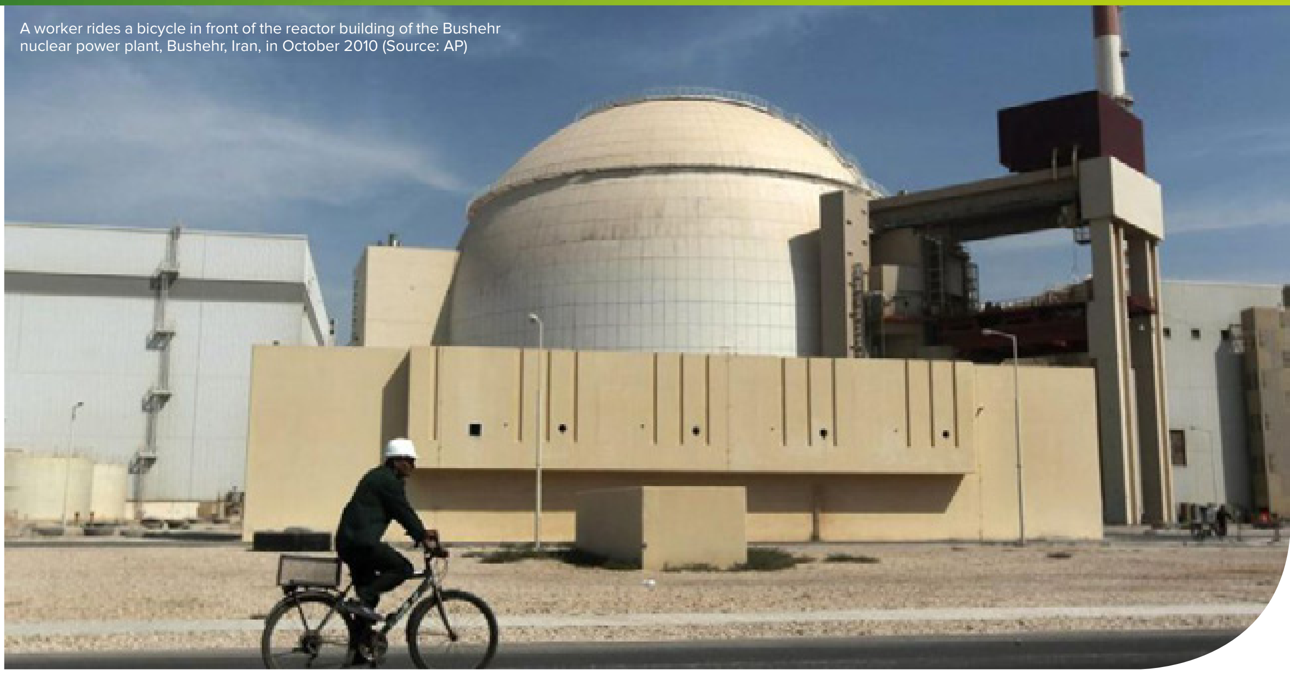
The main argument environmental and anti-nuclear power groups want to make is that the operation of civilian and peaceful nuclear power programmes *can* lead to the development of nuclear weapons. The possibility of this occurring and the similarity of the technology used are the main causes of concern. The anti-nuclear movement started off as an opposition to atomic weapons testing and the link made between the peaceful use of nuclear energy and the possibility of nuclear weapons development is always in the minds of environmental groups.

The issues raised are related to the early development of nuclear energy reactors. In 1947, construction began for the nuclear plants at Windscale Works in the UK and consisted of two air-cooled and open-circuit, graphite-moderated reactors. They constituted the first British weapons grade plutonium-239 production facility. Windscale Pile No. 1 was operational in October 1950 and Pile No. 2 in June 1951. The Windscale site was also the site of the prototype British advanced gas-cooled reactor (AGR)[157]. According to the International Atomic Energy Agency's (IAEA) Pris database, there were 14 AGR-type reactors in operation in the UK in 2015. The physical proximity of reactors for the production of weapons-grade plutonium to the birth-place of the UK's commercial reactor design is problematic for the image of nuclear energy.

In 1956, the first of four Magnox nuclear energy reactors became operational at Calder Hall, adjacent to the Windscale site, just across the river Calder. In 1981, as part of reorganization, the Windscale site was renamed to its current, internationally well-known name: Sellafield[158]. According to reports from 2013, the Sellafield site stores the worlds' largest stockpile of plutonium estimated at around 100 tonnes, out of the UK's total stockpile of 126.3 metric tonnes in 2014[159].

According to former US Vice-President Al Gore, the proliferation of nuclear weapons was a serious issue when he was in office: "For eight years in the White House, every weapons-proliferation problem we dealt with was connected to a civilian reactor programme"[160]. In fact, the connection between civilian and military nuclear technology is the central issue in the negotiations and ensuing agreements between Iran and the P5+1 countries – the US, Britain, China, France, Germany and Russia. In an article in *the Economist* on 7 March 2015, the negotiations were described as aiming to curb Iran's nuclear programme efforts which it insists are peaceful, "but the world is convinced they are designed to produce a nuclear weapon". Iran's facilities for enrichment of uranium could be for the country's operational nuclear energy reactor at Bushehr, or they could be for another purpose. The goal of the negotiations is to have continuous IAEA oversight at the facilities[161].

The Economist also argues that the danger of nuclear weapons falling into the wrong hands is increasing. "Pakistan insists its [nuclear] weapons are safe, but the outside world cannot shake the fear that they may fall into the hands of Islamist terrorists," the article says[162]. Security (not to be



A worker rides a bicycle in front of the reactor building of the Bushehr nuclear power plant, Bushehr, Iran, in October 2010 (Source: AP)

confused with safety) is an issue which all nuclear facilities take seriously, but proliferation issues arise from a lack of transparency in some countries such as China, argues Jim Green, activist for Friends of the Earth and editor of the anti-nuclear publication *Nuclear Monitor*[163].

In Iran, there is an ongoing controversy about the need for its domestic uranium enrichment programme and the operation of its nuclear energy reactor at Bushehr. In November 2014, Russia's state nuclear corporation Rosatom signed an agreement with Iran on the possible construction of up to eight nuclear power reactors[164]. The deal included a provision that Russia will supply the reactors with nuclear fuel and the spent fuel will be transported back to Russia. The question raised by environmentalists is why Iran needs a uranium enrichment programme if it is receiving all of its fuel needs from Russia.

In September 2014, Daryl Kimball, Executive Director of the Arms Control Association, wrote in *Arms Control Today* that the Bushehr commercial nuclear reactor will operate with Russian-supplied fuel until 2021 when the current deal expires, but it could be extended. "Iran's leaders are under heavy political pressure to reduce the country's reliance on foreign energy supplies and to maintain a uranium-enrichment programme that could be expanded if and when the country's nuclear energy needs grow," Mr. Kimball said[165].

Iran also has a heavy-water reactor under construction at Arak which will be able to produce about nine kilograms of weapons-grade plutonium annually, according to a report from the Institute for Science and International Security[166]. The Arak reactor is one of the main points in negotiations between Iran and the P5+1 countries. Yet, according to Jim Green, a nuclear energy programme with eight new reactors could potentially produce 150 to 200 kilograms of weapons-grade plutonium annually, but there is "no effort to prevent their construction"[167].

The link between nuclear energy and atomic weapons is also perpetuated by two further factors. The first is a linguistic one – both terms include the words 'nuclear' or 'atomic'. Because of this, any mention of an accident at a nuclear power station causes a popular image of a mushroom cloud to appear in one's mind, which is the result of the explosion of an atomic weapon. The second is an organizational factor – the government's nuclear regulatory authorities often have to regulate both weapons and civilian nuclear installations. Sometimes, even when the regulatory responsibility is divided between the military and a civilian regulatory body, issues can overlap to a large extent. If this is the case, the industry cannot expect citizens to dissociate nuclear energy from atomic weapons.

c. Nuclear Safeguards

The Treaty on the Non-Proliferation of Nuclear Weapons, commonly known as the Non-Proliferation Treaty or NPT, is an international treaty signed in 1968 and entering into force in 1970. The main objective is to prevent the spread of nuclear weapons and weapons technology, to promote cooperation in the peaceful uses of nuclear energy, and to further the goal of achieving nuclear disarmament and general and complete disarmament[168].

In April 2009, US President Barack Obama gave a speech in Prague, promising to put nuclear weapons reduction back on the agenda and to give new momentum to the NPT. The following year, the US signed an agreement with Russia (called 'New START') which capped the number of deployed strategic warheads allowed to each side at 1,550. One month later, at the NPT's review conference (which takes place every five years) the parties agreed to a 64-point plan intended to reinforce the treaty's aims[169].

However, environmentalists argue that there has been little progress in increasing nuclear security. For example, India and Pakistan are both confirmed nuclear weapons countries but have never signed the NPT. India's government has repeatedly said that it considers the NPT a "flawed treaty" and has refused to sign it, effectively blocking other countries from cooperating with it on civilian nuclear energy technology[170].

Then, in 2006 it finalized an agreement with the US to cooperate on civilian nuclear technology. This led to 14 out of India's 21 nuclear power plants being placed under IAEA safeguards. As a result, India was granted a waiver under the Nuclear Suppliers Group (NSG), a body concerned with reducing nuclear proliferation by controlling the export and re-transfer of materials that could be used for nuclear weapons production[171]. Since then, India has successfully signed nuclear fuel and uranium delivery agreements with Canada and Australia[172].

By contrast, a deal signed between Pakistan and China in 2010 never sought approval from the NSG, according to the Nuclear Threat Initiative (NTI), a non-profit organisation[173]. The deal included a sale of two heavy-water reactors to Pakistan which could be used for plutonium production. They are currently under construction at the Chashma site, where China already built two reactors in the 1990s. China has also started construction of two light-water reactors at the Karachi site, where a Canadian Candu heavy water reactor has been operational since 1972[174].

Environmentalists have serious concerns regarding India and Pakistan's proliferation records. Ian Lowe, emeritus professor at Australia's Griffith University, wrote in December 2014 that Australia's sales to uranium to India "could potentially free up India's domestic uranium stocks for military use"[175]. The deal would also neither help reduce tensions with Pakistan nor promote nuclear non-proliferation. Professor Lowe also says the security of India's nuclear reactors remains shaky because the sector's regulation and governance is deficient. A 2012 report by India's Auditor-General Vinod Rai on the *Activities of Atomic Energy Regulatory Board* sent out warnings of a nuclear disaster "if the nuclear safety issue is not addressed"[176].

Furthermore, former Director-General of the Australian Safeguards and Non-Proliferation Office John Carlson has raised concerns about how Australia can keep track of what its uranium is being used for. Mr. Carlson says that without clear reporting measures in place, Australia has no way of knowing whether India is meeting its obligations to identify and account for all the material that is subject to the agreement[177]. In fact, Ian Lowe, emeritus professor at Griffith University, says Australia has effectively given its consent for India to reprocess uranium and the agreement includes "only a vague reference to management of plutonium"[178].

> *"Disturbingly, it is reported that Indian officials will not provide Australia with reports accounting for material under the agreement, and that the Abbott Government seems prepared to waive this requirement for India. [...] The reporting procedures are not optional; they are fundamental to Australia's ability to confirm that our safeguards conditions are being met. They have long applied to close and trusted partners such as the US, the EU, Japan and South Korea. There is absolutely no case to waive them for India,"* Mr. Carlson wrote in October 2014[179].

This possibility is not a fictitious scenario – in 2005, the UK Atomic Energy Authority reported that 29.6 kilograms of plutonium was unaccounted for in the auditing records at the Sellafield site. The error was accredited to a discrepancy in paper records[180].

Overall, environmentalists see the risk of producing nuclear weapons from peaceful nuclear energy programmes as too high. This issue is linked to the need to safely manage

The historical marker for the Trinity site where the world's first atomic explosion took place in July 1945 (Source: Wikipedia)

and protect spent nuclear fuel because it too could be reprocessed into bomb-making material. In addition, a lack of transparency in the sector and in some countries means that reliable data and reporting does not exist on the stockpiles, production and transportation of nuclear material. In this context, anti-nuclear activists argue against nuclear energy because of the potential for radioactive material to fall into the wrong hands.

d. Conclusions

Jim Green wrote in *Nuclear Monitor* in December 2014 that with several countries willing to engage in nuclear trade with India, with China supporting Pakistan's nuclear programme, and with Russia supplying Iran with new reactors, "previous historical norms and agreements against nuclear trade with countries violating non-proliferation norms and commitments are near-dead"[181]. Pro-nuclear representatives say that the non-proliferation of nuclear weapons is guaranteed by international treaties, agreements and even organisations such as the Comprehensive Test Ban Treaty Organisation, which monitors the globe for any weapons testing activities.

In 2012, Alan Robock, associate director of the Center for Environmental Prediction at Rutgers University, published an article in the *Bulletin of the Atomic Scientists* arguing that a nuclear weapons war would exacerbate the effects of climate change. He said:

> *"Even a 'small' nuclear war between India and Pakistan, with each country detonating 50 Hiroshima-size atom bombs—only about 0.03 percent of the global nuclear arsenal's explosive power—as air bursts in urban areas, could produce so much smoke that temperatures would fall below those of the Little Ice Age of the fourteenth to nineteenth centuries, shortening the growing season around the world and threatening the global food supply. Furthermore, there would be massive ozone depletion, allowing more ultraviolet radiation to reach Earth's surface"*[182].

According to the WNA, following proposals from the IAEA and Russia, and in connection with the US-led Global Nuclear Energy Partnership (GNEP), there are moves to establish international uranium enrichment centres[183]. Part of the motivation for these centres is to bring all new enrichment capacity, and perhaps eventually all enrichment, under international control as a non-proliferation measure[184]. The establishment of a low-enriched uranium (LEU) bank in Kazakhstan in August 2015 is an important step in supporting nuclear non-proliferation, according to the IAEA[185].

Precisely what "control" means remains to be seen, and will not be uniform in all situations. Having ownership and operation shared among a number of countries at least means that there is a level of international scrutiny which is unlikely in a strictly government-owned and -operated national facility. Potential issues which may be raised by environmentalists in the future regarding projects such as the IAEA LEU bank could be about the transparency and safety the IAEA can provide for such facilities.

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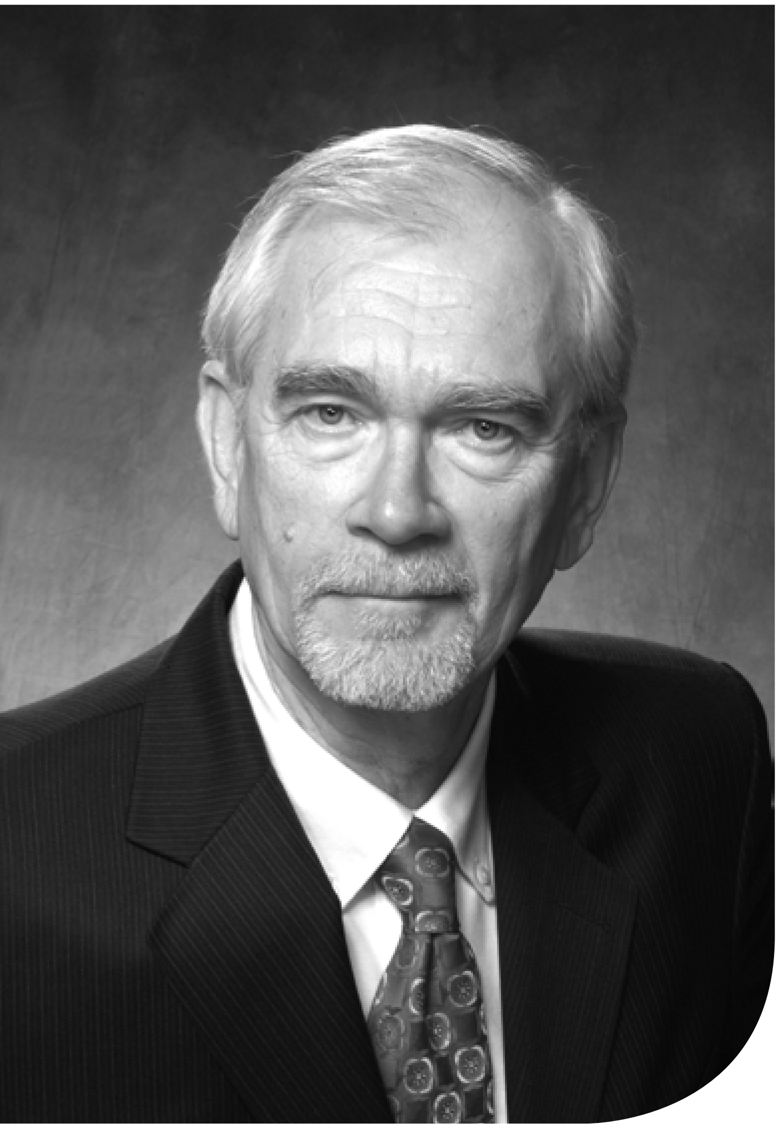
INTERVIEW WITH PAUL GUNTER

Beyond Nuclear

Paul Gunter:

We are seeing the end to the nuclear industry but this is a mixed blessing



What is your opinion of nuclear as an energy source?

I think using nuclear technology for energy production is like using a chainsaw to cut butter or a cannon to ring a doorbell. The amount of energy generated in the fission process, essentially used only for boiling water, is a gross waste. It is a little like burning antiques in your wood-stove. The value is about 33 percent of the energy that actually goes into generating electricity and the other 67 percent has to be dealt with as a very dangerous heat source. As a result, you have to manage all of that excess heat. In the past, the heat was a result of the production of plutonium for nuclear weapons and was seen as a by-product that could be used to generate electricity in a co-generation process. Even in that case, there is a gross waste of energy that has to be dealt with.

On top of all this, the process is inherently dangerous and makes it exorbitantly expensive due to the defense-in-depth structure. The multiple barriers for safety – the back-ups for the back-ups – are all necessary because of the inherent danger of nuclear energy. I also think that the nuclear industry has been allowed to operate with an unmanaged pile of hazardous waste, which is irresponsible. This has been my position consistently since 1975.

What about co-generation of heat and power in nuclear power plants and using the excess heat for district heating?

This was a consideration in the early designs of nuclear power plants but because of the multiple barrier systems it was never implemented. The multiple barriers eventually degrade and the coolant can often be contaminated through leaks in the first barrier – the fuel cladding. The management of radioactive coolant can be difficult and if it potentially goes down the line until it is coming up in your water heater makes it not very practical. I do not believe that this is insurable either. Certainly in the US this idea would face some insurance issues unless the government exempts your radiator from a nuclear accident.

Using nuclear technology for energy production is like using a chainsaw to cut butter or a cannon to ring a doorbell

What do you think is the biggest risk/threat associated with nuclear energy production?

I think the biggest risks derive from the issue of nuclear weapons proliferation. The fuel chain, beginning with the extraction of uranium, opens the door to both power generation and nuclear weapons proliferation. To even consider that you could distribute nuclear power globally on an increased scale from where it currently is, you have to take into account that this means an increased trafficking of nuclear material worldwide. This can potentially be used for nuclear weapons.

Ultimately, this open-ended fuel chain results in the dumping of nuclear waste onto future generations. It was always thought that the waste is someone else's responsibility to manage.

Taking the existence of nuclear waste as a fact, how do we deal with it?

The nuclear industry is allowed to further continue its operations despite the fact that it already has an unmanaged waste problem. This does not make any sense. These are liability issues and the fact that nuclear waste already exists is essentially extortion. The first and most responsible step in nuclear waste management is to stop generating the problem – to cap the waste production. I do not agree that the ongoing irresponsibility regarding the existing nuclear waste is a ticket to keep on generating more of it.

What is the solution to nuclear waste? And if we do have one, wouldn't that push the nuclear industry into continuing its operations and production of the waste?

It is that kind of logic which is so disturbing – that if a frog had wings it wouldn't have to bump its butt. We are now 70 years into the generation of nuclear waste coming out of the nuclear weapons programme and we do not know what to do with the first cup-full. There is now well over 250,000 metric tonnes of nuclear waste globally. It is unmanaged and there is no logic to saying that the industry has a licence to make more. In fact, this borders more on the lines of environmental extortion.

Do you think nuclear energy can contribute to the fight against climate change?

If you consider nuclear on a scale of cost per megawatt-hour, it is not economical. Take as an example a recent financial survey of the investment bank UBS. They have acknowledged that large-capacity centralized generation is a dinosaur that is from the past. Nuclear power in particular is currently sinking in this financial quagmire. To risk our climate mitigation programmes on something that is simply not affordable, particularly on a global scale, is foolish. UBS is saying that it is time to join the revolution – solar power and advanced electricity storage. This is the future and nuclear power is the dinosaur.

We have also now demonstrated that nuclear is inherently dangerous and the industry has to recognize the fact that this image of 'safe nuclear power' is fleeting even from the lexicon. There are no insurers for nuclear power because it is not safe. Because it is such a big risk, only governments can finance the construction of nuclear. These are the arrangements between government and utilities. The government backing still makes it impossible to scale up nuclear energy production enough to address the challenges and surprises that climate change is bringing.

Nuclear power in particular is currently sinking in this financial quagmire

We need to be deploying technology that does not have emergency planning zones around it and that can manage its waste stream. There are technologies that can scale up quickly. So, nuclear is an ineffective energy source for the climate effort and it will also divert resources from the programmes that are going to be reliable for mitigation and are economically scalable.

Do you think that newer generations of nuclear technologies can be safe?

This is not a question that is answered by global insurance companies. Safety is diminished by repeated nuclear accidents and you can offer numerous plans on paper but that does not make them safe in reality. In particular, the idea of small modular reactors is still a pipe-dream. We are still looking at the whole certification process for these designs and they are still questionable. We are unsure whether these designs will be able to have enough finance for their assembly lines.

What Generation IV reactors propose has always been the illusive dream of this 1950s technology.

Solar power and advanced electricity storage are the future and nuclear power is the dinosaur

What is your opinion of government regulation of nuclear power?

I think that from the very beginning, the Atomic Energy Commission in the US had the dual purpose of regulatory oversight and promotion of the industry. This proved to be contradictory because promotion always trumped safety. You continue to see this trend globally. The Japanese parliament, in its determination of the cause of the Fukushima-Daiichi accident, said that it was man-made because of the collusion of government, regulator and industry to the financial agenda of industry. The subordination of environmental impacts and public health and safety issues became clear.

That plays out in the US where the Nuclear Regulatory Commission (NRC) has come to be known as 'No Regulatory Control'. We even have an instance where the NRC staff recommended that the agency order the operators of all General Electric Mark I and Mark II reactors (essentially the Fukushima-type reactors) to install external filters on containment vents. The venting is now necessary as a back-up because the original containment system (the pressure suppression system) does not work under severe accident conditions and is highly prone to catastrophic failure. In its technical wisdom, the staff determined that radiation filters should be installed on these vents to allow for the control release of the extreme pressure, temperature and explosive gases generated in a severe accident but still contain the release of harmful radioactivity from fuel damage. But the industry, in its lobbying of the NRC, was able to trump the staff's own recommendation by influencing a vote of the five Commissioners.

This shows how the fundamental common sense of cost-benefit analysis for public health and safety was trumped because the economically-fragile nuclear industry in the US did not want to burden its plants with the cost of installing filters on these vents. The NRC has five Commissioners, but at the moment only four are present and one position is empty. Those members of the public who are awake to the shenanigans of the NRC are aware that there is an open seat on the five-person commission, which is already practically filled by the nuclear industry. The industry's influence on the NRC stretches even to the point that the Commission defers enforcement of clear non-compliance issues, for example related to fire protection, containment integrity and electrical cabling which is not qualified to be submerged in the case of a flood. The list goes on and on to a point where the NRC's staff disregard the public health and safety issues to allow continued operation.

Do you think there are any advantages to having nuclear power?

The only advantage to nuclear power is that the government supports the nuclear industries. This is not the best solution and we would like to see more distributed ownership, independent generation and effectively socialized energy policy. We do not want an energy industry that pawns off its waste to future generations and doesn't even have enough money for the decommissioning of nuclear facilities which are currently closing. These are all big concerns and the collusion between government, regulator and industry to protect the emolument of a few corporations. We believe that the ongoing energy revolution is about 'no nukes' and it is about shutting this industry down.

Don't you think the energy revolution you mention cannot happen overnight – you can't shut down all the nuclear power stations in one day and replace them with renewables?

For the past 38 years, I have been advocating for a phase-out of nuclear power. Those decisions for phase-outs are now being made, for example, in Germany. The German industry has made the commitment and we also have zero nuclear power operational in Japan and the struggle to keep it that way continues. We are also shutting down nuclear plants in the US – in 1976 I began advocating for the closing down of the Vermont Yankee nuclear power plant, which closed at the end of 2014. We are seeing the end to the nuclear industry but this is a mixed blessing. When the motive of making profit is lost for this industry is when the problems become easier to identify, particularly with the unmanaged nuclear waste. As the nuclear corporations exit the industry, they are leaving less money for the management of nuclear waste and decommissioning than is needed to clean up these sites.

You can offer numerous plans on paper but that does not make them safe in reality

INTERVIEW WITH BRUNO COMBY

Environmentalist For Nuclear

Bruno Comby:

If the worst accident that can happen is an accident that kills no one, I think it is a safe industry

What is Environmentalists For Nuclear?

Environmentalists For Nuclear is a non-profit organisation founded in 1996 which has over 12,000 members and supporters in 65 countries. We have branches in several countries, but our headquarters are in France. We have helped convince a number of senior environmentalists about the need for nuclear. Patrick Moore, one of the founding members of Greenpeace and executive director of Greenpeace International for more than 15 years, left Greenpeace in 1986 and has since come to support nuclear energy, as have other environmentalists including James Lovelock and Stewart Brand.

How did you become an environmentalist for nuclear energy?

I trained as a nuclear scientist. I wrote a book on nuclear energy and gave lectures to members of the environmental movement, and discovered there were mistakes and misunderstandings about nuclear power. It is the cleanest energy on Earth, but is considered the most polluting. So I set out to tell the environmental community about the benefits of nuclear power.

So you are convinced nuclear power is safe?

Yes, of course. There have been accidents, just as we have had accidents in any other industry. But the accidents are not as bad as people think. If you take Fukushima-Daiichi, not a single person died due to radiation exposure. So, if the worst accident that can happen is an accident that kills no one, I think it is a safe industry.

Authorities say almost 20,000 people died as a result of the earthquake and tsunami, which was a terrible disaster. Only four people died at the Fukushima-Daiichi nuclear station. Two stayed in the basement and drowned, one was at the top of a crane when the earthquake struck, and one had a heart attack while he was taking part in the recovery operation. None of them died due to radiation exposure. Less than 10 people received a level of radiation exposure higher than the safety limits, but still far below the doses which would seriously endanger their health.

What do you think about the relationship between increases in safety measures and the increasing cost of construction?

The cost of nuclear power has gone up, that is true. The positive side of this is that nuclear technology is safer than it was in the early years of its development. It has always been a safe energy, even when you include the people who were affected as a result of the Chernobyl accident. It is still the safest energy source. But the fact is it can be even safer, which has resulted in increases regulation and that, in turn, has led to higher costs.

> *Patrick Moore, one of the founding members of Greenpeace, left Greenpeace in 1986 and has since come to support nuclear energy*

Sometimes, the cost is almost unreasonable – the industry can spend billions just to avoid one injury. It seems almost absurd when you consider that you can save one life in Africa with a few dollars. This is a paradox. I think it is sometimes justified to spend more on safety issues, but it can become overly exaggerated.

I think there is also a misconception here. The radiation dose limits which we are concerned with at nuclear power stations today are for manmade, or technical radiation sources. There is no regulation for exposure to radiation from natural sources. A person can walk in nature and be exposed to high doses of radiation and it is not forbidden. On the other hand, we are forced to spend millions on preventing the exposure to a few millisieverts in a nuclear power station. If radiation regulations are developed to protect human health and not just to make nuclear energy more expensive, then they should apply to the total exposure – industrial plus natural.

Are you saying there are risks from natural radiation?

I have measured natural radiation in many places. I travelled to the village of Ramsar in Iran, which is one of the most radioactive inhabited areas in the world because of nearby hot springs which bring radium to the surface. I measured 150 microsieverts per hour with my dosimeter. This is much higher than the dose workers are exposed to in nuclear power stations. Yet, there is no regulation for the local population. The building materials villagers use also contain high levels of radium and the hot spot – the place where the highest readings have been recorded – is inside a primary school. The school, which has been closed, is the highest natural radiation hotspot on the planet. People live healthily and normally there.

Nuclear energy is only 50 years old. Compared to the railway industry, we see a similar line of development

I met the director of the school. He built his house with his own hands – it is the most radioactive house on Earth because it is made from materials containing high levels of radium. In his kitchen, I measured 130 microsieverts per hour. When I met him he was already eight years older than the average lifespan in Iran. If he dies, it will not be an early death due to radiation exposure. This just goes to prove that industrial radiation alone has no health significance and regulations should be adapted to accept this.

Do you think there is a solution to the problem of nuclear waste disposal?

There is no 'one single solution' to the issue of nuclear waste – there are several. However, you first have to recognise that nuclear waste is not really a problem. There is almost none of it. The best energy is the one that would produce no waste at all and nuclear energy is the one source that comes closest to this. One gramme of uranium-235 produces as much energy as one tonne of oil, coal or natural gas. This relation is a factor of one million, which means that the scar we inflict on the Earth when we mine for uranium is a million times smaller than when we pump oil or gas from wells underground.

When it comes to the production of waste, nuclear energy is even better than the one million to one ratio. The density of nuclear waste is much higher than that of other energy sources. In terms of mass, nuclear waste is about one million times less than fossil fuels. When you take into account that gases are about 1,000 times less dense than solids, the difference in volume is a factor of several billions. This is a huge environmental benefit which should be to the credit of nuclear energy.

Another positive side of nuclear waste is that it is self-degradable, which is not the case with toxic chemical waste produced in much higher quantities in other power plants. In fact, nicotine is as toxic as uranium or plutonium, yet it is cultivated and produced in much larger quantities and is sold to be inhaled. Six to 10 million people each year die from nicotine, while nuclear waste is confined and it is not put back into the biosphere. The health impact of nuclear waste is much less than other toxic chemicals.

Do you think the nuclear industry pays enough attention to the topic of risk?

I think the risks of nuclear power are vastly exaggerated. What happens when you talk about these issues too much is that people become hyper-conscious of the risk and end up believing that this is a dangerous industry. Even though nuclear is growing in some countries, it has disappeared in others because of this perception of risk. Nuclear is not growing as fast as it should to help our transition from dangerous and polluting energy sources to clean energy sources. We could do a lot with nuclear power, but to do so we have to stop talking about the dangers so much when they are so small.

Opponents have transformed a very safe solution into a huge problem. They have done this by focusing only on the problems. They have distorted reality and this is not the correct way to present information to the general public.

How do you see the future of nuclear energy?

In the long term, it will be a brilliant future because there is no choice. We will start running out of cheap oil and whatever is left will be concentrated in a small number of unreliable states. Huge portions of the planet will be deprived of oil or will not be able to afford it. China – the world's biggest energy consumer – burns mostly coal to produce its energy. Climate change is becoming worse every day with carbon dioxide increasing in the atmosphere by two parts per million every year. The situation is changing fast and in a couple of decades we will not be in the same world.

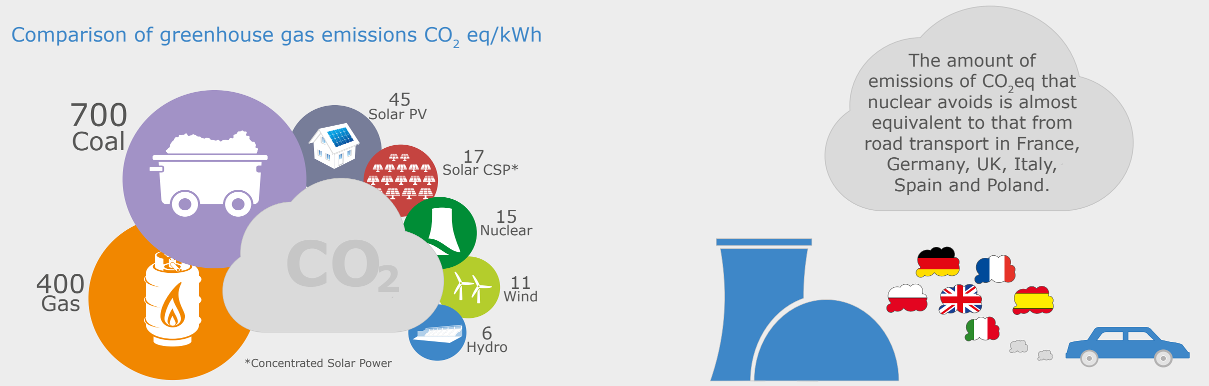
Nuclear energy is only 50 years old. Compared to the railway industry, we see a similar line of development. In the 1880s, the railway industry was seen as very dangerous and some cities went as far as to ban locomotives. They thought it was too dangerous to have a train station. Yet now we have high-speed rail, which is affordable and safe. Most of all, it is convenient and clean, especially when it is powered by nuclear energy. Nuclear energy is in the first phase of its history and some parts of the population have not yet understood the benefits it can bring.

NUCLEAR POWER AND CLIMATE CHANGE

NUCLEAR AND CLIMATE CHANGE

Contributing to the fight against climate change by avoiding CO_2 emissions

The amount of CO_2 emitted by nuclear energy is comparable to that of renewables.



Source: European Commission, NEEDS Project, 2009

Source: Eurostat, 2014

This chapter examines the arguments used by anti-nuclear activists in opposition to the nuclear industry's stance that nuclear energy is a low-carbon technology and can be used to fight climate change.

a. Climate Change and the Energy Sector

In today's world, 70% of the world's electricity comes from fossil fuels, low-carbon energy sources account for only 30% of the electricity mix and the electricity generation sector is the main source of carbon dioxide emissions[186].

Since 1990 (the reference year for the Kyoto Protocol), carbon dioxide emissions have continued to increase, by about 60%[187]. If the electricity mix continues to be dominated by fossil fuels, the average global rise in temperature will be 6°C, well beyond the objective of 2°C[188].

By 2050 the world's population will be around 9.6 billion[189]. The IEA scenarios predict an increase in electricity demand by 2050 between 80% and 130%, mainly driven by the development of emerging economies[190]. The fight against climate change should not jeopardize the development of emerging countries: 1.2 billion people - the equivalent of the population of India or Africa – do not have access to electricity. And 2.8 billion use wood or other biomass products for cooking and heating, which creates pollution that is harmful for human health[191].

Once released, carbon dioxide remains in the atmosphere and its effects are long-term. The IPCC has defined a "carbon budget" of cumulative carbon dioxide emissions that must not be exceeded if we are to contain average increase in temperatures to 2°C. It is estimated that a total of 2,900 billion tons will have been emitted between the start of pre-industrial era to 2050. 2000 billion tons have already been released into the atmosphere, with a strong acceleration recorded in recent years (1000 billion tons in 40 years)[M]. It is, therefore, necessary to initiate immediate reduction efforts, without waiting for future technologies that will contribute in proportion to their availability.

b. Nuclear Power and Low-carbon Technologies

Nuclear power plants produce nearly no CO_2 emissions: 15 grams of CO_2 per kilowatt-hour[193], compared to 11 g CO_2/kWh for wind energy[194], 45 g CO_2/kWh for solar pv[195] and 400 g CO_2/kWh for natural gas-fired power stations[196]. Also, the Intergovernmental Panel on Climate Change's (IPCC) 1,200 possible scenarios for the limiting of global warming to 2°C, only eight of which suggest the phasing out of nuclear power[197].

Nuclear energy has already had a profound effect in limiting global warming and climate change. Statistics from the International Energy Agency (IEA) show that the operating of nuclear power stations has avoided the release of 56 gigatonnes of carbon dioxide since 1971. At current emissions levels, that is two years-worth of CO_2 emissions which have been stopped from entering the atmosphere[198].

c. True, but Not Really

Anti-nuclear activist and environmentalists tend to disagree with the nuclear industry on the issue of climate change and greenhouse gas emissions. Indeed, climate change politics and the United Nations Framework Convention on Climate Change (UNFCCC) process for a legally binding international treaty on climate change have been labelled a "lever by which to revitalise the fortunes of nuclear power" in a report by the *World Information Service on Energy* (WISE) and *Nuclear Information & Resource Service* (NIRS), entitled *Nuclear Power: No solution to climate change*[199].

The Greens/European Free Alliance party in the European Parliament said in September 2015:

> *"Lately there has been an increasing openness towards and support of nuclear energy in Europe. In the run-up to the COP 21 in Paris the lobbying efforts by the nuclear industry are intensifying. Huge amounts of money are spent to promote nuclear power as "low carbon technology" or "climate-friendly indigenous energy source", in order to encourage the construction of new nuclear reactors and prevent the shutdown of dangerous old reactors that cannot compete economically with clean energy sources like wind and solar power. This lobbying offensive clearly needs a Green answer."*[200]

The report acknowledges that "the actual fission process whereby electricity is generated does not release greenhouse gasses". However, it also says the idea that nuclear power provides a solution to climate change is based on the mythical "assumption that the generation of electricity by nuclear fission does not lead to greenhouse gas emission"[201]. The argument is based on the fact that various stages of the nuclear process such as uranium mining, milling and enrichment, as well as nuclear power plant construction, require huge amounts of energy. This energy typically comes from fossil fuels "and therefore nuclear power indirectly generates a relatively high amount of greenhouse gas emissions"[202].

The report goes on to say that according to a comprehensive study done by the Öko Institute in Germany, nuclear power emits about the same quantity of greenhouse gasses (35 grams of carbon dioxide-equivalent per kilowatt-hour) as electricity produced from a number of renewable sources (20 for wind and 33 for hydroelectric power). These emissions originate mainly from the mining of uranium, and during the transportation and the enrichment process for the production of nuclear fuel. It also includes estimated emissions for the decommissioning of a nuclear reactor[203].

The anti-nuclear activist argument moves on to say that, due to the "dramatic decrease" of the percentage of uranium content in ores, uranium extraction will become more difficult and energy consuming in the future, resulting in an increase in emissions[204].

Furthermore, anti-nuclear activists have attempted to calculate how many reactors are needed to reduce carbon dioxide emissions to the required levels to maintain a 2ºC temperature increase. The WISE/NIRS report estimates that it would be necessary to build 2,000 new reactors with a power output of 1,000 MW to have a "noticeable reduction" in global carbon dioxide emissions[205]. An article in *Nuclear Monitor,* entitled *Ten reasons not to nuke the climate*, says other studies have also produced between 1,500 and 2,000 large new reactors worldwide to replace coal-fired power plants. This would reduce global emissions by 20%[206].

The *Nuclear Monitor* article says that the construction of so many reactors would face several problems[207]:

- The resources required would make it impossible to implement other, more effective means of addressing climate change
- It would take an impossible amount of time to complete their construction and "addressing the climate crisis cannot wait for nuclear power"
- The operation of so many reactors would create the need for a spent nuclear fuel repository the size of the US' Yucca Mountain every three to four years
- There would be a "Fukushima-scale" nuclear accident every five years
- We would need "a dozen or more" uranium enrichment plants. Former US Vice-President Al Gore said that due to this "we'd have to put them in so many places we'd run that proliferation risk right off the reasonability scale".

However, "leaving aside the huge costs this would involve, it is unlikely that it is technically feasible to build so many new plants in such a short time," the WISE/NIRS report says. In addition, if this does indeed happen, "the world supply of uranium would be exhausted very quickly"[208].

Other anti-nuclear organisations argue that nuclear energy has had only a "marginal influence" to the emissions avoided compared to a scenario without nuclear power. The argument is that nuclear power plants have a "limited and insufficient" effect on emissions and therefore are not worth building. One nuclear activist recently said: "I do not know if we can have an argument against nuclear in terms of climate change" but it is "not rational" to invest in nuclear energy instead of alternatives such as renewable energy sources and energy efficiency measures[209].

d. Conclusion

Anti-nuclear groups argue that nuclear energy in fact produces greenhouse gas emissions, even if this is not as a direct result of electricity generation but in relation to other related activities. However, the argument that the construction of a nuclear power station requires the emission of greenhouse gasses does not take into account that the fabrication of a solar pv panel or wind turbine *also* includes such emissions.

A study conducted by Benjamin Sovacool, visiting and associate professor at the Institute for Energy and Environment at Vermont Law School, on the materials used for nuclear and renewable energy plant construction, found that a typical nuclear reactor requires about 217,000 tonnes per gigawatt equivalent (t/GWeq) of materials such as concrete, copper and steel. For wind, the amount is 411,000 t/GWeq and for solar pv it is 169,000 t/GWeq. Mr Sovacool also argues that: "large capacity wind turbines need magnets composed of neodymium, iron, and boron," as well as other rare earth minerals[210].

The anti-nuclear activist argument that construction of nuclear reactors is not realistically possible does not address the point made by the nuclear industry – that "nuclear is part of the solution". Rather, environmentalists address the issue as if all of the world's electricity should be coming from nuclear energy in order to frame the argument in the most unrealistic way. Furthermore, the arguments against nuclear energy's potential role in reducing greenhouse gas emissions can all be boiled down to the four basic anti-nuclear arguments discussed in this report.

UNDERSTANDING THE ANTI-NUCLEAR ENVIRONMENTAL MOVEMENT

e. A Pro-nuclear, Anti-climate Change Environmentalist

Interview with Stephen Tindale, former Greenpeace UK Executive Director and current Director of the next-gen pro-nuclear energy Alvin Weinberg Foundation[211]

I spent twenty years campaigning against nuclear as strongly as I could, but in the mid 2005 or so I began to realise that the climate crisis was so severe that we needed to rethink our opposition to technologies and approaches that we currently opposed. The melting of the Siberian permafrost in the summer of 2005 was really a tipping point for me. I thought this really is very serious and I then began questioning my opposition to nuclear. I was then working for Greenpeace and I couldn't have changed my line on nuclear while still working for Greenpeace, but I left Greenpeace in 2007. So after that I decided it was an obligation on me having been reasonably prominent in the anti-nuclear camp to say "I now accept I was wrong" and nuclear is a necessary part of the solution.

Nuclear is an important energy source in the UK, because we have nuclear power stations that are very well regulated. There isn't much public concern about their safety. We have quite a good safety record. The British public are supportive of nuclear. The question is, which energy source should we face out first and people concerned about climate are saying coal must go first before nuclear goes. Even if you want to be a hundred percent renewables, which not everyone does, but even if you do it's going to take many decades to get there, probably sixty or seventy at least. So nuclear is an essential low-carbon bridge technology for those decades. It's not the whole answer and technology tribalism for those concerned about climate change is one of the big failings. People saying nuclear is better than renewables or saying renewables are better than nuclear. We need both of them. In fact we need carbon capture and storage as well and we need energy efficiency. So, all the low-carbon options need to be adopted. We must end the squabbling between low-carbon energy sources and between those and energy efficiency and accept that it has to be an all of the above approach.

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CONCLUSION

UNDERSTANDING THE ANTI-NUCLEAR ENVIRONMENTAL MOVEMENT

The report *Understanding the Anti-nuclear Environmental Movement* was conceived by the International Youth Nuclear Congress to collect, structure, examine and describe the argument used by anti-nuclear activists. The report is the starting point for the creation of a communications tool through which individuals working in the nuclear industry can understand the history behind anti-nuclear activism, the basis for the arguments used and learn to communicate with anti-nuclear activists. The report has gathered a vast amount of theoretical papers, reports and publications which were used as a basis for the examination.

The subject of the birth of the environmental, anti-nuclear movement was presented using several books and academic papers which describe and analyse the history of this global phenomenon which shares a single aim (to stop nuclear energy). The report concludes that the rise of anti-nuclear activism from the age of nuclear weapons testing, and the general association of nuclear weapons and energy, are detrimental to the further development of the civilian uses of nuclear technology. Several accidents during weapons testing, most notably in the Pacific Ocean, bring about negative emotions which are directly associated with operational nuclear power stations.

The first section also showed that anti-nuclear activism takes different forms depending on the political, social and economic context in which it is manifested. In the USA, anti-nuclear activists have managed to lobby political structures with limited success to ban nuclear energy in several states. Such processes continue to this day, including continuous lobbying against the Yucca Mountain national spent nuclear fuel repository project. In Europe, due to differences in the political structures, protests which sometimes turned violent had to be staged because it was not possible to effectively lobby the government in the same ways.

A different story comes out of the Soviet Union, where anti-nuclear activism was born as a channel of nationalist and independantist sentiment which was banned at the time. Once the USSR disintegrated and states such as the Ukraine and Armenia obtained independence, the activism disappeared. In fact, in several cases, the previously 'anti-nuclear' organisations and activists soon realized that their newly-founded states required nuclear energy to become truly independent from the old Soviet system.

In Japan, academics display yet another form of anti-nuclear activism. Japan is the only country in the world that has first-hand experience in the suffering due to the use of nuclear weapons as well as nuclear weapons testing in the Pacific. However, the so-called 'nuclear village' composed of government and industry in a 'cozy relationship' managed (with extreme success) to separate the military and civilian uses of nuclear technology in the mind of the public. This made the accident at the Fukushima-Daiichi nuclear station more horrific for members of the public who had been led to believe that such events were not possible.

The remainder of the report includes two general parts: a description of the arguments used by anti-nuclear activists divided into four main categories, and four interviews with representatives of environmental organisations. The aim of the first is to display the main types of arguments used by anti-nuclear activists:

a. "*Nuclear energy is expensive*" (the economic argument)

b. "*Nuclear energy is dangerous*" (the safety argument)

c. "*There is no solution to nuclear waste*" (the waste argument)

d. "*Nuclear energy technology can result in the creation of nuclear weapons*" (the non-proliferation argument)

At the end of every sub-chapter, we summarise and give conclusions regarding each argument. It becomes apparent that the nuclear industry enjoyed a period of development when everything was acceptable and nothing was challenged. This created a culture where small events or non-safety related accidents were commonplace and technological hurdles were answered by throwing more money into research. In today's market economies governed by competition and a slow reduction in government spending, this tactic no longer works.

As regards safety, the industry can neither argue that nuclear power stations are "100% safe" because nothing can be completely safe (not even walking on the street), nor admit that the stations are not completely safe. This is a perfect example of a Catch 22 situation where no solution exists. In the spirit of full transparency, the industry tries to provide full disclosure of even the smallest problem at a nuclear plant, which tends to lead to unfounded panic. However, if this policy would stop, anti-nuclear activists would blame the industry for hiding secrets. After all – when the Chernobyl accident happened, there was no disclosure of information from the Soviet government, resulting in widespread contamination without the public's knowledge.

It is also a widespread viewpoint that no solution to nuclear waste exists and that it is unsafe. Several of the interviews and arguments described in this report show that anti-nuclear activists want the production of nuclear waste to stop by shutting down nuclear power stations. 'Disposal' and 'long-term storage' are not concepts which are accepted as a solution. The only way out is for politicians to take responsibility for the waste and make a final decision.

In the final sub-chapter, we return to one of the main issues with nuclear energy – it is inseparable from the military use of nuclear technology. Nuclear non-proliferation continues to be a hot topic, especially in today's discussions between the West and Iran on the development of a civilian nuclear programme. Several countries which have recently decided to develop nuclear energy technology, such as the UAE, have waived their right to process and re-process uranium – a condition to cooperation with the USA. However, India and Pakistan both developed nuclear weapons despite an international ban on nuclear testing and despite that neither state has signed the nuclear non-proliferation treaty. This shows that there is a misalignment between the theoretical ban on developing nuclear weapons from peaceful nuclear technology and the realistic threat of this happening.

Anti-nuclear activists and environmental organisations manage to capture the attention of both politicians and the public with passionate arguments on the scale of the threat that nuclear energy poses. The technical arguments and assurances on safety do not usually have much of an effect on calming these sentiments. For this reason there is a growing anti-nuclear feeling in many countries across the world while political elites tend to avoid the question of nuclear energy so they do not become mired in controversy.

The report also aims to present the way that anti-nuclear activists argue. The four main ideas presented in the report are clearly used by the three environmentalists we interviewed in their arguments. In this case, the author of this report decided to allow the readers to draw their own conclusions from the interviews. The questions which were asked were also intentionally kept the same in all interviews to allow the readers to compare answers.

The final interview, with a pro-nuclear environmentalist serves as an example for the future. This report aims to develop a communications tool to help nuclear scientists understand and answer anti-nuclear arguments. Mr. Bruno Comby has been involved with this process since the mid-1990s and his insights were helpful and can serve as examples of arguments to be used in answer to anti-nuclear activists. In fact, the arguments presented in this interview can be used with the general public by young nuclear professionals.

It is the opinion of the author, but not of the IYNC, of this report that there are numerous arguments which can be used to highlight the benefits of nuclear energy in answer to anti-nuclear or environmental activists. However, the main argument which has no answer is composed of real examples where the industry has made mistakes. Several such cases have been presented in this report where the nuclear industry has allowed radioactive releases to occur, safety protocols have been disregarded or 'unexplained' accidents have happened. Such instances provide anti-nuclear campaigners with fuel to be fed into the fire. In more extreme cases, such incidents or events have been covered up, which usually makes matters even worse. These cases make nuclear energy indefensible but young nuclear professionals need to be aware of the fact that such events happen and be able to be optimistic for the future where lessons can be learned from negative experiences.

The next steps for which this report can be used are to develop suggestions of how to reply to anti-nuclear activists. Using the four general categories of anti-nuclear arguments, ideas should be put together to create general answers to these arguments. Then, by looking at the way that these arguments are used by environmentalists, the responses should be prepared for use. One of the main advantages the environmentalist movement has over the nuclear industry is its use of passionate, emotional arguments when attacking nuclear energy. This report has laid the groundwork for young nuclear professionals to use pro-nuclear arguments in a similar way by evoking passion and emotion.

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