IPPNW Global Health Watch

Rethinking Nuclear Energy and Democracy After September 11, 2001

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1985 Nobel Peace Prize

IPPNW is a non-partisan, global federation of national medical organizations in 58 countries dedicated to research, education, and advocacy relevant to the prevention of nuclear war. To this end, IPPNW seeks to prevent all wars, to promote non-violent conflict resolution, and to minimize the effects of war and preparations for war on health, development, and the environment. IPPNW is the recipient of the 1985 Nobel Peace Prize.

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At the time this paper was presented,. **Jean-François Collin** was Directeur de Cabinet de l'ex-Ministre de l'Aménagement du Territoire et de l'Environnement. in France. He read the paper on behalf of then-Environment Minister Dominique Voynet.

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Photos and Credits

Page 6: Worker checking the precipitation tank at Tokai-mura, Japan, about one month later after the accident on September 30, 1999. Courtesy of Hideyuki Ban.
Page 24: Indian Point nuclear power plant, 24 miles north of Manhattan. Courtesy of Kyle Rabin, Riverkeeper, Inc.
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IPPNW Global Health Watch
Report Number 4

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Introduction

In April 2002, the affiliates of International Physicians for the Prevention of Nuclear War (IPPNW) in Germany, France, and Switzerland organized a symposium in the city of Basel, Switzerland, entitled "Rethinking Nuclear Energy and Democracy after 9/11." The symposium was motivated by a common concern as to the risks of civilian use of nuclear energy after the September 11, 2001 attacks on the World Trade Center in New York City and the Pentagon in Washington, DC.

The symposium considered several aspects of nuclear energy use, including the health and environmental consequences of accidents, the new threats of terrorist attacks against reactors, the costs of nuclear energy, the roles of democratic and civil society institutions, and the fact that nuclear plants nowadays—mostly due to public opposition—can hardly be sited anywhere in the Western world. Indeed, with very few exceptions the only chances for new nuclear plants are in countries with centralized governments, for example in parts of Asia and in Russia, and in countries such as France, where nuclear energy is the predominant source of electricity. Of paramount concern during the symposium was the abrupt awareness of the feasibility of a terrorist attack against a nuclear facility brought on by the events of September 11. Recent disclosures that there were, indeed, terrorist plans to attack US nuclear plants in an expanded September 11 operation by the al Qaeda network have only underscored such concerns.

Although the magnitude of the World Trade Center attack was enormous, a successful strike against a nuclear plant would have an even greater impact on civilian societies. Reactor failure and the breach of containment would result in radioactive fallout and contamination. As IPPNW members knowledgeable about the deadly impact of nuclear weapons, our responsibilities to appreciate and address this broader context have expanded in the light of such scenarios. We must ask ourselves today if the general arguments underlying our governments' nuclear policies—arguments based on decades of outdated assumptions as to energy growth and security—are still valid today and, therefore, acceptable to us as citizens. Can such policies successfully be modified? Is it possible to defend ourselves and our nuclear plants from terrorist attacks? Is the nuclear energy option really viable in today's insecure world, where the links between military and commercial uses of nuclear energy are well known? Can nuclear energy really contribute in any major way to the world's energy needs, considering its high costs and generally low public acceptance? Is nuclear energy, as is often claimed, essential for the economic growth of many developing countries, or should all nations not rather take their lead from those who are successfully creating a paradigm shift in the energy question? If the latter, we will do well to close down nuclear plants as soon as possible and shift to conservation and the use of solar, wind, biomass, and other renewable energy sources on the largest possible scale. These questions are of concern to every citizen and taxpayer living in the highly developed and technologically interdependent nations of the industrialized world.

This IPPNW Global Health Watch Report collects a number of talks by speakers at the Basel symposium. Their analyses and evaluations should give the reader a better knowledge of the security and safety issues involved with nuclear power plants. Nuclear policies in several European countries and in Japan, as well as some phaseout scenarios advocated by civil society groups, are discussed side by side with descriptions of some recent, serious accidents within power plants such as Tokai-mura in Japan and Chernobyl in the Ukraine. "Probabilistic risk analysis" is assessed and questioned. Flightpaths and their shocking proximity to large nuclear power plants in England are illustrated, as are mechanisms through which accidents or assaults with airplanes could lead to catastrophic plant failures. The financial liabilities of nuclear plant operators and insurance alternatives such as risk pooling are explored. The possible role of the military in providing security for the nuclear industry, as well as the role of the International Atomic Energy Agency (IAEA) in terrorism protection are examined. Decision making on nuclear issues in countries with democratic political institutions and robust civil society groups is discussed, as are the options of non-governmental organizations (NGOs) in advocating for changes in nuclear energy policy.

We hope that readers of these essays will come to share the serious reservations some IPPNW affiliates have with nuclear power. One goal of the symposium was to engage IPPNW doctors and concerned citizens in a much-needed conversation about our democratic rights to participate in the decision making processes related to the future of nuclear energy, including the transition away from nuclear energy and toward clean, renewable, and sustainable energy sources. We further hope that some six years after the adoption of the IPPNW resolution on "Nuclear weapons and nuclear energy—the links" in Melbourne, Australia (see facing page), the discussion on the issue of nuclear energy within IPPNW will intensify. In the meantime, the risks associated with our aging, inherently dangerous nuclear power plants only increase, as do the new threats from the likely selection of commercial nuclear reactors as targets of terrorist attack in the foreseeable future.

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Nuclear Weapons and Nuclear Energy—The Links

Bearing in mind that:

- The acquisition of nuclear-weapons-usable materials is the most difficult step in the making of nuclear weapons and the most important obstacle to proliferation.
- Commercial reprocessing produces plutonium that can be used to make nuclear weapons.
- The creation of a technical infrastructure and of plutonium (and/or uranium-235) is an inevitable accompaniment of the use of nuclear energy, and large surpluses of weapons usable commercial plutonium have been built up as a result.
- Nuclear power makes proliferation more likely and verification more difficult.
- All existing designs of nuclear reactors are vulnerable to accidents and can become targets of attack, for instance in conventional wars or due to terrorism, thereby creating an intolerable risk for health and environment.
- The commercial nuclear fuel cycle creates health risks for many generations in a manner similar to nuclear weapons production.
- There are far more satisfactory ways, from the point of view of economy and health, to meet the world's energy needs than nuclear energy.
- Unless the industrialized countries of the West make a firm commitment to phase out nuclear energy other countries are unlikely to give it up.

Be it resolved that IPPNW will work towards the following goals:

- Reprocessing, both commercial and military, should be stopped.
- No new nuclear power plants should be built or commissioned in any country and existing nuclear power plants should be phased out at most by the end of their current license periods.
- Separated plutonium, whether from commercial or military sources, should not be used in nuclear reactors to generate energy.
- Immobilization of plutonium should be used as the way to put all military and all separated commercial plutonium stocks into non-weapons-usable form.
- The financial, scientific, and technological resources of society should be used to meet energy needs in far more efficient and less dangerous ways than nuclear power.

The first steps to be taken should include:

- Informing all IPPNW affiliates about the links between nuclear energy and nuclear weapons.
- At this crucial juncture, creating a project to work in coalition with other groups to stop all military and commercial reprocessing.
- Creating a project to analyze the health implications of use of nuclear power as an energy source.

Resolution adopted at the 13th World Congress of International Physicians for the Prevention of Nuclear War, Melbourne, Australia, December 9, 1998.

Rethinking the Health Threats

The Chernobyl Disaster

A Human Tragedy for Generations to Come

Mycle Schneider

The accident at Chernobyl caught the world by surprise. Until Chernobyl, the worldwide nuclear industry claimed—to some extent continues to do so—that in the very-worst-case nuclear accident only a tiny percentage of the reactor core and its radioactive inventory would escape the containment for dispersion into the human environment. On that fateful April day in 1986, the fatally crippled number four reactor at Chernobyl spewed out not just a tiny fraction but almost all of its contents of deadly radioactive fission products.

We now know that in the immediate aftermath of the accident the by then failing Soviet system could not cope; its seemingly ad hoc actions and disorganized countermeasures more likely added to, rather than mitigated, the short and interim term health impacts. But now, almost two decades later, the world is dealing with the longer term consequences of Chernobyl and, moreover, there is no end in sight to the human legacy of this technological catastrophe.

"Even if there was this type of accident every year...I would consider nuclear power to be a valid source of energy."

—Morris Rosen, then Head of Department of Nuclear Safety of the Vienna-based International Atomic Energy Agency
August 1986[1]

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

—Kofi Annan
Secretary-General of the United Nations
July 2004[2]

On April 26, 1986, unit number four of the Chernobyl nuclear power plant exploded. Reconstruction of the event, so far as it is practicable today, suggests that a "power excursion" increased the nominal energy output within four seconds by a factor of 100, followed in an instant by a factor of 1,000 or more; then a hydrogen explosion peeled open the reactor containment leaving the molten nuclear fuel and the burning graphite reactor core open to the atmosphere. No modern reactor containment has been designed to withstand such huge levels of abrupt energy liberation. A graphite fire that lasted for several days pumped radioactivity high into the atmosphere, spreading around the northern hemisphere of the globe.

Chernobyl, 100 kilometers north of the Ukrainian city of Kiev, then in the Soviet Union, has become a synonym for industrial disaster, environmental pollution, and devastating health effects.

The farther you go away from "ground zero," the more surprising are the levels of impact; the closer you get and the longer you wait, the more terrifying are the overall health consequences, both the established ones and those to be expected.

Public Unconsciousness and Government Coverups

More than 18 years after the worst industrial catastrophe in human history, the lack of public information and collective consciousness of the terrible consequences of the event is stunning. The manipulation of data on the consequences of the Chernobyl accident started with the Soviet government failing to inform the public in 1986, when it was left to the Swedish authorities, after measuring increased radiation levels, to alert the world.

Today, the Moscow News recognizes that "the failed cover-up attempt denied people in the area information that could have saved lives."[3] In 2001, however, Prof. Yuri Bandashevsky, head of the Gomel State Medical Center in Belarus, paid for his significant work on the effects of internal radiation with an eight-year prison term. Amnesty International "believes that his conviction is related to his scientific research into the Chernobyl nuclear reactor catastrophe of 1986 and his open criticism of the state authorities" and adopted him as a "prisoner of conscience."[4]

Similar coverup attitudes could be seen in other countries. In France, Prof. Pierre Pellerin, then Head of the national Agency for Radiation Protection (SCPRI), declared in a formal statement dated May 2, 1986: "Neither the current situation nor its subsequent evolution justifies in our country any sanitary countermeasure."

Part of the uniqueness of the Chernobyl accident is the geographical dimension of radioactive contamination. The general public is not aware and is therefore totally ignorant that, for example:

- Still today, in 2004, in the United Kingdom, at 1,500 miles (2,500 km) distance from Chernobyl, a total of 382 farms with some 226,500 sheep on more than 200,000 acres (80,000 ha) of land remains under restriction order since Chernobyl.[i] Lambs are raised on contaminated pastures and, according to a complex field management scheme, have to be transferred to "clean" pastures for several months until the ratio of caesium in the meat (radioactivity per kilo) has decreased below legal limits (via a combination of the body weight gain as the lambs mature and the purging of their biological system).
- In the most severely contaminated areas of Southern Germany, soil contamination of up to 70,000 Bq/m^2 of cesium-137 was measured. Had they been in Belarus, Russia, or Ukraine these areas would have been designated a contaminated zone.[6] In 2004 German hunters are still compensated for contaminated wild game and some varieties of mushrooms and berries continue to exceed the limits.
- While farmers across the border in Germany and Italy ploughed their crops under following the accident, the French government considered that no precautionary measures were necessary. Although contamination levels of more than 10,000 Bq/l of iodine-131—20 times the EU legal limit—were identified in milk from Corsica, no advice was given in particular to protect children.[7] French government authorities admit that cesium contamination in some cases still reaches levels equivalent to the category in Ukraine, Belarus, and Russia that led the respective authorities to provide radiation monitoring, social protection, and countermeasures in agriculture. According to the French national Institut de Radioprotection et de Sûreté Nucléaire (IRSN), mushroom contamination today is variable, depending on the species, from 15 to 5,000 Bq/kg; wild boar, feeding on roots, glands, and mushrooms, show concentrations of cesium up to 2,000 Bq/kg, measured in the Vosges. "This situation will last for several decades yet."[8] No advice on food consumption follows this web-based information.

i. Originally, in 1986, a total of more than 3.3 million sheep on 4.2 million acres (1.7 million ha) of land were under restriction order.[5]

The French policy has been consistent over the past 18 years. In 2001, more than 200 people, including many who contracted thyroid cancer, filed a complaint along with the independent laboratory CRIIRAD for "involuntary attack on peoples' integrity" (atteinte involontaire à l'intégrité des personnes). No judgement had been pronounced as of July 2004.

Massive Evacuations

Of course, the health and economic impacts in western European countries, while they illustrate the exceptional geographical extent of the disaster, are small when compared to the tragedy sustained by millions of people throughout the areas closer to the Chernobyl plant. About 400,000 people have been dislocated from their homes in the worst Chernobyl fallout regions in Belarus, Ukraine, and Russia. Some families had to move several times because certain of the new locations turned out to be equally contaminated as the places they left in the first place.

Comparing Chernobyl with past peacetime catastrophes puts the magnitude of the human suffering into perspective. In the devastating San Francisco earthquake of 1906, "perhaps the most discussed earthquake in history,"[9] an estimated 225,000 people were left homeless, from a population of about 400,000. In the Chernobyl area, it was as if in 1906 the entire population of San Francisco had to leave its place for good and, as a Ukrainian photographer put it, "step in a new life, naked with no home, no friends, no money, no past and with very doubtful future." Not only did people quickly rebuild their homes after the San Francisco earthquake, but about one hundred years later the city has doubled its population to 800,000. The worst Chernobyl fallout regions will likely remain a mere list of ghost towns[ii] for centuries to come.

For many people, particularly in the West, large-scale evacuations and the enforcement of an exclusion zone around the destroyed reactor have given the false impression that the remainder of the population must have been safe and, therefore, lives in safe places today. The reality is different. The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) states:

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

ii. More than 160 municipalities had to be evacuated.

the lingering effects of the Chernobyl disaster. Chronic health problems, especially among children, are rampant."[10]

Contaminated territories, as officially designated, account for 23% of the surface area of Belarus, 5% of Ukraine, and 1.5% of the Russian Federation. About 19% of the population of Belarus lives in such areas, 5% of the population of Ukraine, and about 1% of the population of the Russian Federation.

The right to compensation payments, health holidays, new housing, and schools for registered Chernobyl victims does not mean that the support is actually being provided. A special mission on behalf of the United Nations Development Program (UNDP) and UNICEF[11] notes that in 2000 in Belarus only 60% of the 500,000 people who were eligible for health holidays were able to leave the area. The mission report states:

> "In practice, funding for the Federal Chernobyl programmes has declined steadily in recent years. This has left many projects half completed. Thus the Briansk Region in Russia has only been able to build 62% of the housing needed for relocation, 14% of the schools and 27% of outpatient centres. According to Briansk administration data, there are more than 1,200 uncompleted houses, water supply stations and other public buildings in the Region."

Who pays attention to the wounded, the economically mutilated, and the homeless?

Widespread Long-Term Contamination

In the immediate aftermath of the Chernobyl explosion, those people living and working in the area of the developing radioactive plume were exposed to radiation in air and water and from contaminated foodstuffs. While the radioactivity in the air was especially a short-term problem, most of the radiation was deposited on the ground within days after the accident. This has resulted, over the years since the initial release, in the development of more complex uptake routes, many of which are difficult to manage on a dose-minimization basis.

The chimney effect of the fire led to significant portions of the radioactivity travelling long distances; climatic conditions—wind, rain, and atmospheric stability—determined the overall dispersion patterns and areas of radioactive fallout. Some of the health effects that are obvious now are due to short-term exposure, in 1986, to short-lived radioisotopes (particularly radioiodine-131, with a relatively short half-life of 8 days, which fixes on and concentrates in the thyroid gland, heightening the risk of cancer) that were present in significant concentrations in air, water, and food. Other emitters have intermediate half-lives, in particular cesium-137 and strontium-90, with periods of, respectively, about 30 and 28 years, with radio strontium fixing mainly in the bones and cesium in various organs. Particular problems are caused by radioisotopes with long half-lives, such as plutonium-239 (24,000 years), with the respiration of a few dozen millionths of a gram capable of triggering fatal lung cancer.

Of all of the radioisotopes released at Chernobyl, radio cesium is reckoned to have caused by far the largest share—perhaps up to 75%—of the interim and longer term radiological impact of the Chernobyl accident.[iii]

Nor will the Chernobyl health legacy fade away quickly. Some 70% to 90% of the cesium, 40% to 60% of the strontium, and up to 95% of the trans-uranium elements such as plutonium remain in the upper root-inhabited layer of the soil, which attests to the "continuing danger of radioactive contamination of agricultural production and of food, fodder and medicinal crops."[12]

Health Problems

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

There are literally thousands of studies into health effects of the Chernobyl catastrophe. The following description, therefore, can only constitute an incomplete overview of the kind of problems that have been identified. None of these symptoms are getting any better with time. On the contrary, most indicators tend to point to a future that will be even worse.

Demographic Disaster

Following the Chernobyl accident, the birth rate in many of the regions of serious fallout began to decline rapidly. In the Gomel region in Belarus, between 1986 and 2000, the birth rate fell by 44%, mortality increased by over 60%, and natural population growth vanished from +8% to -5%. These trends can be observed in Belarus, Ukraine, and Russia, and seem to be "a consequence of factors such as emigration and the difficult economic circumstances facing these countries, which have led to increased ill-health and caused young couples to defer having children. Demographic factors have contributed strongly to the pattern of morbidity and mortality in the affected areas."[11]

General State of Health and Various Disabilities

The UNDP-UNICEF mission sums up in 2002:

> "The health and well-being of populations in the affected regions is generally very

iii. One has to imagine that the total quantity of cesium released to the environment during the accident is estimated to be 26 to 27 kg, a volume that would fit into a backpack.

depressed....Life expectancy for men in Belarus, Russia and Ukraine, for example, is some ten years less than in Sri Lanka, which is one of the twenty poorest countries in the world and is in the middle of a long drawn out war....Cardiovascular disease and trauma (accidents and poisonings) are the two most common causes of death followed by cancer (this situation is not confined to the Chernobyl affected regions)....The health situation encountered in the populations living in the affected territories is thus a complex product of inputs ranging from radiation induced disease, through endemic disease, poverty, poor living conditions, primitive medical services, poor diet, and the psychological consequences of living with a situation that was frightening, poorly understood and over which there seemed to be little control."[11]

Moreover, the situation is worsening at a frightening speed. In 1991, the Ukrainian government had registered around 2,000 individuals with "disabilities connected with the Chernobyl disaster," but their number had risen to almost 100,000 by January 1, 2003.[13]

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Psychosocial Problems

About 14%—or 15,000—of the 110,000 children examined under the US Agency for International Development's (AID) Chernobyl Children Illness Program (CCIP) were found to be in need of assistance.[14] "Children found to have severe depression and suicidal tendencies are given immediate consultation by the mobile team psychologists. Early in the program, CCIP staff found that on-site crisis intervention was needed because many children had no one in whom they could confide or were so depressed that they had seriously considered suicide."[15]

Chronic Health Effects

Yuri Bandazhevsky has demonstrated the serious accumulation of radioactive cesium in children's organs. Bandazhevsky considers that "the Cs-137 burden in the organisms of children must be further investigated and the pathogenesis of different diseases intensively studied. This is an urgent need, as radiocontaminated agricultural land is being increasingly cultivated and radiocontaminated food is circulating countrywide."[16] In October 2003, while Bandazhevsky was still in prison, the science journal Cardinale published an article by the Belarusian scientist and his wife that revealed two spectacular research results:[17]

- The bad news: While more than 80% of the children who have a body charge of between 0 and 10 Bq cesium-137 per kilogram body weight showed a normal electrocardiogram (ECG), two thirds of the children with a burden of 11-36 Bq/kg presented ECG anomalies and 80%-90% of the children with body burdens between 37 and 100 Bq/kg had abnormal ECG.
- The good news: A cure with a substance based on apple pectin—known in the treatment of intoxication by heavy metals—reduces the body charge of cesium-137 three times faster than the application of non-contaminated food alone. Under the condition that the reduction in the body burden of cesium is significant, there seems to be a significant curing effect on degenerated heart functions (cardiomyopathies).

Dramatic Increase in Thyroid Cancers

The Belarus government has stated that from 1986 to 2001 there were 8,358 cases of thyroid cancer in Belarus alone, of which 716 occurred in children, 342 in adolescents, and 7,300 in adults.[12] According to a recent study,[18] age-adjusted average thyroid cancer incidence rates in Belarus have increased between 1970 and 2001 almost 9-fold (+775%) among males and 20-fold (+1,925%) among females. The relative 11-fold increase among males (+1,020%) and the dramatic 34-fold increase among females (+3,286%) in "high exposure" areas vastly exceeded increases among males (+571) and females (+250%) in "lower exposure" areas of the country. Dramatic increases in thyroid cancer incidence rate ratios were noted among both males and females and in all age groups. The highest incidence rate ratios were observed among people from "higher exposure" areas, ages 0-14 years at time of diagnosis.

Thus, it might be concluded that children always pay the highest price.

Hereditary Effects

Beyond the devastating consequences for the living, the Chernobyl effects have moved into successive generations. Sperling et al reported that in West Berlin, as early as January 1987, there was a significant increase in Down's syndrome; a cluster of 12 cases was found, compared with two or three expected. After excluding factors that might have explained the increase, including maternal age distribution, only exposure to radiation after the Chernobyl accident remained.[19]

Vladislav Ostapenko, head of the Belarus Radiation Medicine Institute, stated in March 2000: "It is clear that we are seeing genetic changes, especially among those who were less than six years of age when subjected to radiation. These people are now starting families." Ostapenko reports that girls in affected areas had five times the normal rate of deformations in their reproductive systems and boys three times the norm. Each year, 2,500 births were recorded with genetic abnormalities and 500 pregnancies were terminated after testing.[20]

The Belorussian geneticist Gennady Lazjuk has elaborated a statistical record of the ten most common hereditary defects observed among newborns in Belarus since 1982. The scientist compared the number of birth defects before (1983 to 1985) and after (1987 to 2000) the Chernobyl accident. According to Lazjuk, the incidence of defects rose in proportion to the radioactive contamination of the areas.[21,22]

A study by Yuri Dubrova presented at the February 2003 IPPNW-Switzerland Conference on "Health Consequences of Chernobyl in Children" on germline mutation concludes that an exposure to 0.2-0.4 Gray can lead to a 1.6-fold increase in minisatellite mutation rate as found in families from Ukraine and Belarus. These data, therefore, provide "strong evidence that the elevated minisatellite mutation rates in the Ukrainian and Belarus families can be attributed to post-Chernobyl radioactive exposure."[23]

This brief review has explored the statistics of fact, leading to the axiom that the grand-grand-grandchildren of our children will suffer from the effects of an accident to a machine that was built to provide a service to people.

That machine generated power for two years, four months, and four days but the human suffering and health detriment will go on for generation after generation. Who would dare to say it was worth the risk?

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The Criticality Accident at Tokai-mura

Hideyuki Ban

Tokai-mura is a village with a population of 34,000 and with 12,000 households (mura means village and, thus, Tokai-mura means Tokai Village). The very first development of Japanese nuclear energy occurred in this village. On October 26, 1963, the first Japanese nuclear power plant began generating electricity. One third of the village's population now works for the nuclear industry; another one third of the residents are involved with Hitachi, a conglomerate that extends its trade to nuclear power-related business.

The criticality accident at JCO (a uranium conversion company) on September 30, 1999 was the first of its kind in Japan and was also the first time that workers lost their lives due to a radiation exposure accident at a commercial nuclear facility. A number of residents in the vicinity of the accident site were also exposed to radiation and had to be evacuated—another first, as was the compensation paid to local residents in the wake of such an accident. The accident had a great impact on the residents, changing their minds from active promotion of nuclear energy to a desire for a nuclear phase-out. Moreover, in response to this accident, a review of nuclear disaster measures was carried out, which led to the establishment of an emergency system with a new off-site center as its main project.

The Citizens' Nuclear Information Center (CNIC) established the Comprehensive Review Committee of the JCO Criticality Accident and has been conducting an investigation of the cause of the accident and its impact on the local citizens. The Committee consists of 17 members, who published a report in 2000. In February 2001, the Committee carried out a public discussion with the Nuclear Safety Commission (NSC) on the causes of the accident. A second investigation on the impact on the residents is being carried out. While continuing its fact finding mission into the causes of the accident, the Committee monitors the trial of JCO and its employees.

Causes of the Accident

The accident began with a sudden flash of blue light at around 10:35 am on September 30, 1999. Criticality was reached while workers were preparing a uranyl nitrate solution. There were 124 workers at the JCO plant at the time of the accident. This figure includes the three workers who were directly involved in this process and who were seriously exposed. Two of those three have died: one on December 21, 1999, three months after the accident, and the other on April 27, 2000 from multiple organ failures caused by radiation exposure.

Criticality continued for 20 hours and was finally contained in the early morning of October 1 following an extremely dangerous operation carried out by JCO workers, who had no alternative but to extract the coolant water surrounding the precipitation tank that contained the uranium solution. Even then, they only just managed to stop the chain reaction. The coolant water was acting as a reflector of neutrons that were contributing to the fission chain-reaction. According to an investigation after the accident, an estimated 1 mg of uranium-235 had fissioned (2.5×10^{18} fissions) during those 20 hours.

The neutron monitors at the Naka Laboratory of the Japan Atomic Energy Research Institute, approximately two kilometers away from JCO, detected a large amount of neutrons released due to criticality at the plant. In addition, radioactive rare gases and radioactive iodine were released into the environment. Because the ventilation system was left on and was not properly adjusted, radioactive gases were continually released for about a month until the plant was equipped with charcoal filters to absorb and block such gases.

The Tokai-mura municipal office voluntarily decided to evacuate approximately 180 people who were within a 350-meter radius of the JCO plant to a community center 1.5-2 kilometers away from the plant, five hours after the accident. At around 2 pm, while the discussion about evacuation was going on, an air dose of 0.75mSv/h (measured by gamma ray detectors) was recorded at one place in the area surrounding the accident site. At this stage, however, neutrons were not being measured. The evacuation started at 3 pm and was completed around 8 pm that night (about 10 hours after the accident). The evacuees stayed at the community center for more than two days. Moreover, 310,000 people within a 10 km radius of the JCO plant were requested by Ibaraki Prefecture to stay indoors from the evening of the day of the accident (September 30) until 3 pm the next day. The Prefectural government reportedly made this order out of fear of the greater harm that would arise if criticality resumed.

The direct cause

Workers had poured uranyl nitrate solution containing 16.6 kg of uranium, with an enrichment level of 18.8%, into a precipitation tank in order to evenly homogenize the solution. The precipitation tank was not supposed to be used for homogenization. Furthermore, according to the government regulations, no more than 2.4 kg of uranium enriched to such a high concentration should have been poured into a tank. Since there is an inherent danger of criticality at such facilities, the form, shape, and size of the containers must be designed with anti-criticality specifications to counter criticality even in the case of human error. This is called "geometrical control." The most significant error was that there was no geometrical control of this precipitation tank.

The underlying cause

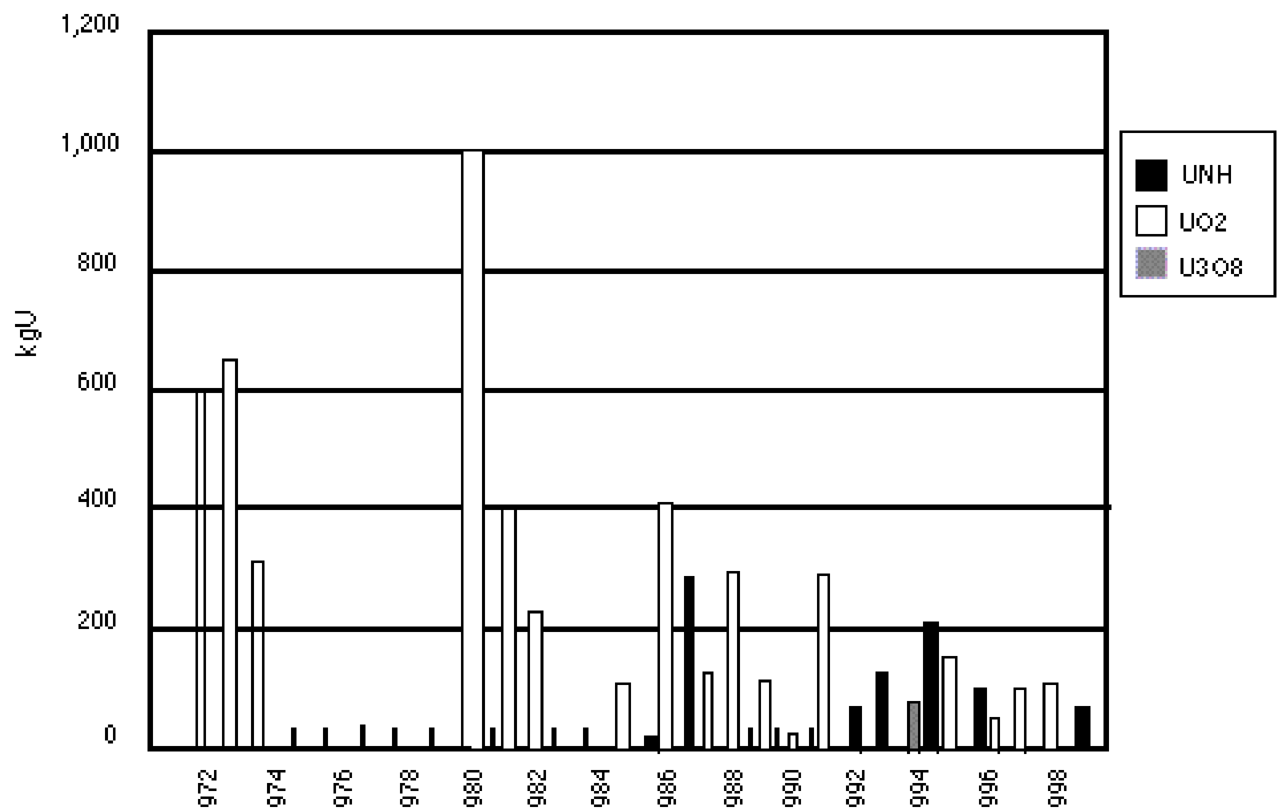
JCO's main work consisted of reconversion of low-level enriched uranium from UF_6 to UO_2 for light water reactors (LWRs). The company triggered the accident, however, when it was preparing uranium for the Joyo Fast Experimental Reactor (Joyo FR). Preparing uranium for Joyo was different from what JCO normally did, because it required a process called "redissolution" in order to obtain the final product in the form of uranyl nitrate solution (see process described below). Business for Joyo made up only 1% of JCO's earnings, however, and thus the company placed very little importance on training its employees for this process. The three employees directly involved with the process that led to the accident had no experience with redissolution and were not educated or informed on the risks of criticality. In addition, the company had not undertaken the particular process that led to the accident for three years.

Though JCO shared a large part of the market for reconversion in Japan with Mitsubishi Nuclear Fuel Co., it had been steadily losing sales due to the effects of increasingly severe competition. Moreover, it was under immense pressure from the utility companies to lower prices. Table 1 shows that JCO sales plummeted from 3.25 billion yen in 1991 to 1.8 billion in 1998, while staff numbers were reduced from 162 in 1991 to 110 in 1998.

Science and Technology Agency Safety Assessment System

The precipitation tank, the source of the accident, was the only equipment in the JCO Conversion Test Building that was not designed with geometrical control. Upon conducting a safety assessment for installation licensing of the plant, this lack of geometrical control was discussed within the Science and Technology Agency (STA). The agency decided to settle the matter by checking the mass control specified by JCO. In other words, STA was satisfied by simply checking the amount and the concentration of uranium that would be put into the precipitation tank. The agency's conclusion was that no crit-

Figure 1. Joyo's track record for uranium



icality accident would take place if the employees would only abide by the specified amount.

The officer in charge of this assessment in the STA was a person seconded from the Power Reactor and Nuclear Fuel Development Corporation (PNC, now the Japan Nuclear Cycle Development Institute, JNC). Thus, the safety assessment was being carried out directly by a stakeholder.

In order to prepare a uranium solution for use in making fuel for the Joyo FR at the JCO plant, U_3O_8 (tri-uranium oct-oxide) was dissolved once in order to be refined, then was calcinated into uranium oxide, then was dissolved once again with nitrate to provide uranium in the form of a solution (Figure 2).

The second dissolution is called "redissolution" and the uranium reached criticality during this process. To be precise, the accident was triggered during the last process of redissolution, when the employees attempted to homogenize the solution. Instead of transferring the concentrated nitric acid from a beaker to the storage column (itself an unapproved procedure), they transferred it directly to the precipitation tank. As mentioned above, the precipitation tank had no geometrical control. JCO insisted that they carry out this homogenization process to simplify the products' transportation procedures. Redissolution of uranium for Joyo required a high concentration of uranium (370g/liter). JCO did not install proper equipment for preparing a uranium solution of such a high concentration, however, and instead used equipment already existing in the plant.[1] In order to avoid installing new equipment, a complicated and

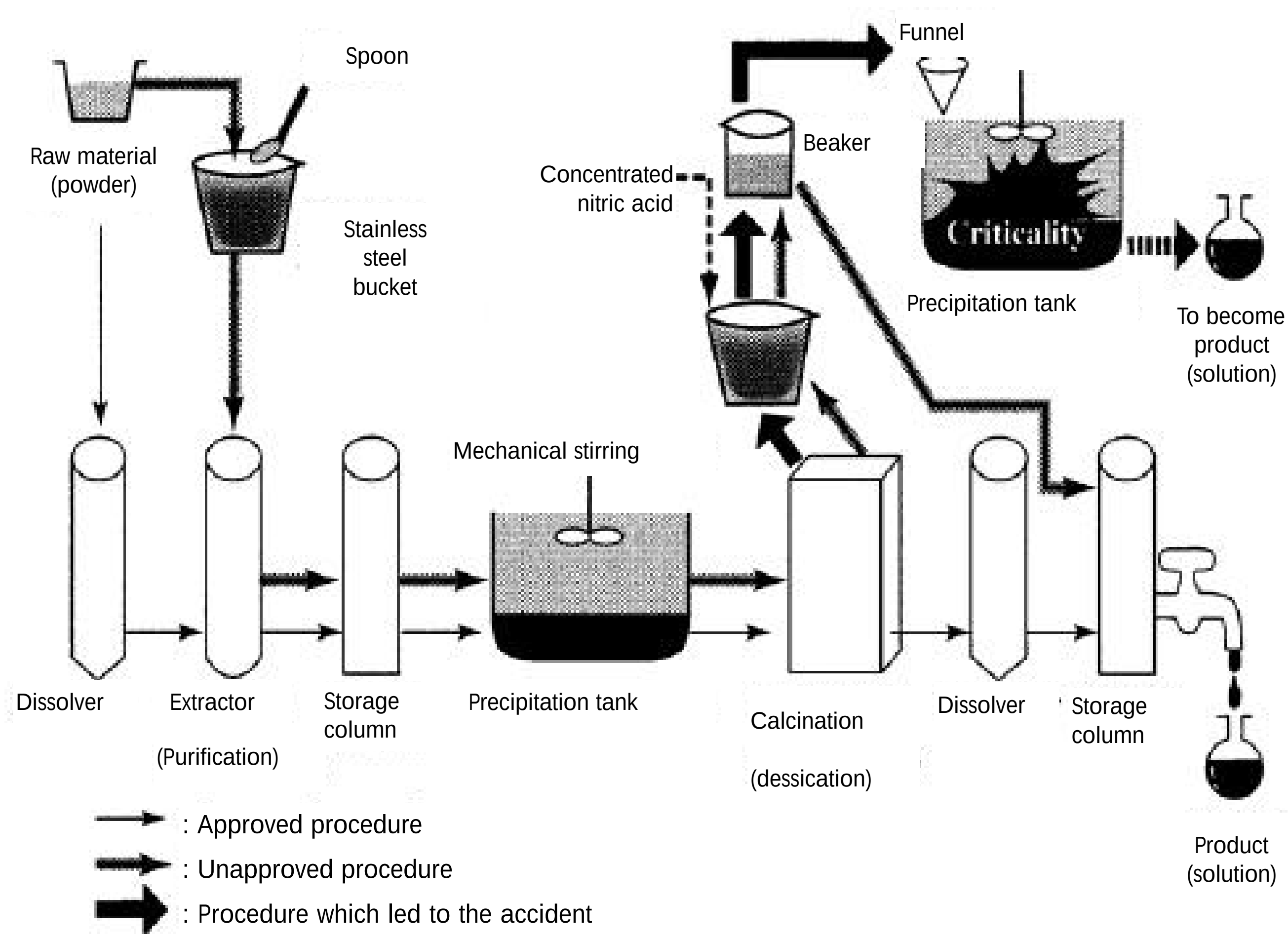
Table 1. Data on JCO

Year	1991	1995	1998
Staff	162	145	110
Engineers with college degree	34	33	20
Output (t)	552	495	365
Sales (million yen)	3,250	2,806	1,800

Source: NSC Subcommittee on JCO Criticality accident.

1. Dissolution tank 24 liter; 100 gU/liter, Storage column 40 liter; 60 gU/liter, Precipitation tank 53 liter; 45 gU/liter, Product (uranyl nitrate) 6.5 liter; 370 gU/liter, (Uranium Processing Facility Criticality Accident Investigation Committee of the Atomic Safety Commission)

Figure 2: Process at the conversion test building



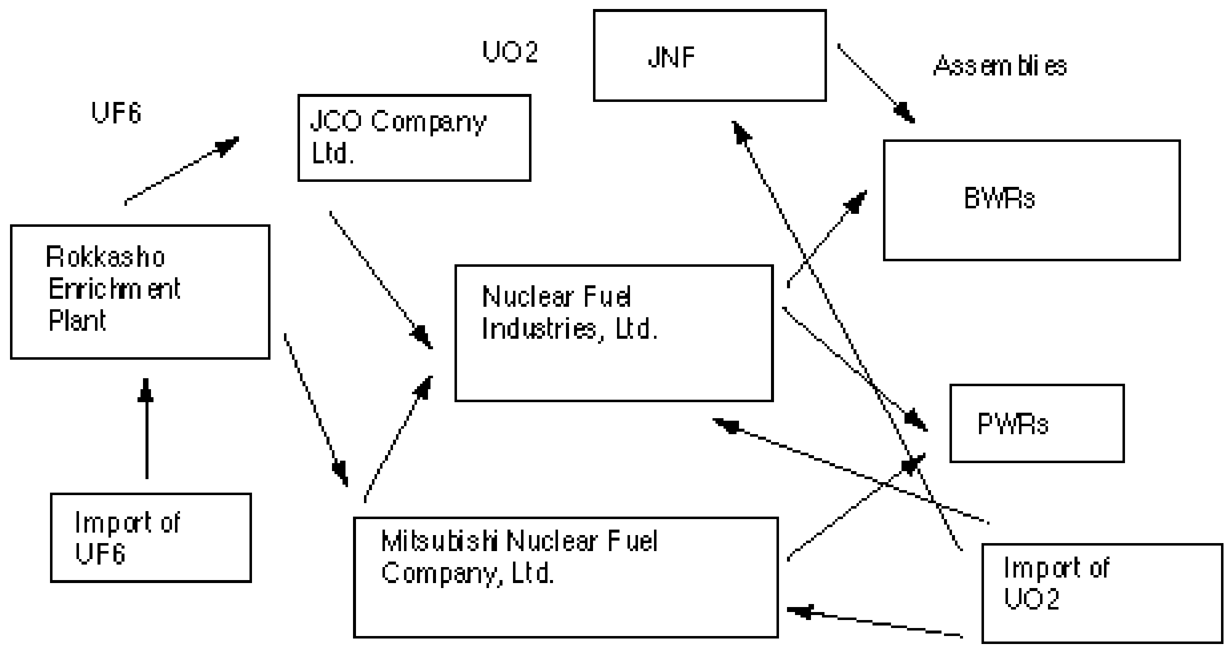


Figure 3: Japan's nuclear fuel cycle

impractical manual was drawn up to carry out the process with existing equipment. This manual was approved by the STA. It is rather natural, then, that in efforts to simplify the process, the employees used procedures that deviated from the impractical manuals and used equipment not designed for redissolution. The STA should have made the installation of equipment for redissolution a prerequisite before giving approval for JCO to carry out redissolution.

PNC had been involved in the accidents at Monju in 1995 and at the Tokai Reprocessing plant in 1997. PNC was exonerated from serious responsibility for these accidents, but was made to change its name to JNC. JNC made a contract with JCO, which was commissioned to purify the uranium dioxide or uranyl nitrate for Joyo FR. At the time of the accident, the workers were instructed to dissolve U_3O_8, imported from France, into the uranyl nitrate solution. The materials were transported from JNC to JCO, and were then sent back to JNC in the required form.

The contract between JCO and JNC stated that JNC held the responsibility and the power to control the process as the need arose. The contract also stated that JCO could make changes to the manufacturing process simply by consulting—and then receiving a verbal approval from—JNC. Thus, it is clear that JNC was aware of—and approved of—the procedures taken at JCO. JCO has never followed the process approved by STA and JNC should have known this from the contract. There is, however, no evidence that JNC approved the use of the precipitation tank for homogenizing the uranium solution.

Moreover, JNC was in a position from which it could have easily been aware of the dangerous procedures that were being taken at JCO. From these two points, it can be seen that JNC had responsibility for indirectly causing this accident by placing that particular order. Nevertheless, the report of the government's investigation committee does not mention JNC.

Disconnected Nuclear Fuel Cycle

When natural uranium is imported in the chemical form of UF_6, it is enriched at the Rokkasho Uranium Enrichment Plant. The enriched UF_6 for pressurized water reactors (PWRs) is transported to Mitsubishi Nuclear Fuel Co.,Ltd, where the whole process from reconversion to fuel fabrication is carried out. On the other hand, UF_6 for boiled water reactors (BWRs) is transported to JCO, where the reconversion process is undertaken and UO_2 is then shipped to two nuclear fabrication facilities, JNF and Nuclear Fuel Industries, Ltd. Thus, there are only two reconversion plants in Japan. Due to the accident, JCO's operation license was cancelled. Therefore, a part of the nuclear fuel cycle is now stopped. Since electric companies have long-term contracts with uranium producers abroad, there is a move toward the resumption of the operation of JCO. At this point, however, there is no prospect of that. Currently, UF_6 for BWRs enriched at Rokkasho is exported to the US and companies manufacturing BWRs fuel are managing their production by depending solely on imported UO_2.

Improvement of Emergency Plan

Mayor Murakami of Tokai-mura made the brave decision to evacuate village people. In the emergency plan at that time, he was supposed to wait for a decision by the emergency advisory body under the NSC. At the time that the mayor made his decision, however, such a body had not even been established. The Nuclear Safety Commission (NSC) itself responded slowly, and was hardly functioning at all.

From the lessons learned after the accident in December 1999, the Nuclear Disaster Prevention Law was established. This law specifies the system in which emergency evacuation is to be carried out under the authority of the Prime Minister's crisis management. Until the new system was established, mayors of municipalities were supposed to make a judgment after receiving advice from the NSC. There was strong criticism of this system, in response to which it was decided that the central government would take responsibility for countermeasures in a case of a disaster. The law has made it mandatory for companies to prepare an accident countermeasure plan and to set up a disaster countermeasure section. It also calls for the strengthening of the role of the central government and a speedy reaction by it during a nuclear disaster. To meet this requirement, a so-called Off-site Center has been planned for construction near each nuclear facility. This law, however, requires countermeasures to be taken for the downwinders from one to 10 km away only when the radioactive leak has reached 10,000 times the normal reading (air dose of 500 micro SV/h). This is a completely inadequate regulation for preventing the exposure of residents to radiation.

The amount of compensation paid by JCO was unprecedented, but was only a portion of the total damage caused by the accident.

Compensation For Damages

Ibaraki Prefecture announced that direct damages from this accident have reached a total of 15.3 billion yen (US $125 million) for 7,000 cases (Table 2). Direct damages, for example, include compensation for the forced closure of businesses and suspension of agricultural activities and fisheries. Perceived damage is not included in what is called "direct damages." In addition, real estate prices have not been evaluated and are still falling as are the prices of agricultural products.

JCO has paid all of the 15.3 billion yen compensation, with assistance, from its parent company, Sumitomo Metal Mining, which sold land and other assets to cover the costs. The amount of compensation paid by JCO was unprecedented, but was only a portion of the total damage caused by the accident. No compensation has been paid to those who complain that their health has deteriorated.

Radiation Effects From Accident

Radioactive products

A monitoring post approximately 7 kilometers away from the JCO plant detected radioactive gases that were carried by the wind. The wind direction altered four times, rotating a full 360 degrees during this period. The radioactive gases were heading directly towards the community center used for evacuation from 9 pm on the day of the accident until midnight. The government officials said that the exposure dose was low. Monitors in Tokai-mura, however, detected radiation more than 20 times higher than normal.

Since the filtering devices at the plant were insufficient, almost all the radioactive rare gases and iodine were released into the atmosphere. These included nine isotopes of krypton, nine isotopes of iodine, and six isotopes of xenon. Some of these isotopes and their daughters were detected in the environment. Looking at effects on human health, especially skin irritations caused by exposure to radiation, we should not ignore the beta-rays emitted from all of these isotopes, which were released as a direct result of the criticality accident. JCO claims that there is no relation between beta rays and skin irritation, but there are grounds for thinking that the relationship is significant.

Radiation Exposure of Employees and Residents

Exposure dose that was made public

The Nuclear Safety Commission asserts in the government's investigation report that 664 people were exposed as a result of the accident (Table 3). Among local residents, 131 were exposed to doses higher than the annual dose limit of 1 mSv and 27 who were exposed to doses higher than 5 mSv. According to this report, no employee other than the three directly involved in the accident was exposed to doses higher than the annual dose limit of 50mSv for employees.

Widespread exposure can be assumed due to the fact that neutrons were detected at a laboratory approximately two kilometers away from the JCO plant. Thus

Table 2. Damages inside Ibaraki Prefecture at the end of Oct. 2000

Category	Amount of damages (million yen)
Commercial Industry	9,596
Agricultural, Livestock, Fishing Industry	2,504
Tourist Industry	1,472
Transportation Industry	211
Other Industries	750
Reduction of Tax Revenue (expected)	769
Total	15,302

the number of exposed people reported by the government is just the tip of the iceberg. In addition, the exposure dose was reviewed twice and the numbers decreased with each review. The government succeeded in lowering the dose values by calculating effective doses, which based the radiation weighting factor from neutrons on outdated information from The International Commission on Radiological Protection (ICRP) publication 26 (1977). For example, a dosimeter worn by one of the employees who took part in the coolant extraction detected 120 mSv. Following the government's review of exposure doses, however, the final report said that this employee had received a dose less than 50 mSv. (It was important for the government to keep the official report

Table 3. Exposure Dose

Dose (mSv)	JCO Employees	Accident response task-force members	Citizens in locality at time of accident	Total
<1	41	202	104	347
1=<-<5	82	51	104	237
5=<-<10	15	7	18	40
10=<-<15	6	0	6	12
15=<-<20	10	0	2	12
20=<-<25	8	0	1	9
25=<-<30	1	0	0	1
30=<-<35	2	0	0	2
35=<-<40	0	0	0	0
40=<-<45	1	0	0	1
45=<-<50	3	0	0	3
Total	169	260	235	664

(Figures do not include 3 employees directly involved in accident.)
(Source: STA's Request—October 13, 2000)

Table 4. Correlation between distance from JCO site and number of people experiencing physical abnormalities

Distance (radius, m)	Abnormalities on day ofaccident (%)[1]	Abnormalities experienced up to time of survey (%)[2]	Number of all respondents from area (%)
350	6 (15.0)	15 (37.5)	40 (100)
350-500	41 (21.9)	78 (41.7)	187 (100)
500-1,000	39 (15.7)	106 (42.6)	249 (100)
1,000-1,500	38 (11.9)	93 (29.2)	319 (100)
1,500-2,000	35 (9.0)	122 (31.5)	387 (100)
Total	15.9 (13.5)	414 (35.0)	1,182 (100)

Notes:
1) X2=19.768 d.f.=4 p<0.001
2) X2=31.209 d.f.=16 p<0.05

Table 5 Do you or did you have any of the following symptoms? (In Feb.2000)

Symptoms	Persons	Ratio %
Nausea	17	1.4
Headache	68	5.8
Dizziness	24	2.0
Rash or itching	29	2.5
My body feels weak	60	5.1
I get tired more easily	70	5.9
I catch colds more easily	51	4.3
I get a slight fever sometimes	10	0.8
I readily get nosebleeds	10	0.8
I have palpitations	29	2.5
I have no appetite	30	2.5
I can't sleep	75	6.3
I have nightmares	30	2.5
I suddenly have vivid flashbacks of the accident	111	9.4
I'm afraid to approach the accident site	214	18.1
I feel uneasy and irritable	81	6.9
I can no longer concentrate	45	3.8
I don't want to see any news about the criticality accident	113	9.6
I've become lethargic	44	3.7
I feel extremely anxious	233	19.7

Table 6. What do you think about the following opinion?

"Japan should not build any more nuclear power plants."

	Counts	Ratio %
I agree.	489	41.4
I mildly agree.	263	22.3
I mildly disagree.	100	8.5
I disagree.	133	11.3
Don't know.	161	13.6
NA36	3.1	
Total	1,182	100.0

Table 7. What should be done with the many nuclear power facilities in Tokai-mura?

	Counts	Ratio %
They should continue operation as at present, with attention to safety.	420	35.5
They should be gradually reduced.	233	19.7
Dangerous facilities should be shut down immediately.	395	33.4
Other	27	2.3
Don't know	65	5.5
NA42	3.5	
Total	1,182	100

of exposure dose under 50 mSv since this is the annual exposure dose limit for occupational exposure.) In 2001, however, Japan had adopted the radiation weighting factor specified in ICRP publication 60 (1990). As a result, despite their efforts to reduce the estimated doses, the government's final figures on exposure doses from the accident will increase twofold.

Government Propaganda

The STA and the NSC promote the view that if the exposure dose is lower than 200 mSv, there is nothing to worry about. They claim that they base this argument on ICRP publication 60, paragraph 64, which discusses health effects from radiation exposure of Hiroshima and Nagasaki atomic bombs victims. They have taken what they need, however, and have manipulated the information to back up their claims.

The Comprehensive Review Committee on the JCO Criticality Accident formed by CNIC conducted an investigation of local residents who were near to the JCO plant at the time of the accident.[2] The outcome of this investigation shows that many felt ill or had skin irritations after the criticality accident (see Tables 4 & 5).

There were 129 people who experienced one symptom, 21 with two symptoms, and 9 with three or more symptoms immediately after the accident and until the next day. At the time of the survey (February 2000), 145 people cited one of 20 items (see Table 5), 97 people cited two items, 99 people cited 3-5 items, and 73 people cited 6 or more items. When the relation between the distance from the JCO plant in a straight line and the complaints of more than one physical abnormality were examined by chi-square test, significant differences were detected at the 1% level. When the correlation coefficient is examined, the distance from the scene of the accident to the residences

2. The investigation was carried out in February 2000. 946 households randomly chosen from residents of three zones (350 meter radius, 500~1000 m radius, 1~1.5 km radius and 1.5~2 km radius of the JCO plant) were polled. Each household was provided three sheets. 1,082 people from 692 households answered the questionnaires. The second investigation of the 692 households who answered the first questionnaire was carried out in February 2002 by the same committee. In the second investigation 1,008 people out of 535 households responded.

and the physical abnormalities experienced on the day of the accident and also at the time of the survey have a statistically significant negative correlation.

The Committee carried out the second investigation on the local residents who responded to the first investigation and found that some cases of physical abnormalities had increased. For example, nausea increased to 3.8% from 1.4%, headaches to 10.2% from 5.8%, dizziness to 5.8% from 2.0%, rash or itching to 5.8% from 2.5%, feeling weak to 7.7% from 5.1%, and palpitations to 4.5% from 2.5%. Local residents are still suffering from damages caused by the criticality accident.

Investigation of Effects on Local Residents

According to the mayor of Tokai-mura, the villagers' perception of nuclear energy has dramatically changed. Before the accident, the villagers were proud of their village's status as "the Nuclear Village." Now they feel that the word "nuclear" itself gives a negative impression of their village. It is symbolic that the words "the Nuclear Village" were removed from the village sign board after the accident.

A poll of the local residents of Tokai-mura was conducted in February 2000 by the Comprehensive Social Impact Assessment of the JCO Criticality Accident, initiated by CNIC. The results show that 63.7% are against any further development of nuclear energy (Table 6) and 53.1% felt that nuclear business in the village should be downsized from that point on (Table 7). The results of this poll were largely reproduced in a second poll conducted in February 2002.

According to the polls conducted by the Japan Public Opinion Poll Association, 80-90% of those polled were worried over the safety of nuclear energy. The Japanese public is now actively interested in renewable energy sources and wants to retreat from nuclear energy.

Final Comments

According to the government's safety assessment, a criticality accident should not have taken place at the JCO Plant—yet the accident did occur. The harm reported here was caused by the fission of just 1 mg of uranium-235. The criticality accident at JCO foretells further such damages.

As a result of the accident, the mindset of Tokai-mura changed greatly and the number of people who want a shift from the nuclear-dependent village policy has increased. This is also shown in the opinion polls. Nationwide, too, there are more voices of concern about the dependence on nuclear energy and more opinions favoring nuclear phase-out.

Since the accident, two referenda have been held in Japan. One, held in May 2001, was on the loading of MOX fuel[3] at the Kashiwazaki-Kariwa nuclear power plants. The other, held in November 2001, was on the siting of a nuclear power plant in Miyama-town in Mie prefecture. In Kashiwazaki-Kariwa, the voter turnout was 88.14%, of which 53.4% were opposed to the use of MOX in reactor No.3. The referendum in Miyamacho was originally set up by the promoters, but the opposition reached 67% with a 90% turnout, which led to the rejection of the siting. This shift in public opinion was brought about by the JCO criticality accident.

3. MOX fuel: Uranium-plutonium mixed oxide fuel. The agreement between the Governors of Niigata and Fukushima Prefectures, the Mayors and Tokyo Electric Power Company (TEPCO) regarding Japan's MOX program was cancelled after a scandal at TEPCO which occurred three years after the JCO criticality accident.

Uncertainty in Risk Estimates from External Radiation

Ian Fairlie

Estimating risk from radionuclide intake involves, among other things:

- the use of biokinetic models to estimate radionuclide distributions within organs/tissues;
- the use of dosimetric models to estimate absorbed dose (grays) in organs/tissues from each type of radiation emitted;
- weighting each component of absorbed dose by factors to take account of the likelihood that the energy deposited by each type of radiation will lead to biological damage (radiation weighting factors—wr—derived from RBEs and SEEs);
- summation of weighted components to obtain equivalent doses (sieverts) in each organ/tissue;
- multiplication of equivalent doses to each organ/tissue by the probability (risk) that unit dose will lead to a health effect.

Uncertainties exist at each stage: this paper is concerned with uncertainties related to fatal cancer risks per unit absorbed dose used in the last stage. These risk estimates are derived from epidemiological studies. Current estimates of risks for individual organs and tissues, and the overall risk for the whole body, rely heavily on epidemiological studies of exposures to external radiation. By far the most important of these are the life span studies (LSS) of Hiroshima and Nagasaki survivors, who had relatively large, acute exposures to gamma radiation and high-energy neutrons.[1,2,3] For a smaller number of nuclides, including radon and radium, sufficient epidemiological information is available (e.g., from uranium miner studies) to derive risk estimates independent of LSS-derived estimates. In the case of exposures to radon + daughters, a difference exists between risk estimates derived from epidemiology and those derived from dosimetry using the revised ICRP lung model [4]. Dosimetry-derived risk estimates are a factor of three greater than those derived from epidemiology.[i]

Two US studies[5,6] and a joint US/EU report[7] have examined uncertainties in fatal cancer risk estimates used in radiation protection. The corollary of "uncertainty" is "reliability," that is, the degree of confidence that can be placed in the ultimate risk estimates for fatal cancer.

EPA Report

The 1999 US Environmental Protection Agency report described a method for estimating uncertainties in current risk projections. The uncertainty in whole-body risk estimate was treated as the product of several independent sources of uncertainty, including

- sampling errors in the LSS;
- the model used to project risks into future;
- transfer to other populations;
- errors in A-bomb dosimetry;
- uncertainty in extrapolation of observations at high acute doses to chronic low dose conditions, called the dose and dose rate effectiveness factor (DDREF); and
- diagnostic misclassification.

A subjective distribution was assigned to each source of uncertainty, which defined the probability that the assumption with respect to this source of uncertainty either underestimated or overestimated the risk by any specified amount. The joint probability distribution for the uncertainty due to all sources combined was then calculated using Monte Carlo techniques.

Uncertainty analyses were performed for the risks from uniform, low-LET irradiation of the whole body, lung, and bone marrow. For whole body and bone marrow, the upper limit on the 90% confidence interval was about two times higher, and the lower limit about three times lower, than the EPA's respective nominal risk estimates (5.75×10^{-2} per Gy for whole body). For whole body, the uncertainty was distributed approximately lognormally, with a mean risk of 5.4×10^{-2} fatal cancers per Gy. The 90% subjective confidence intervals were 2.0×10^{-2} and 1.1×10^{-1} fatal cancers per Gy. In the case of lung, the upper bound was about a factor of two higher,

i. More precisely, epidemiology suggests a dose of 5 mSv per Working Level Month (WLM) whereas lung dosimetry suggests 15 mSv per WLM and the lower bound about a factor of five times lower, than the EPA's nominal estimate. In all cases, the major uncertainty was the DDREF chosen.

NCRP Report

Similarly to the EPA report, the 1997 NCRP report quantified uncertainty in cancer risk projections using subjective probability distribution functions (PDFs) to represent current knowledge of the individual factors that contribute to risks. These PDFs were drawn up by estimating the range of possible values; probable weightings were assigned using current knowledge and data. Uncertainty distributions were then propagated for each factor using Monte Carlo sampling techniques (100,000 runs).

The NCRP paper identified and discussed the following sources of uncertainty:

- statistical uncertainty in lifetime risk coefficient estimated from the available information on number of excess cancer deaths among Hiroshima and Nagasaki cohorts;
- estimates (under- or over-reporting) of cancer deaths in cohorts, resulting in a net bias due to under-reporting;
- estimates of equivalent doses for LSS cohort; including:
  - -random errors in overall doses,
  - -estimated doses from gamma rays,
  - -equivalent doses from neutrons, including values of Wr and magnitude of fast neutron dose;
- projection of observed risk to lifetime risk;
- transfer of risk coefficients in the Japanese population exposed in 1945 to other populations;
- extrapolation from acute exposure at high dose and dose rate to a chronic or fractionated exposure at low dose and dose rate (DDREF).

The NCRP report identified additional sources of uncertainties not taken into account in its report. These included the following:

- the dose-response model could be supralinear or have a threshold. All other dose response possibilities were essentially accounted for with the range of DDREFs from one to five;
- the LSS sample was not representative of the Japanese population;
- changes in the shielding conditions in the seconds following bomb detonation may have had a net average impact on dose received;
- the gamma rays at Hiroshima and Nagasaki were of relatively high energy (2 to 5 MeV) and risk estimates are applied to the more biologically effective low-energy radiations, i.e. gamma, x-ray , or beta radiation;
- uncertainty was introduced by using intestinal dose as a surrogate dose for all solid tumors.

The NCRP report found that the uncertainty distribution for a US population of all ages was approximately lognormal with a mean of 3.99×10^{-2} per Sv and 90% confidence intervals of 1.20×10^{-2} to 8.84×10^{-2} per Sv. It concluded that values of lifetime risk could range from about one quarter to about two times the present estimate of 5% per Sv. It did not recommend changes in the risk estimate. It stated that the eightfold range of uncertainty was considerable but smaller than ranges found using environmental models. The NCRP report identified the main source (40%) of uncertainty as the value chosen for DDREF; followed by all the factors listed above as ones it had identified and discussed added together (30%); transfer to different populations (20%); statistical uncertainties (4%); and all other factors (1%).

NRC/EC Report

The third study, by the US Nuclear Regulatory Commission and the European Commission, elicited uncertainties in dose/risk estimates from a number of US and European experts.[8] Using a formal methodology, the uncertainties provided by the experts were combined to obtain an overall uncertainty distribution that took account of differences between the various subjective assessments.

The NRC/EC report estimated that for an acute dose[ii] of 1 Gy (low-LET) to a hypothetical EU/US population of all ages and both genders, the median risk was 10.2%. 90% confidence intervals were 3.47% and 28.5%, that is, a factor of three higher and lower than the median. This uncertainty range is larger than the NCRP and EPA ranges. The NRC/EC study also carried out uncertainty analyses for a number of specific organ cancers. The uncertainty intervals for these were much larger than for all cancers, often extending over three orders of magnitude.

DDREFs

In all studies, the choice of DDREF was the largest source of uncertainty. DDREFs are used to extrapolate from risks derived from high-dose, high-rate exposures to estimate risks from low-dose, low-rate exposures. Considerable debate continues over the existence and value of DDREFs. DDREFs are closely linked to the shape of the dose response curve on which much uncertainty exists particularly at very low doses.

Evidence for the value of any DDREF comes from two sources: curve-fitting and human/animal data. On the former, damage from low-LET radiation at low and moderate doses is commonly modelled as a linear-quadratic (LQ) function of dose ($R = aD + ßD^2$). At low doses, the relationship reduces to a linear function of dose. Experiments on animals or mammalian cells indicate the contribution from the quadratic term is negligible below about 0.2 Gy. In this domain, multi-track effects are presumed to be negligible and, as a result, the response is expected to be independent of dose rate. According to the LQ model, the linear component of the dose response is expected to be predictive of the risk at very low doses and dose rates. The DDREF, in this view,

ii. At high dose, high dose rate.

is obtained from the ratio of the slopes calculated using linear and LQ fits to the data, respectively. Under the assumption of an LQ dose response, the maximum likelihood estimate for the DDREF derived from LSS data is about 2 for leukemia and about 1 for solid tumors.[9,10]

With regard to human/animal data, very limited data on humans bears directly on the question of extrapolation to low dose rates. Data on medically irradiated cohorts indicates dose fractionation has little effect on radiogenic thyroid cancer risks or breast cancer risks.[11,12,13] On the other hand, the apparent absence of radiogenic lung cancers in fluoroscopy patients receiving fractionated doses of X rays suggests a larger DDREF may be applicable to lung cancer.[12,13] Tumorigenesis in animals most often yields DDREFs in the range of 2 to 5.[10,14]

As a result, assigning an uncertainty distribution to DDREF requires subjective judgement. For all cancers combined, the NCRP report suggested a triangular linear distribution spanning the interval 1 to 5, peaking at 2. The EPA report adopted a uniform distribution from 1 to 2, falling off exponentially for values greater than 2.

Novel Cellular Effects

Evidence exists that low dose radiation may induce or activate cellular DNA repair mechanisms through a so-called "adaptive response," leading to suggestions that low doses may be protective against cancer.[15] The effects seen to date, however, have been essentially short term; for this reason, UNSCEAR[14] concluded that the relevance of hormetic effects to radiation protection may be limited. At this point, too little is known about adaptive response to influence estimates of risk at low doses and dose rates. It is also theoretically possible that low dose radiation could stimulate other protective mechanisms, e.g., programmed cell death (apoptosis). A detailed review of radiation-induced adaptive responses was contained in the 1994 UNSCEAR report.[14]

The US reports did not assign probabilities to a dose threshold or protective effect of low dose rate radiation. Likewise, they did not assign weights to the possibility of a heightened sensitivity at low doses (DDREF < 1). Neither alternative is incompatible with the epidemiology data, which are generally uninformative about risks at very low doses. Currently, evidence from radiation biology for these effects remains at an early stage.[2]

Other effects of ionizing radiation on cells, including genomic instability[16,17,18] and bystander effects[19,20,21] could eventually lead to some fundamental revisions in the theory of radiation carcinogenesis and estimates of risk at low doses. Our present understanding of these phenomena remains limited, however, and it is still too early to make recommendations on the uncertainties in risk estimates which may result from these effects.[22]

Age-at-Exposure and Gender Dependencies

Dependencies on age-at-exposure and sex are important matters: ICRP risk estimates apply to populations. These dependencies were discussed by RERF[1] in the latest of its series of reports on cancer mortality in the cohort of A-bomb survivors. The RERF team stated that the excess lifetime risk per sievert for solid cancers for those exposed at age 30 was estimated at 0.10 for males and 0.14 for females. Those exposed at age 50 had about one-third of these risks. Projection of lifetime risks for those exposed at age 10 was more uncertain. The team stated that under a reasonable set of assumptions, estimates for this group ranged from about 1.0 to 1.8 times the estimates for age 30.

For leukemias, the RERF team stated that the excess lifetime risk for those exposed at either 10 or 30 years of age was estimated at about 0.015 for males and 0.008 for females. Those exposed at age 50 had about two-thirds this risk. These risks were calculated using absolute risk projection models.

From these findings, females appear to run 40% higher risks of exposure to radiation than males for solid cancers, but half the male risk for leukemias. In addition, children exposed at 10 years run up to 80% greater risks to radiation for solid cancers but not for leukemias. Those exposed at age 50 years run lower (two thirds) risks of leukemia compared to those exposed at 30, and considerably lower (one-third) risks of solid cancer.

Use of Incidence vs Mortality Data

A comparison between Japanese A-bomb survivor incidence and mortality data[23] concluded that, for all solid tumours, the estimated excess relative risk at 1 Sv for incidence was 40% larger than the excess relative risk (ERR) based on mortality data. For some cancer sites, the difference was greater. These differences reflected the greater diagnostic accuracy of incidence data and the reduced numbers of radiosensitive but relatively nonfatal cancers, such as breast and thyroid, in the LSS mortality data.

Non-fatal skin cancers, most of little clinical significance, are not included in the Japanese incidence estimates. With regard to these cases, the EPA report stated:

> "If—as often occurs for external exposure to a beta emitter—the dose is predominantly to skin, the inclusion of all nonfatal cases could increase the incidence estimate by up to a factor of 500. For uniform whole-body irradiation, the total cancer morbidity estimate would be increased from 850 x 10^{-4}/Gy to 1350 x 10^{-4}/Gy. A small fraction of nonfatal radiogenic skin cancers are serious in that they require substantial medical intervention and may result in significant residual impairment or disfigurement. Although there appear to be no published estimates of this fraction, it is not expected that inclusion of these serious nonfatal cases would appreciably increase the incidence for uniform, whole-body irradiation. However, in cases where the dose to the skin is high compared to other organs, inclusion of serious nonfatal cases might increase the incidence by as much as an order of magnitude."

The EPA report concluded that, although Japanese incidence data had not been used so far to develop comprehensive risk projections for other populations, it was likely that this data would increasingly serve as a basis for radiogenic cancer risk estimates in future.

Specific Cancers

This paper mostly considers whole body risk estimates; important differences exist, however, for risks of specific types of cancer, as noted in the NRC/EC report. On the risks of childhood thyroid cancer, the NRPB commented[24] on the uncertainty regarding the lifetime risk to a child exposed to a thyroid dose of 30 mGy (the currently recommended Emergency Reference Level) of developing thyroid cancer. This was in the range 1:1,000 to 1:10,000, i.e. a 10-fold range of uncertainty,[iii] although Annex A of the same report restricted this to around a factor of 2-5.[iv] This may be compared with the NRC/EC report's finding that 90% confidence intervals for uncertainties in thyroid cancer risks were <10-3% and 0.71% from 1Sv, i.e. a range of three orders of magnitude, with a median value of 0.06%

Conclusions

The NCRP and EPA uncertainty reports conclude that whole body risks of fatal cancer to populations from external exposures to low LET radiation lie within a factor of 2 up and down of their current risk estimates . This is similar to the UNSCEAR 2000 estimate of uncertainty for acute low-LET risk (not specific to childhood leukemia) which is a factor 2 each way, plus a DDREF uncertainty of a further de facto 2.

The main source of uncertainty in these reports is the value chosen for DDREF, on which differences of view remain. If a DDREF of 1 were applied instead of the present recommended value of 2, current fatal cancer risk estimates would increase from 5% to 10% per Sv. The EPA Addendum stated that several reviewers of its Main Report had recommended that, in view of what appeared to be a linear dose response in LSS data, the EPA should assign a finite probability to a DDREF of 1, at least for solid tumors. The BEIR V report (NAS 1990) was unenthusiastic about the application of DDREFs >1 to humans. The 1994 UNSCEAR report had stated that a DDREF near 2 was applicable. The 2000 UNSCEAR report stated that risk estimates "could" be reduced by 50% to take account of low-dose, low-dose-rate exposures.

Considerable sex and age dependencies exist which are not currently reflected in ICRP risk estimates for populations. Significant dose response differences also exist between solid cancers and leukemias. Considerable differences also appear to exist between the magnitudes of uncertainty for whole body risks and for specific cancer risks. The use of mortality instead of morbidity data may result in underestimations of total health detriment. Finally, our present understanding of the phenomena of hormetic effects, genomic instability, and bystander effects remains limited. It is too early to make substantive recommendations on the uncertainties in risk estimates that may result from these phenomena.

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iii. Bullet (h) of Executive Summary, page 5.
iv. Bullet (d), page 27.

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Between Stable Iodine Prophylaxis and Evacuation

Keith Baverstock

Iodine prophylaxis is a countermeasure that can protect the thyroid against irradiation in the event of exposure to radioactive iodine that might result from an accident to a nuclear power plant. In these circumstances, radioiodines are an important potential hazard, especially to children, as the Chernobyl accident has so clearly demonstrated. Some 2,000 cases of thyroid cancer in those who were children at the time of the accident have been confirmed as resulting from exposure to radioactive iodine.

Iodine is a very volatile element. At reactor operating temperatures it is a vapor that diffuses rapidly as soon as the fuel pin containment is breached. If there is no secondary containment and the primary containment is breached, release to the environment is inevitable. The Chernobyl accident illustrated how far radio-iodine could travel after release: excess cases of childhood thyroid cancer have been observed more than 500 km from the site of the accident.

Children are at greater risk than adults for two reasons. First, the thyroid is a small gland, weighing about 1 gram at birth and 20 grams in an adult. The thyroid avidly absorbs and retains iodine once it has reached the blood. Since the radiation dose is the energy absorbed per unit mass of tissue, the dose per decay of I-131 in the thyroid will be higher the younger the child. Second, a child's thyroid is much more sensitive, per unit of dose, to the carcinogenic effects of ionizing radiation than is that of an adult. This is probably due to the biological function of the thyroid in controlling growth. Normal thyroid cells have little capacity to divide further after adulthood is reached.

Although inhaling iodine from a contaminated cloud released during an accident can be an important source of I-131, much larger populations are generally at risk from ingesting the isotope in milk. Since children and adults consume roughly equal amounts of milk, children get much higher doses to the thyroid as well as being much more sensitive to the effects of the exposure.

Of course a nuclear accident requires much more by way of response than protecting children from radioiodine. But since iodine is almost always present in fallout from an operating reactor, it represents a typical "microcosm" embedded in the much larger problem that an accident such a Chernobyl poses.

How Should We Respond to a Nuclear Accident?

There are three important factors to consider:

1) the important routes of exposure;
2) the important characteristics of the exposed populations;
3) means to minimize exposures.

Exposure routes depend on one's location in relation to the source of the exposure and on certain behavioral characteristics. Close to the source (say within 5 km) inhalation could be a serious hazard but it lasts only while the released radioactivity is in the air. At greater distances (say >20 km) ingestion will be the greater threat, particularly where fresh milk produced locally is consumed, because radioactivity deposited on pastures can enter the food chain. This threat lasts for a few months in the case of iodine (decades for radioactive cesium), but radioactive decay and weathering of the pasture reduces the level of fallout with time.

Age is the most important population characteristic, because of the size of the thyroid. Gender is also a factor because of pregnancy (fetal thyroid activity starts about three months after fertilization) and lactation status. Women are also about three times more sensitive than men to the carcinogenic effects of radiation on the thyroid.

Five potential countermeasures can be taken to reduce the exposure of populations to radioiodines. They are:

- Evacuation
- Shelter
- Food controls
- Agricultural controls
- Stable iodine prophylaxis

Implementing Countermeasures

The ICRP recommends that countermeasures should only be introduced if they carry a net benefit in terms of the dose they can avert. This means that not only the effectiveness in averting dose but also the risks entailed in taking the countermeasure need to be considered. Thus, in effect, a cost/benefit analysis has to be performed with respect to each countermeasure.

Evacuation, therefore, should be used close to the source and preferably before the exposure starts, i.e., as a pre-emptive action. Evacuation is essential for high-risk groups. Providing shelter close in, though less effective, is also appropriate, and can be used in conjunction with other measures, such as stable iodine prophylaxis. Sheltering may be preferable to evacuation if there is a risk of exposure during the evacuation. Agricultural controls are a good measure at all distances to reduce ingested doses if sufficient stored fodder is available. This may not be the case at all times of the year. Food controls are an effective measure at all distances to reduce ingested doses. Stable iodine prophylaxis is a good short-term measure close to the source of the exposure. At greater distances it can also be used for children for a few days only, while other measures are put in place.

Table 1. Comparison of the benefits of countermeasures with their risks and costs.

Countermeasure	Benefits	Risks and costs
Evacuation	Immediate removal from the threat	Accidents, exposure during the process, social disruption, policing
Sheltering	Reduced exposure to inhalation hazard	More-or-less risk and cost free; but social implications if prolonged
Agricultural controls	Reduces amount of radioiodine entering food chain	Risk free but stored fodder required while cattle are off pasture
Food controls	Reduces uptake of radioiodine by the thyroid from ingestion	Few risks but milk has to be thrown away; administrative costs in redistribution of supplies
Stable Iodine/ Prophylaxis	Complete blocking of radioiodine uptake for about two days if given at the right time.	No risk to children; some risk or potential risk for adults and neonates. Tablets have to be made, stored, and distributed.

All these countermeasures affect people, who should understand what is being done and why. Parents may be separated from their children; specific instructions (e.g., "children should take tablets but not adults") must be heeded; some milk supplies may be safe to drink while others are not. Issues such as these may arise and cause concern and anxiety, in themselves public health detriments. Thus, ongoing public education is an important aspect of an effective response to an accident.

A number of lessons have been learned about best practices:

- Protecting public health just from exposure to radioactive iodine in the event of an accident involves a complex web of factors. The optimum response will be "case specific," depending on many circumstances that cannot be anticipated. Therefore, each accident has to be considered in its particular context.
- Public health expertise is essential in developing the case specific response.
- The necessary administrative structures to coordinate the response must be in place, must be regularly reviewed, and must be tested with exercises.
- Public education is essential if the psychosocial effects are to be minimized.

In some countries these lessons are applied in practice, but in many they are not. Adequate preparedness requires a substantial investment in planning, exercising, expertise, and public education, in a highly coordinated way, among many players.

The cost of not investing in this infrastructure, however, can be great. In Ukraine, the costs incurred by the Chernobyl accident have been at least $5.6 billion between 1992 and 2000. The collective dose to 2055 is estimated to be 6,000 person-Sv. That is $93,000/ person-Sv. The full cost, including those incurred between 1986 and 1992 and costs still to come, may well be closer to $200,000/person-Sv.

As stated earlier, protection from radioactive iodine is a "microcosm" of a much greater issue. We have seen the results of exposure to iodine after Chernobyl. It is far from certain that we have seen all effects that are to come, or indeed, that are present now, in the exposed populations.

Responding to reactor accidents in order to protect public health is a complex matter involving many disciplines, but most notably, public health expertise. The most effective response will be that tailored to the specific circumstances of the accident, carried out within a well-coordinated framework that is subject to regular review and exercising. As the threat of exposure to fallout does not respect national borders an international coordinating role has to be fulfilled.

Rethinking the Terrorism Threat

Terrorism Threats and Nuclear Power

Edwin S. Lyman

On the morning of September 11, 2001, American Airlines Flight 11 flew directly over the Indian Point nuclear plant, 35 miles north of New York City, on its way to the World Trade Center. It is an unmistakable fact that if al Qaeda had desired it, one or even both of the hijacked airliners from Boston could have directed their enormous destructive energy at the Indian Point reactors or spent fuel pools. This realization has dramatically focused the attention of the American public, politicians, and the media on nuclear power issues that had not been prominent since the great anti-nuclear demonstrations of the late 1970s. Industry and government assurances that the risk of nuclear power accidents are low are meaningless when the threat of deliberate attacks is considered.

The threat of aircraft attack has also made the public aware of the other ways that terrorists could attack nuclear plants to cause a meltdown. Nuclear plants are vulnerable to attacks by well-trained and equipped groups from land or sea, large vehicle bombs, or insider sabotage.

Despite the level of public concern, the US Nuclear Regulatory Commission (NRC), has been extremely reluctant to order systematic upgrades of security at nuclear plants to protect against September 11-scale assaults. The NRC's lackadaisical attitude stems from a combination of pressure from the nuclear industry and an apparently sincere belief among some NRC Commissioners that nuclear plants pose little threat to public health and safety, even in the event of a successful terrorist attack. Without unrelenting public pressure and stringent Congressional oversight, it is unlikely that the glaring security vulnerabilities at US nuclear plants will be corrected in a timely manner. Thus the risk that terrorists will be able to cause an "American Chernobyl" is not likely to go away any time soon.

Nuclear Plant Security Before September 11

The NRC has had regulations in place since the 1970s for protecting nuclear plants against commando attacks, but the regulations were not designed with the current level of terrorist threat in mind. Nuclear plant licensees are required to protect against the "design-basis threat" (DBT): an attacking force consisting of "several" well-trained individuals operating as a single team, armed with automatic weapons and explosives, and assisted by an insider (who either actively participates in the attack or only supplies information). Following the 1993 car bomb attack on the World Trade Center, the DBT was enhanced to include a "four-wheel drive vehicle bomb." Airborne attack of any sort, including the use of a helicopter to gain entry, is not considered. More detailed information about the DBT, including the number of attackers, the types of weapons carried, and the size of the vehicle bomb is considered "safeguards information" and is not publicly available.

The objective of the attacking force is "radiological sabotage"—that is, damage to the plant causing a radiological release that could endanger the public health and safety. In operational terms, this is assumed to be equivalent to causing a core meltdown. Although not every core melt accident would lead to a large radiological release to the environment, terrorists would be able to facilitate such a release by mechanically breaching the reactor containment or causing a containment bypass.

The consequences of a Chernobyl-type radiological release at a US reactor could be devastating. Many reactors are located in close proximity to large cities, or are in the midst of suburban areas with rapidly growing populations. NRC computer models predict that protective actions, such as potassium iodide administration and evacuation, would be required for individuals well beyond 50 miles from plant sites. The models also estimate the occurrence of hundreds to thousands of fatalities from acute radiation exposure, and tens to hundreds of thousands of eventual cancer deaths from lower doses.

To protect against the DBT, nuclear plant licensees must develop a security plan, describing in detail the strategies that would be used by armed responders to prevent the attackers from destroying enough equipment to cause a meltdown. Procedures must also be in place for controlling access of persons and vehicles to the plant, including vehicle barriers to maintain safe setbacks from truck bombs. To guard against the insider threat, licensees must also have procedures for granting unescorted access to sensitive areas of the plant.

Simply having a security plan on paper, however, is not a guarantee that the plan will work in practice. For this reason, in 1991 NRC introduced a program to test nuclear plant security by carrying out exercises involving mock attacks, known as the Operational Safeguards Response Evaluation (OSRE). The OSRE program was intended to test both the effectiveness of the protective strategy and the skills of the armed response force.

In OSRE exercises, the mock attacking force does not work for NRC, but is hired by the nuclear plant licensee. NRC, however, employs "contractors" with highly specialized knowledge to assess the security of each plant and advise the mock attacking force on strategy. Before the OSRE, a series of "tabletop" exercises are conducted, in which elements of the licensee's protective strategy are probed by the NRC contractors. This is meant to simulate the role of a "passive insider" who provides detailed security information to the attackers. Finally, four different "force-on-force" exercises are conducted over a two-day period. A number of different scenarios are conducted, ranging from a lone adversary (the so-called "Farmer Brown" scenario) to a group with capabilities close (but not identical) to that of the full DBT. The scenarios are chosen by NRC and its contractors, based on their observations of the tabletops.

Mock attack failure rates

The goal of the attacking force in OSRE is the destruction of a "target set." A target set is defined as the smallest combination of pieces of equipment that, if simultaneously disabled or destroyed, would result in damage to the reactor core. Therefore, the attackers are judged to have "won" the exercise only if all elements of a target set are reached. Conversely, the defending force is considered to have "won" if it is able to protect a single element of a target set. However, a nuclear plant presents many different possible target sets, so the design of a protective strategy that can defend the plant against any possible attack scenario is a complex task.

At some nuclear plants, a target set may consist of only one element, that is, a single location with enough safety equipment in close proximity that a single well-placed explosive could result in a meltdown. The existence of such vulnerabilities is a clear indication that sabotage resistance was not a consideration when the current generation of nuclear plants was designed.

The OSRE exercises obviously have little in common with a real attack. They typically are scheduled six to ten months in advance, allowing considerable time for advance preparations and security force training. (In fact, in some cases additional guards were hired simply to participate in the OSRE.)

Despite these advantages to the defensive force, OSRE performance has been poor. According to the NRC, from 1991 to 2001, 81 OSREs were run. At least one target set was destroyed in 46% of the exercises, meaning that the security force was unable to prevent the attacking force from gaining access to vital areas and destroying enough equipment to cause a meltdown. In most of these cases, the plant was fully in compliance with the security regulations. In a number of these exercises, the mock attackers also used explosives to breach the reactor containment; if the attack had been real, there would have been no barrier to release of radionuclides into the environment once the core began to melt.

Overall OSRE performance did not improve over time. Over the last two years of the program (2000-2001), the failure rate remained at 46%. In fact, the last OSRE to take place before the September 11 crisis led to a suspension of the program—at the Vermont Yankee plant—was the worst one on record.

The nearly 50% OSRE failure rate at US nuclear power plants was largely due to the fact that the nuclear industry long regarded security as an unnecessary expense, and had drastically cut security budgets to reduce operating costs during the 1990s to try to make nuclear power more competitive with other sources of electricity. During this time, the NRC looked the other way.

> *The nearly 50% OSRE failure rate at US nuclear power plants [during mock attacks] was largely due to the fact that the nuclear industry long regarded security as an unnecessary expense.*

NRC denies the problem

The NRC has tried to downplay the significance of the OSRE test results, arguing that the OSREs are not "pass-fail" exams but merely learning experiences. Some of the results documented in NRC inspection reports, however, reflect an incompetence so profound that the word "failure" is perfectly appropriate. To quote from a June 2001 inspection report at one plant, "the licensee failed to prevent the mock adversaries from gaining access to two target sets...numerous responders were unable to deploy ... without being vulnerable to the adversary."

Armed assault is not the only threat that nuclear plants are not equipped to handle. Although plants are required to defend against vehicle bombs of a certain size (the "design-basis" bomb), at a number of plants the level of protection is not adequate. For instance, the regulations require that all vehicles must be searched and declared free of explosives before they reach a point where a design-basis vehicle bomb could threaten safe plant operation. At 15-20% of plants in the US, however, the physical layout of the plant and its surroundings make this requirement difficult or impossible to meet.

Personnel access authorization programs at nuclear plants also have problems. Although NRC and the industry often say that no one is allowed unescorted access to sensitive areas of nuclear plants unless they have undergone an FBI background check, this is an untrue statement. At US nuclear plants, contract workers can obtain "temporary" unescorted access for up to six months before their background checks have been completed. This provides a loophole that could be exploited by terrorists.

The response of the nuclear industry to the significant security vulnerabilities uncovered by the OSRE program was to try to kill the program. In 1998, as a result of industry pressure, NRC quietly cancelled OSRE, only to have to restore it promptly after word of the cancellation was leaked to the press. The industry, however, did not cease in its efforts to discredit the OSRE program, and its complaints got a sympathetic hearing in NRC. In fact, before the events of September 11, NRC and the industry were collaborating to weaken the program by giving the nuclear plant operators themselves the responsibility to conduct and grade the exercises.

The cavalier attitude toward security in the nuclear industry is best expressed by Lynette Hendricks of the Nuclear Energy Institute (NEI), the chief lobbying organization for the US nuclear power industry, which appeared in the magazine US News and World Report on September 10, 2001:

> "We believe the [nuclear] plants are overly defended at a level that is not at all commensurate with the risk."

Then came the events of September 11, which one would think might cause a reevaluation of this position. There is no indication that such a reevaluation has taken place, however, since even now, the industry is fiercely opposing more stringent security requirements. Ms. Hendricks would likely make the same statement today.

The response of the nuclear industry to the significant security vulnerabilities uncovered by the OSRE program was to try to kill the program.

Nuclear Plant Security After September 11

Immediately following the World Trade Center attacks, the NRC "advised" its licensees to go to the highest level of security, but refused to issue a mandatory order, saying that it was unnecessary. In the absence of NRC guidance, some states called out National Guard troops to augment plant security forces, but others did nothing. Increased demands on security guards were largely met by compelling existing guards to work overtime, rather than by hiring new guards. The result was spotty and inconsistent security.

Also, NRC suspended OSRE exercises after September 11, arguing that it was dangerous to engage in such games when the US was at high risk of a real terrorist attack. There may have been some merit to this argument in the aftermath of September 11, but while the US has largely returned to normal, OSREs still have not resumed. Thus there is no way to confirm whether plant security is up to the task of defending against the level of terrorist threat that is now known to exist.

More than five months after September 11, the NRC did issue a mandatory order—at the prompting of the White House—but gave plant operators six months to comply. Each plant was required to provide a schedule within 20 days for implementing the measures specified in the order, but nearly 75% missed the deadline, primarily because they had not carried out blast analyses to determine if their facilities were adequately protected from vehicle bombs. This implies that the state of technical knowledge of the resistance of nuclear plants to terrorist attack is still rife with uncertainty.

As a result of the terrorist attacks, the NRC initiated a "top-to-bottom" review of its security regulations and procedures. One key unresolved issue is whether the DBT should be revised. The DBT traditionally consists of only a small number of individuals working in a single team, based on an outdated assessment that any coordinated group of terrorists would be detected by intelligence activities once it reached a certain size. The September 11 attacks, which involved a coordinated assault by 19 individuals in four teams, clearly shows the fallacy of this argument. The DBT also does not include the threat of aircraft attack. Despite the inadequacy of the current DBT, there is little indication that the NRC intends to make it more challenging in the near future.[1]

In fact, there is an effective legal limit on the severity of the DBT. Protecting against threats posed by "enemies of the United States," such as missile attacks from a foreign country, are not the responsibility of private entities. NRC and nuclear plant owners have asserted that protection against terrorist groups like Al Qaeda is the responsibility of the US military, because such groups are "enemies of the state." However, the US military has not assumed this responsibility by providing armed forces or anti-aircraft weaponry at nuclear plants. The issues of who will set the necessary level of security, who will provide it, and who will pay for it are difficult and far from being resolved. Meanwhile, the ability of nuclear plants today to protect against September 11-scale threats remains a great unknown.

One thing the US government has not hesitated to protect is basic information on nuclear plant safety that was routinely accessible by the public before September 11. The NRC website was shut for several weeks, and only a fraction of the material that was formerly on the site has been restored. NRC argues that much nuclear plant safety information could be used as a blueprint for terrorist attacks and a guidepost to choosing targets. A new, sweeping category of "sensitive homeland security information (SHSI, or sushi)" has been created to

1. Editor's note: Since the time of this presentation in April 2002, the NRC has developed what it considers a more stringent DBT standard, due to be fully implemented in October 2004, "adequate and reasonable for a private security force to protect against." The new standard, however, was criticized by the Project on Government Oversight, at a March 2004 NRC conference, as "not even close to reaching the...level that is appropriate."

encompass any materials that might be helpful to terrorists in seeking weapons of mass destruction. Unfortunately, this standard is so broad that it can be interpreted to include information that is important for public understanding of the safety of nuclear power plants. There is a great danger that the SHSI label will be used to restore the opaque screen behind which the nuclear industry operated during the height of the Cold War.

Legislation introduced in the US Congress and recently approved by a Senate committee, calls for an interagency review of nuclear plant security, including an upgrading of the DBT, and establishes a Federal nuclear counterterrorism force to supplement the private guard forces at nuclear plants. This may be the only realistic means of bypassing the entrenched bureaucracy at NRC and forcing nuclear plants to apply the level of security needed to protect the public against radiological sabotage by sophisticated terrorists.

It may well be the case, however, that this level of security is simply too expensive or infeasible. If plant operators are unwilling to pay the necessary security costs, then taxpayers would be stuck with the bill, effectively subsidizing nuclear energy by providing public funds for protection of private facilities. If the public objects to this use of taxpayer dollars, the viability of nuclear power as a long-term energy option must be called into question.

The Aftermath of September 11

The Vulnerability of Nuclear Plants to Terrorist Attack

John H. Large

In September 2001, international terrorists targeted the World Trade Center, successfully demolishing the twin towers which, together with the simultaneous attack on the Pentagon, cost 3,000 or more lives. Instead of using guns and conventional explosives, the terrorists adopted and adapted high technology in the form of fully fuelled aircraft that they directed towards their targets. To do this, the individuals comprising each group of hijackers had to give their own lives. This demand for mass casualties, in combination with technological prowess and a willingness to make the ultimate of self-sacrifices, breaks open what had until then been a taboo: that terrorists would not attack highly hazardous plants.

International terrorism centers around, but is not confined to, attacks on the United States. Organized terrorism seems to pay no heed to international borders: following the September atrocity, active cells of Osama bin Laden's group, al Qaeda, were unearthed across continental Europe. The World Trade Center groups trained for months to gain proficiency in piloting the aircraft they used. In 1995 the apocalyptic Aum Shinrikyo group itself developed and manufactured the chemical agent that its members released into the Tokyo subway, all at great cost, using highly skilled technicians. It is, perhaps, just a short and logical step for terrorists to latch onto the fact that highly hazardous plants themselves might be triggered into releasing energy and toxins via an aerial attack. If and when they make the attempt, could such plants provide a robust defense against an aerial attack and, if not, are there particularly vulnerable parts of the buildings and processes that, if penetrated, could lead to a devastating release of energy and toxins?

Nuclear power stations are such highly hazardous plants. Within the nuclear power station site, as well as within the nuclear reactor itself, a variety of processes, some of which involve intensely radioactive materials and highly reactive chemicals, are underway. Radioactive components and wastes are stored for the longer term. To mount an attack on a nuclear plant, however, a terrorist cell would have to plan ahead, locate the particularly hazardous plants and/or safety-critical equipment, determine the amount and nature of the radioactive contents and how readily this might be dispersed into the atmosphere, and identify the most vulnerable aspects of the buildings and containments of the targeted plants.

A review by Large & Associates undertook to examine the vulnerability of nuclear plants to terrorist attack. The outcome was disturbing. Using the United States and Britain as yardsticks, first, it is relatively straightforward to obtain all of the required information by simply accessing publicly available documents. Government agencies and ministries are sources of quite detailed published information. Second, the requirement that aircraft crashes, irrespective of the forecast accident frequency, be accounted for in the regulatory safety case was not introduced until 1979 for nuclear reactors and until 1983 for chemical separation and nuclear fuel plants such as those at Sellafield. Where the nuclear industry has taken aircraft crashes into account, such as for the UK nuclear power station Sizewell B pressurized water reactor (PWR), it is almost dismissive of the risk solely on the basis that the calculated frequency renders such an accidental event to be entirely incredible. Hence, there may have been little incentive to account for such a remote event in the design of the plants. Third, nuclear plants are ill-prepared for a terrorist attack from the air, and the design of the most modern plants does not seem to provide much defense (in terms of containment surety and segregation of hazardous materials) against the impact of a commercial aircraft.

A terrorist cell charged with attacking a nuclear plant could readily obtain sufficient information from publicly available documents to identify highly hazardous and vulnerable targets on sites for which there exists little defense in depth. Most state nuclear safety regulators acknowledge that, at this time, the plants are only capable of resisting an impact from a light aircraft. The nuclear industry worldwide is not prepared for and could not sustain a terrorist attack of the cunning and ferocity of September 11, 2001. Existing plants are not presently defended and new plants, even those claiming passive response to accident scenarios, cannot be adapted and modified to upgrade their resistance to attack. The nuclear industry needs time to reconsider its plant designs and, particularly, its probabilistic (as chance would have it) approach to nuclear safety. Such a reconsideration will take several years. In light of all of these uncertainties and the need to physically change the design and functionality of plant protection systems and containments, proceeding with new nuclear power plant construction projects would be an act of folly.

If it is acknowledged that an accidental aircraft crash could lead to a very severe radioactive release, then—however remote the probability of this event—there is a requirement that the consequences be identified and assessed.

Chance of Accidental Aircraft Impact

Assume that the mode of attack chosen by terrorists is airliners such as those hijacked by al Qaeda on September 11 in the United States.

In the United Kingdom, the Nuclear Installations Inspectorate (NII) regulates the safety of nuclear power plants through the regulatory framework of the Nuclear Installations Act (1965), as set out by the Safety Assessment Principles (SAPs)[1] and the Tolerability of Risk guidelines.[2] Principles 126 and 127 of the SAPs refer to aircraft impact in the following way:

> The predicted frequency of [accidental] aircraft and helicopter crash on or near safety-related plant at the nuclear site should be determined. The risk associated with the impacts, including the possibility of aircraft fuel ignition, should be determined to establish whether Principle P119 is satisfied. [P126]
> The calculation of crash frequency should include the most recent crash statistics, flight paths and flight movements for all types of aircraft and take into account forecast changes in these factors if they affect the risk. Relevant bodies should be consulted by the licensee with the object of minimizing the risk from aircraft approaching or overflying the plant. [P127]

Principle 119 relates to the anticipated frequency of the hazard, in this case an aircraft crash:

> It should be shown for all hazards that the design basis analysis principles and the PSA principles are satisfied as appropriate, unless it can be demonstrated that the frequency of an event being exceeded is less than once in 10 million years, or if the source of the hazard is sufficiently distant that it cannot be expected to affect the plant. [P119]

In assessing accidental aircraft crash probability, the guidelines and principles set out by the US Department of Energy are generally adopted.[3] Essentially, this approach assumes some form of loss of control of the subject aircraft, its subsequent deviation from the intended flight path, and the chance of it crashing into the target nuclear plant. The nuclear plant is defined as a crash area and the parameters relating to the crash are calculated from the effective fly-in, footprint, shadow, and skid areas that are determined from established codes.[4]

Applied to a civil airliner operating at altitude and passing along a prescribed flight path, this a posteriori probabilistic approach adopts rates drawn from actual crash incidents and yields a very low accidental crash probability.[5,6,7] Applying this model to nuclear plants suggests that accidental aircraft crash rates are sufficiently low ($<10^{7}$ per year) to satisfy the requirements of Principle 119, that is, the hazard occurrence is so remote that it cannot be expected to affect the plant.

In the 1987 safety analysis of the UK Sizewell B PWR,[8] an aircraft crash onto the power station site was identified and considered as an external hazard with the potential to initiate events that could lead to an accidental release of radioactivity. The expected frequency of impact of all classes of aircraft onto identified vulnerable areas of the power station site was reckoned to be extremely low: approximately 7×10^{-7} per year. Impacts of aircraft and helicopters under 2.3 tons were not expected to penetrate the containment structures. Thus, the design criteria for Sizewell B translated into a construction that provided defense against only the first and lightest level of aircraft impact, that from a small aircraft such as a Piper Cherokee. Director General Jukka Laaksonen of the Finnish Radiation and Nuclear Safety Authority[9] accepts that the lightest level of defense against aircraft crashes continues to be acceptable for Finland's two existing nuclear power stations and its proposed fifth power reactor:

> [The] world's nuclear plants are designed on three levels against airplanes. First, against kinds of light airplanes, then against starfighter-type airplanes and then against large commercial airplanes. This design depends primarily on how close to flight-routes these plants are sited and our plants are far from flight routes and we have no fly zones to all planes in the proximity. We have considered the lightest level to be sufficient as a design basis.

Studies of the impact of a heavy military aircraft or commercial airliners, although cited[7] for the Sizewell B assessment, were not then in the public domain and remain unavailable to the public. The title dealing with the military aircraft scenario, however, refers to "The Effects of Impact Heavy Military Aircraft Adjacent to but Not Directly on the Vulnerable Buildings" [emphasis added], suggesting that somehow the pilot of this hypothetical aircraft was able to retain sufficient control to avoid the most vulnerable parts of the plant (the location of which he apparently knew). Claims by the Sizewell B operator that the likelihood of an unacceptable fire or explosion following impact by a heavy military aircraft is sufficiently low to be discounted have been made on the basis of this analysis. In other words, the nuclear industry has concluded that the installation of additional features to provide aircraft crash resistance is unwarranted.

The NUREG-0800-based analysis permits the introduction of the mitigation that military pilots, independent of all other considerations, will retain sufficient control to avoid striking the nuclear plant 95% of the time—or a $>_{hit}$ probability equal to 0.05.

Of course the probability—or even the chance of occurrence—of a malicious human act, such as the terrorist attack of September 11, 2001, cannot be determined by classical a priori probabilistic analysis. Thus, it is only realistic to apply chance to the success of an attack once it has been initiated. Put another way, applied to the terrorist attack of September 11, the $>_{hit}$ or success rate was 3 out of 4 airborne aircraft, ($>_{hit}$ = 0.75).[10] If the aircraft that crashed in Pennsylvania is discounted, the $>_{hit}$ for those aircraft on their target run was 3 out of 3 or 100%. In other words, the hijackers had obtained sufficient flying skills to ensure that, once the aircraft had been commandeered, the mission would have a high, almost certain rate of achieving its objective. Whereas the military or civil pilot would not be expected to have been trained to identify the vulnerable parts of a nuclear plant (even though it is assumed that the pilot will strive to avoid certain parts of the plant), it would be in the hijacker's interest to identify the most vulnerable parts of the selected target. Hence, the same NUREG-0800 mitigation factor applies, but in this case in reverse, so that the terrorist intent upon striking the plant has a $>_{hit}$ of perhaps 95% once committed to the final run to the target.[11]

Of course, notional restraints such as no-fly zones in the vicinity of nuclear plants can have no effect once an aircraft has been commandeered and the terrorist attack is underway.

Forecasting Possible Outcome and Consequences of a Terrorist Attack

Because an accidental crash of a civil airliner on some part of a nuclear site would be reckoned, on the basis of the established assessment routines,[3] to be a very remote event, it is likely to be considered beyond the design basis. Principle 28 of the NII SAPs,[1] however, requires that fault sequences beyond the design basis with the potential to lead to a severe accident must be considered and analysed (by bounding cases[12] if appropriate) and that there may be specific, unpublished requirements for protection of the plant against sabotage.[13]

In other words, if it is acknowledged that an accidental aircraft crash could lead to a very severe radioactive release, then—however remote the probability of this event—there is a requirement that the consequences be identified and assessed. This consequence analysis approach disregards any offset from the probabilistic value of a foreseeable event happening. If the aircraft crash is an act of sabotage, then the probability must be assumed at unity ($>_{hit}$ = 1) and the event must be considered only in terms of its consequence mitigation.

Application to a Nuclear Power Station Site

The SAPs Principle 28 particularly applies to the containment of the plant, requiring identification of "failures which could occur to the physical barriers to the release of radioactive material." It is not clear whether Principle 28 can be practicably applied to all of the plants and processes within a nuclear power station or, indeed, to all types and ages of nuclear power stations. If Principle 28 has been applied, it is not clear whether i) the general premise is that the plant containment would survive the impact and fuel burn or, ii) that the chance of an accidental air crash (as posited, for example, in the Sizewell B nuclear safety case) is considered so remote as to be entirely incredible. If it is acknowledged that a terrorist attack by aircraft crash is now, a posteriori, an established external hazard, uncertainty remains as to whether the operator has been required to review and amend the nuclear safety case to account for this.[14]

Returning to Finland and its preparation to select the type of reactor plant for its fifth reactor, the safety regulator seems to have conducted preliminary reviews of plant types, setting these against "new safety requirements" and noting that:

> "STUK has not made facility-specific assessments of how the facility concepts presented in the application meet the new safety requirements. According to STUK the structural designs of all the plant concepts would require some modification. However, none of the proposed power plant types would be need to be rejected based on current knowledge."[15]

Application of Principle 28 and Consequence Mitigation

The design and construction of the buildings of these sites were likely to have complied with the regulations and good practice of the times, being considered then "fit for purpose."[16] Even if the designers had included within the building and containment designs (and interior processes) features resistant to aircraft crashes, their assessment would have related to the types of aircraft flying at that time. Similarly, the need to incorporate such features—and the priority given to such need (i.e., the probability of a crash event)—would sensibly have related to the density of aircraft traffic at that time.

Moreover, for those plants designed and regulated from a probabilistic basis, it is very doubtful indeed that any intentional aircraft crash resistance was built into the system—not just for the building structures and physical containments, but also for safety equipment that would need to resist impulse loading and the fires associated with aircraft crashes.

These two limitations alone suggest that the world's nuclear plant operators would find it impracticable to modify existing plants in ways that would provide reasonable assurance that they would survive an aircraft crash. The severity of impact as an aircraft drove through the plant might render ineffective the normally accepted physical systems that serve to limit the consequences: safe shutdown mechanisms, continued availability of utilities, adequate containment integrity, and on- and off-site emergency preparedness. If so, the accident would still have to be "managed" by improvising uses for surviving systems and resources. This would require an increased reliance upon operator intervention, because accident management strategies must be implemented by plant personnel.

Nuclear plants are designed to withstand, as far as is practicable, specified external hazards such as earthquakes and floods. These defenses are "scenario specific" and the capability of certain items of equipment to survive depends not only on the custom-engineered resistance to particular impacts but, importantly, on the diversity of function of the safety systems and equipment involved. It is doubtful whether the diversity of the installed equipment is sufficiently broad to resist a common mode failure across all of the equipment and systems that could be triggered by aircraft impact and the subsequent fires.

Doubt also exists that the outcome of a consequence analysis could be practicably implemented to provide an effective consequence mitigation management regime. Moreover, accident management, even if performed as planned, might prove ineffective, leading from one severe accident sequence to another that is just as hazardous. In other words, accident management may, in certain rapidly developing situations, be counterproductive.

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Impact and Ensuing Fire of an Aircraft Crash

Aircraft, for all of their speed and power, are relatively fragile structures. The 190 or so tons of each Boeing 767 that crashed into the south and north towers of the World Trade Center may have provided a colossal kinetic energy, but the wings and fuselage would have shredded almost immediately, leaving just the compact masses of the engines and a few solid spars and undercarriage frames to act as very energetic projectiles to penetrate the building structure. Accompanying this high energy impact was the release of the 80,000 liters or so of aviation fuel, partially vaporized, that erupted into fireballs to ignite all flammable materials within range. Vaporized and unburnt fuel would have been squeezed into building voids by the expanding flame and pressure fronts and the remaining fuel would have gushed into the internal spaces of building, spreading downwards through buckled and punctured floors. As the tragedy unfolded, it was clear within minutes that about 10 floors of each tower were burning furiously, so intensely that the structures buckled and progressive collapse commenced on the south tower within one hour of the aircraft impact.[17]

Application of Aircraft Crash to Engineered Structures of Nuclear Power Plants

Obviously, the effect and outcome of an aircraft crash, including burning fuel, on any one of the active plant buildings or processing/storage areas would depend upon how each of the individual target buildings performed under specific conditions.

As a result of impact, (kinetic) energy is transferred from the aircraft to the building.[18] The energy transferred is absorbed by the building components in the form of strain energy, while each component deforms elastically up to the point of permanent yielding. The impact can be segregated into two regimes: first, at the moment of impact the aircraft can be considered to be a very large but relatively "soft" projectile which, by self-deformation, will dissipate some fraction of the total kinetic energy being transferred during the impact event. Second, some components of the aircraft will be sufficiently tough to form rigid projectiles that will strike and penetrate components of the building fabric and structure.

The first of these damage regimes involves quasi-impulsive loading, so the response of the structure is obtained by equating the work done by the impacting load to the strain energy produced in the structures. Setting aside localized damage in which individual structural components are removed (blasted away), the most probable failure mode of the structure overall is that of buckling and collapse in response to the impact. Radioactive waste and spent fuel buildings, among other building structures at nuclear power plants, would not withstand the impulse magnitude delivered by a crashing commercial aircraft.[19]

For impact damage the aircraft—more particularly parts and components of it—have to be considered as inert projectiles. The energy transfer upon impact relates to the kinetic energy (KE); the key parameter in determining the target (building component) response is the kinetic energy density, which relates the KE and the projected area of the projectile. In terms of projectile velocity, a diving civilian aircraft is unlikely to exceed 500 knots so the damage mechanism falls below the so called hydrodynamic regime where the intensity of the projectile-target interaction is so high that a fluid-to-fluid damage mechanism prevails (as utilized by tungsten tipped and depleted uranium sarab or long rod penetrator armor-piercing rounds).[20] In the sub-hydrodynamic regime more conventional strength of materials characteristics (i.e., strength, stiffness, hardness, and toughness) will determine the penetration mechanism.

For uniform, elastic materials, such as low-carbon steel used in the steel frame construction typical of diesel generator sheds, radioactive waste stores, and, sometimes, irradiated fuel storage buildings, a good first estimate of the penetrating power of a projectile can be obtained from the Recht equation, which, for certain hard components of the aircraft engines, could be as high as 200mm.[21] For a steel-framed industrial building structure, web and flange thicknesses of the steel section girders and beams is typically about 20 to 40mm. So even with penetrator break up, the resulting projectiles would be more than sufficient to structurally damage the building steel frame.

The failure of concrete to ballistic loading applies to the different ways in which this common building structural material is used: for very thick-walled structures the concrete is considered to be a semi-infinite mass; for concrete walling and flooring (and roof) slabs the account has to be taken of the flexure of the slab, and to prevent scabbing (where the back face of the concrete surface detaches) the reflective characteristics have to be modelled. The first two of these applications are important in respect to the whole structure remaining intact, and the last that in even where complete penetration is not achieved, the detached scab can form a missile in itself, damaging and/or disabling safety critical plant within the concrete containment. The ballistic loading of ferro-concrete (steel reinforced concrete) structures is a little more empirically derived,[22] although even with broad brush assumptions about the detailed design of the ferro-concrete structures the hardened projectile striking most of the concrete structures of a nuclear power plant would achieve full penetration. For example, a glancing impact on a typical reinforced concrete framed building would be sufficient to possibly penetrate the reinforced concrete roof slabs which are not practicably greater than 400mm thickness, (because of self-weight loading considerations over the 4m spans).

The point here is that the building structures of a nuclear plant require that complete containment be maintained during an aircraft crash, because even relatively small penetrations will permit the inflow of aircraft fuel with an almost certain fire aftermath. This would, in itself, heighten the likelihood that any radioactive materials held within the building structure would be released and dispersed.

For the purposes of this review, it is quite reasonable to assume that the building containment would be breached, because of the absence of any extraordinary civil engineering features visibly incorporated into the building design. Once the building is breached, the particular processes and/or substances stored within are likely to add to the damage, by explosion, and by the ferocity of the fire. For a typical nuclear power plant, the following scenarios might arise.

Irradiated Fuel Storage

If the roof structure of covered fuel ponds were penetrated and the pond wall structure were breached, then loss of pond water and an aviation fuel fire could lead to a breakdown of the fuel cladding and fuel itself, resulting in a high release fraction of fission products, possibly mixed with emulsions of the aviation fuel. The fuel pond radioactive inventory depends on the degree of irradiation of the fuel (the burn-up) and the post in-core period, although the quantity of fuel might represent (in mass) 7 to 8 times the reactor core load.

Zircalloy clad oxide fuels provide opportunity for an exothermic and self-sustaining zirconium/steam (or air) reaction at elevated temperatures that will result in failure of the fuel cladding and increased oxidation of the exposed fuel pellet surfaces. The hydrogen liberated from the oxygen stripping and exothermic chemical reaction $Zn + H_2O$ would provide a hydrogen explosive atmosphere, with a potentially very significant accompanying radioactive release of spent fuel fission products.[23] For the UK Magnox nuclear power stations, and for certain other research reactors, the magnesium alloy cladding and the base elemental metal fuel are pyrophoric in air, which could result in a very efficient release of the reactor core or spent fuel pond inventory.

Intermediate Radioactive Wastes

The radioactive inventories and chemical makeup of the stored radioactive wastes at nuclear power and nuclear fuel manufacturing and reprocessing plants is varied, chemically complex, and poorly protected against external threat. Also, defunct nuclear plants awaiting decommissioning and dismantlement—a process that is to be set aside in the UK for 100 or more years—although they contain large inventories of radioactive waste and reactor cores, are effectively abandoned, with little security against terrorist attack.

Operational Nuclear Reactors

The range of potential outcomes for operational reactors subject to terrorist attack is large.

A direct impact on the reactor locality, breaching the reactor pressure vessel and/or the primary coolant circuit would most probably result in a radioactive release into and through the secondary containment systems that would have also been breached by the impacting airframe.

Other safety-critical equipment of operational nuclear power plants include the electricity supply grid connections and the emergency diesel electricity generators, both of which provide essential electrical suppliers for safety systems, reactor cooling, and heat sinks, loss of which—particularly effective core cooling—could result in containment challenging events developing in the reactor core.

Comments and Observations

This review set itself three objectives:

1) Is there sufficiently detailed information available in the public domain for a terrorist group to plan an attack with sufficient confidence of success?
2) Does the regulatory safety case requirement include provisions for accidental aircraft crash and, if it does, is this sufficient to safeguard against intentional aircraft crash?
3) Could the plants and processes be modified and prepared to withstand such an intentional attack and, if so, how much of this defense would depend upon accepting intentional aircraft crash as inevitable, thereby relying almost totally upon consequence management to mitigate the outcome.

Information Accessibility

Using nuclear plants in the United States and the United Kingdom as yardsticks, it is relatively straightforward to obtain all of the information required by simply accessing publicly available documents. Ministries and agencies of central government publish most of these sources of quite detailed information, and local authorities maintain records of planning applications that include details of extant as well as proposed plants and buildings. These records and documents are readily accessible, it being possible to obtain copies directly from the originating department of documents that dated back to 1996 and earlier.[i]

Also, there are a number of "storehouses" of related information. Local, national, and international environmental (and other) groups hold pools of information that they have accumulated over the years. For example, one local group was able to provide photographs of locations deep within the BNFL Sellafield fuel reprocessing site, fully detailed engineered drawings of buildings, and scaled site maps that included the location of essential services. These were available for the Sizewell B PWR reactor via Large & Associate's previous involvement in its planning Public Inquiry, although none of this information was used in this review.

It is assumed that these groups would not release such information to strangers upon demand, although it would seem to be a relatively easy task for individuals requiring access to this information to join the group in question or, better still, act as a volunteer working on an apparently innocent but related subject over a period of months. When responding to requests for information and documentation, both HMG and the relevant local authority did not enquire for what purpose the information was requested. Moreover, requests by Large & Associates for such information were not met, it would seem, by double-checking of the bona fides and identity of the enquirer.

Surprisingly, although as a result of the September 11 attacks the US Nuclear Regulatory Commission closed down all of its Internet web sites while it reviewed their contents, web pages relating to Sellafield (HMG, BNFL itself, and those of Greenpeace) remained open and accessible.

Intentional Aircraft Crash: External Hazard

Although this review centers around an intentional aircraft crash, a future terrorist attack against a nuclear plant might be in the form of some other external, man made hazard. We have only considered aircraft crashes in any detail, although a future terrorist incident might involve, for example, a truck bomb driven close to or actually into the plant secure area.

Defending the Plants and Processes: Consequence Management

Nuclear plants are almost totally ill-prepared for a terrorist attack from the air. The design and construction of the buildings date from a period of more than 50 years. Many of the older buildings would just not withstand an aircraft crash and subsequent aviation fuel fire. Some buildings, now redundant for the original purpose, have been crudely adapted for storage of large quantities of radioactive materials for which they are clearly unsuited. The design of the most modern plants on the site does not seem to provide that much defense (in terms of containment surety, dispersion of stocks to different localities, and segregation of hazardous materials) against an aerial attack.

It would not seem to be practicable for each and every building and process at such nuclear plants to be modified to provide adequate protection against aircraft crashes. The investment required would be enormous and the practical difficulties challenging indeed—many processes would have to be relocated, possibly to underground caverns and bunkers, which in itself might introduce other safety related detriments.

If a terrorist group planned to intentionally crash an aircraft onto a nuclear power station then the probability of the event becomes unity. Considering an aircraft crash as a certainty, rather than as some remote probability, requires the event to be assessed in terms of its consequence management alone. In other words, there are no practicable measures that might be implemented on site to provide a defense in depth to avert such an event, in which case the only mitigation available is to manage the consequences of the event. The idea that a severely damaging event, arriving like a bolt out of the blue, could be "managed" by improvising the use of other systems and resources, however, is doubtful, particularly because ad hoc decisions and actions (taken in unpracticed situations) might lead from one severe condition situation to another that is just as hazardous.

[Author's note: This Review has concentrated on nuclear site plants and processes on the Sellafield site itself. It should also be noted that Sellafield depends upon the continuous import of services, particularly electricity and mains water, to maintain safety on the site, and if imported electricity supplies fail solely on the on-site CHP plant. These imported services (the national grid electricity lines and the water pipeline to the lakes) may also be susceptible to terrorist attack.]

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i. At a 2004 Nuclear Regulatory Commission hearing on the Plutonium Disposition Program (Eurofab), the transportation and other details for a large consignment of weapons-grade plutonium from the US to France (and return as MOX fuel) were in open discussion and publicly available.

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8. Sizewell B PWR Preconstruction Safety Report, Chapter 3, November 1987.
9. Finland is currently planning a fifth nuclear reactor and has consolidated this position since the 11 September incident, with a final parliamentary decision expected about June 2002. Transcript of interview by Finnish Broadcasting Company, A-Studie 12 November 2001—the transcript is in English and there is no authority on the accuracy of any translational/transcription.
10. Although it is acknowledged that this is drawn from a statistically insignificant grouping (just the 1 September data), the assumptions for the reliability of military pilots to avoid the vulnerable parts of the building must also be drawn from a lean set of data.
11. Homing in and striking on a low target (ie a low rise building), however, would present greater difficulty to a novice pilot than that of striking a large high rise structure.
12. A "bounding case" is one where the different faults and fault sequences may be grouped together in that the consequences for any fault sequence is at least as severe as every member of the groups of fault sequences to which it is bound.
13. For example, the US Code of Federal Regulations Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage, S55, PT73 applies although this includes little protection against deliberate aircraft crash. In the UK there are controls applied to the proximity of aircraft to nuclear plants with Statutory Instrument 2001 (1607) The Air Navigation (Restriction of Flying) (Nuclear Installations) Regulations 2001 came into force on 11 May 2001—this prohibits flying below specified height of 2,200m above circular areas defined for Sellafield for a radius of 2 miles at OS 542505N 032944W.
14. Following September 11, 2001, HM Government established the Chemical, Biological Radiological and Nuclear (CBRN) to (apparently) consider the defence against such attacks. The CBRN is a sub committee of the Cabinet Civil Contingencies Committee which is chaired by the Home Secretary—other than the political chairs of these two committees, nothing is known of the expert membership of the committees or, indeed, their remits and how findings and recommendations are passed down to emergency planners and the like.
15. Preliminary Safety Judgement on the Application for a Fifth Nuclear Power Plant, STUK, December 2001
16. The Building Regulations 1976 (as amended) - first introduced by Section 61 of the Public Health Act 1936 the Building Regulations were made for the following broad purposes a) securing the health, safety and welfare of people; b) furthering the conservation of fuel and power; and c) preventing waste, undue consumption and misuse or contamination of water. It is sufficient to note here that the regulatory system of building control in the United Kingdom, The Building Regulations, centres about protection of the occupants of buildings, particularly in the event of fire, inasmuch that sufficient means of escape, compartmentilization to inhibit the spread of smoke and fire, and time for escape shall be provided. In this approach it is left to the building designer to specify specific types of loading, etc., that might apply to the building during the course of its function and use, so other that standards set down for floor, wind, snow, etc., loadings and, since the late 1960s, safeguards against progressive collapse for buildings of five or more stories, nothing specific is prescribed for external/internal hazards including aircraft crash.
17. Official report produced by the American Society of Civil Engineers (ASCE) for the Federal Emergency Management Agency (FEMA), May 2002.
18. Just on the basis of kinetic energy alone the three levels of aircraft crash referred to by the STUK regulator increase from Level 1 (light aircraft) to Level 2 (Jet Fighter) to Level 3 (Commercial) airliner in the ratio 1 to 200 to 6,000 or that the energy available from a crashing commercial airline (impact alone) is 6000 times that of a light aircraft.
19. The maximum impact before yielding commences is given by

$$i_r = [2Lim/En]^{0.5}\, \partial_y/Ah$$

which (adopting conventional notation) for the a typical rc construction, with a roof slab load per column assumed at 35t, the structure yields at about 1,750 Pa-s. The impulse force arising from a crashing aircraft of, say 200 tons all-up weight considered impacting over its projected front end fuselage area (about 30m^2) with the event lasting over the entire collapse of the fuselage length, gives an impulse force of about 20,000 Pa-s or about x10 the yield strength of the structure.
20. At projectile impact velocities below 1,000m/s all impacts are sub-hydrodynamic - at 500 knots the closing velocity at impact would be approximately 260m/s.
21. After R F Recht, Ballistic Perforation Dynamics of Armor-Piercing Projectiles, NWC TP4532, 1967. which, for a blunt nose ogive, is

$$x = 1.61M/(bA)[V - a/b\ln([a+bV]/a)]$$

where a and b relate to the material properties of the target, M is the mass of the projectile and V the projectile closing velocity. For an aircraft impact, if it is assumed that a sufficiently robust penetrator will present itself in the form of a main turbine shaft of an aero engine which, with its blades and other attachments, might represent a mass of 0.25 tonnes of 150mm projected diameter (stub end of shaft), typical strength of materials properties give $a = 2.10^9$ and $b = 10.10^6$, so that the final penetration thickness into a steel element (ie a building stanchion) is about 200mm.
22. MOD Assessment, Strengthening, Hardening, Repair and Demolition of Existing Structures, Army Code No 71523, MoD 1992 which, for the same missile adopted for Footnote 21 the slab penetration is about 1,100mm.
23. Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants, NRC October 2000.

Ways and Means to Protect Against Nuclear Terrorism

An IAEA Perspective

David B. Waller

The International Atomic Energy Agency (IAEA) is an independent United Nations agency comprising a staff of about 2,200, with headquarters in Vienna, regional offices in New York, Geneva, Toronto, and Tokyo, and scientific laboratories in Monaco and Austria. The IAEA has 137 member states, representing both industrialized and developing countries; 35 of those member states make up its Board of Governors. It is sometimes referred to as the world's "nuclear watchdog"—and many people associate it with the destruction of the secret nuclear weapons program in Iraq following the 1991 Gulf War, or with ongoing issues related to North Korea's nuclear activities.[1] In reality, the work of the IAEA goes far beyond this watchdog—or nuclear verification—role.

On September 11, 2001, as the terrorist attacks in the United States began, the Agency's Board of Governors was in formal session at its headquarters in Vienna and, by coincidence, was reviewing an agenda item concerning the physical protection of nuclear and other radioactive materials. News of the attacks filtered—slowly at first and then more rapidly—through to the delegates in the room. As more information was provided to him, the Director General took the floor with an announcement regarding the unfolding situation. Several delegates intervened with words of condolence and support for the United States. The American Ambassador acknowledged the statements but strongly urged that the work of the Board—which he noted had suddenly become more important than ever—should nevertheless continue.

The next week—again, by coincidence—was the annual session of the Agency's General Conference—the coming together in Vienna of all of its member states. The threat of nuclear terrorism, quite naturally, had moved to the very top of the agenda—both inside and outside the formal sessions. By the end of the week the General Conference had adopted, by consensus, a resolution requesting the Director General to "review thoroughly the activities and programmes of the Agency with a view to strengthening the Agency's work relevant to preventing acts of terrorism involving nuclear and other radioactive materials."

1. Also, more recently, with temporarily resumed inspections in Iraq, and with events in Iran and Libya.

To put the Agency's activities in response to this charge in perspective, one must first understand a fundamental principle of "balance" that is crucial to how the Agency operates. The nuclear terrorism issue must then be placed in the context of the Agency's broader mandate.

The Balance Principle

When the IAEA came into being nearly 50 years ago, the number of nuclear weapon states was on the rise and several farsighted world leaders were anxious to bring weapons proliferation to a halt. The "Atoms for Peace" initiative that led to the establishment of the Agency—as well as the 1970 Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which is the most adhered to treaty in the world—had at its root a "balancing principle": that the non-nuclear-weapon states would agree not to initiate weapons programs or would abandon any they had started if, in exchange, the nuclear weapon states would agree to provide them peaceful nuclear technology and, eventually, would themselves move toward disarmament.

This bargain—the benefits of the peaceful uses of the atom in exchange for non-proliferation—has resulted in the Agency having three major areas of activity: first, nuclear technology itself; second, nuclear safety, to ensure the responsible use of the technology; and third, the watchdog or verification activity.

Nuclear Technology

Nuclear and radiation technologies can bring many benefits to humankind. The IAEA's human health program, for example, covers subjects including cancer treatment, ways to combat malnutrition and infectious diseases, and health-related environmental studies. In 2001 more than 18,000 Latin Americans were screened for hepatitis C using an immuno-radiometric assay technique. In East Asia, a screening network for neonatal hypothyroidism screened 1.3 million infants and, as a result, identified 360 who were rescued from mental retardation. More than 70,000 tests for the detection of tumors were carried out in 17 African countries—with simultaneous training of clinical laboratory graduates in tumor marker assay techniques.

With evidence of a growing number of cases of illicit trafficking in radioactive materials, the IAEA established a program to prevent them from falling into the wrong hands.

In its food and agriculture program, which is carried out in conjunction with the Food and Agriculture Organization (FAO), a wide range of projects use nuclear and radiation techniques to improve food production and preservation. Of particular interest is the use of the sterile insect technique to eradicate insect pests. This is a technique in which male insects, sterilized by radiation, are released in mass into the wild to compete with fertile males. The technique was used successfully to eliminate the tsetse fly from Zanzibar; it did the job where the application of massive quantities of insecticides had failed. Tsetse, of course, causes trypanosomosis, or sleeping sickness, which is a three-pronged cause of poverty in Africa—not only does it kill humans, but it severely inhibits the ability to raise healthy livestock either as a food source or as draft animals for farming.

Another example of our nuclear technology work relates to water management. Under IAEA projects, scientists in developing countries are trained to use nuclear techniques to improve the efficiency of water use, to better understand climate change, and to grow healthy crops in saline environments. Using isotope hydrology, for example, we are working with the World Bank and others to protect and sustainably manage the Guarani Aquifer—the largest groundwater aquifer in South America, with enough freshwater, if protected, to supply the needs of more than 300 million people.

The IAEA is energetically and earnestly engaged in carrying out this part of the "bargain"—transferring peaceful nuclear technology in a way that will serve basic human needs—just as it is committed to the other half of the bargain—helping prevent the proliferation of nuclear weapons or, for that matter, any illegitimate or malicious use of nuclear technology.

In addition to health, agriculture, and water, the Agency's technology activities, of course, include nuclear power. As with any nuclear technology, the IAEA is committed to ensuring that where nuclear power is used it is used safely, securely, and in a manner that does not contribute to weapons proliferation. Recent comparative analyses of energy options have focused heavily on greenhouse gas emissions as a factor in climate change—a clear reason why, in some areas of the world, there have been early signs of a possible renaissance for nuclear power, which can produce electricity on a large scale with negligible resulting emissions of greenhouse gases.

As with other comparative assessments, the IAEA's goal is not to promote nuclear power vis à vis other credible energy sources, but rather to provide interested states with the means to make an informed choice, taking into account the full range of benefits and disadvantages of the various energy options. In that regard, nuclear power technology, with more than 40 years of experience, has evolved dramatically. In recent years, nuclear power research and development has become much more focused on "user priorities," emphasizing reactor and fuel cycle designs with inherent features for safety and proliferation resistance (both of which contribute to the prevention of terrorism), as well as with improved economic competitiveness resulting from smaller size and shorter construction timetables. These innovations will help nuclear power to be a more attractive option and one less vulnerable to terrorism; but it remains to be seen precisely what role it will play in future electricity generation.

Nuclear Safety

The second major area of IAEA activity involves nuclear and radiation safety—that is, the safety of existing power plants and other fuel cycle facilities on the one hand, and safety in the use of radiation sources on the other. Although safety worldwide has improved dramatically in recent decades, global performance is still uneven—that is, it varies from country to country and region to region. Thus, much of the IAEA's work in this area is to raise safety practices in all countries to the highest levels. It does this in three ways:

- by getting members of the international community to agree to adhere to legally binding norms—often referred to as safety "conventions";
- by promulgating high-level safety standards for use by nuclear operators and national regulators; and
- by organizing "safety services"—international peer reviews in which a team of experts visit a given country or facility to observe safety practices, point out weaknesses and submit recommendations according to the latest, best international practices.

Regarding radiological safety, IAEA also conducts studies such as the assessments by expert international teams in recent years at the Bikini atoll and, subsequently, at the Mururoa and Fangataufa atolls, the sites in the South Pacific of earlier nuclear weapons tests. The resulting reports were widely praised by many observers, including Greenpeace. In the medical arena, an assessment was carried out of a serious incident in Panama where radiotherapy patients were overexposed due to a calculation error resulting from data entry to the treat-

“Orphan sources” of radioactive material are a source of concern to the IAEA. Photo courtesy of David Waller

ment plan. Tragically, at least 12 out of the 28 overexposed patients have died.

The Agency has also been heavily involved in the search for so-called orphan sources—radioactive sources, used originally, perhaps, in hospitals or in industry or by the military—that have escaped from regulatory control and the whereabouts of which may be unknown. The media has reported examples of such sources in the Republic of Georgia. The sources pictured here [see photo] consisted of a hefty 40,000 curies of strontium-90 originally intended for heat and electricity generation in remote locations. Early in 2001, experts assembled by the Agency responded to reports that a cobalt-60 source had been found in an abandoned wing of a hospital in Kabul, Afghanistan, raising concerns that one or more such sources could be used to create a “dirty bomb.”

Clearly, the safety of both nuclear installations and radioactive sources is directly related to the prevention of nuclear terrorism. The IAEA’s capabilities and program in this area provide a natural springboard for some of the work that has taken place since September 11.

Verification and Security

The IAEA’s verification and security program—the third major area of the its work—relates most fundamentally to safeguards, that is, monitoring the compliance of states party to the NPT with their non-proliferation undertakings. The Agency uses an array of techniques for verification—including remote surveillance, on-site inspections, and satellite monitoring—and it has two fundamental legal instruments that enable it to carry out this mission. The first, the “comprehensive safeguards agreement,” allows IAEA to verify (and thereafter monitor) that a state has not diverted to non-peaceful purposes any of its “declared” nuclear material or equipment (that is, the inventory provided to the Agency by the state). Experience in Iraq in the immediate wake of the 1991 Gulf War, however, made it quite clear that for safeguards to be fully effective, further steps are needed. So a second instrument was created, referred to as the “additional protocol” under which states permit IAEA to look for “undeclared” nuclear material and equipment. The additional protocol gives Agency inspectors even greater access to information and sites. A major Agency focus, therefore, is to press for more universal subscription to both these instruments.

A few years ago, with evidence of a growing number of cases of illicit trafficking in nuclear and other radioactive materials, the Agency established a program focused on the security of such material, to prevent it from falling into the wrong hands and to detect and respond to illicit or malicious acts involving such material, should they occur. The IAEA Office of Physical Protection and Material Security,[2] which works closely with both member states and other international organizations such as Interpol and the World Customs Union, has now become a coordinating center for the additional activities the Agency is carrying out in response to heightened concerns post-9/11.

Nuclear Terrorism

Given its concentration on these areas of technology, safety, and verification, it is logical that the Agency assumes a central role in responding to the events of September 2001. The IAEA is the only intergovernmental nuclear organization with a truly global reach—and thus it is ideally suited to taking on those nuclear security activities that require international cooperation.

As previously mentioned, the events of September 11 coincided with a meeting of the Agency’s Board of Governors and the following week the General Conference called for a review by the Director General of Agency work in the area of nuclear security. Bureaucracies sometimes move at a snail’s pace, yet the Agency’s efforts proceeded with remarkable speed. Within a matter of weeks it had convened a special session of recognized experts worldwide to consider various aspects of the nuclear terrorism threat; secured an agreement from the Turner Foundation’s Nuclear Threat Initiative to provide $1.2 million as seed money for a fund to carry out needed anti-terrorism activities; and launched a media campaign to alert the public at large to the nuclear and radiological risks as viewed in a post-9/11 light and to publicize its efforts to mitigate those risks. The prevention of nuclear terrorism became a major agenda item at each meeting of the Board of Governors that followed. All of this activity was funneled into compiling a comprehensive Action Plan[3] to upgrade nuclear security worldwide, a plan that was presented to the Agency’s Board in preliminary form in November 2001 and approved in final detailed form in March 2002. The Action Plan was based on the identification of four basic threats:

> 1) The theft of a nuclear weapon. While arguably highly unlikely, this clearly represents the most serious threat in terms of its potentially devastating consequences.

2. Now renamed the Office of Nuclear Security.
3. Now called the Nuclear Security Plan of Activities.

Responsibility for preventing such an action rests primarily with the states that possess nuclear weapons. The IAEA, however, can reinforce national efforts by its activities directed at detecting cross-border smuggling of nuclear material and equipment.

2) Nuclear material. The primary threat related to material used in the nuclear fuel cycle (plutonium or high enriched uranium) lies in the acquisition by terrorists of sufficient quantities of such material to construct nuclear weapons. Although it is difficult and requires sophisticated equipment and expertise to manufacture and successfully detonate a nuclear explosive device, the possibility cannot be discounted. Another threat related to nuclear material, which is perhaps more likely, is the deliberate exposure of individuals or more general dispersal, leading to harmful effects to people, property, and the environment.

3) Other radioactive materials. The primary threat associated with materials such as radioactive sources used in hospitals or industry and radioactive waste lies, as with nuclear materials, in deliberately exposing individuals to radiation through the dispersion of the material. The immediate consequences of this threat may be limited in comparison with the other threats mentioned here, but the ease of acquiring such material is certainly greater—particularly "orphaned" sources such as those mentioned earlier—and the potential certainly exists for causing panic and economic damage, using either a so-called dirty bomb or some other means of dispersal. The risk, of course, varies with the intensity and form of the source as well as with the effectiveness of a country's controls on radioactive sources.

4) Nuclear facilities. The primary risks associated with nuclear power reactors; fuel fabrication, enrichment, reprocessing, and waste management plants; and research reactors involve physical attack or sabotage (external or internal) with a view to causing a radiological hazard. A spectrum of approaches has been adopted by different countries to counter such threats, including design and operational measures, supplemented by facility security forces and a range of local and national security measures.

IAEA Action Plan

The IAEA Action Plan is based upon two assumptions:

1) that the events of September 11 prompted a thorough re-evaluation of the potential for coordinated malicious attacks by sophisticated terrorist organizations and a recognition that the risk for nuclear materials and facilities has increased (as it has for countless other modern operations and facilities, such as chemical plants, sports complexes, and infrastructures such as water supplies);

2) that in responding to this increased risk of terrorism, we must make a fundamental decision regarding whether to abandon life as usual or, instead, to take the prudent measures necessary to protect against these new levels of risk.

The first area of focus under the Action Plan concerns national assessments of the vulnerability of nuclear facilities. Traditionally, this has been a very country specific effort, due in part to concerns about confidentiality. The degree of the threat varies from state to state, as does the level of experience and capability in determining the realistic level of threat. Thus, a more specific methodology for making these vulnerability assessments is being developed and the Agency will, on request, assist states in their performance.

Next, there is widespread recognition that the international regime for the physical protection of nuclear material and nuclear facilities needs to be strengthened and that some states require assistance in their efforts to evaluate, upgrade, and/or establish nuclear security programs. This assistance is being provided to states upon request, using international peer reviews to analyse physical protection programs, with follow-up training and other actions where needed to improve security arrangements at specific locations.

Safeguards are a fundamental prerequisite for physical protection. Indeed, the first step in preventing terrorist activities involving nuclear material is to ensure that all such material in a state is properly accounted for at all times (i.e. that there is "good housekeeping" of nuclear material). The national mechanisms for achieving that goal are commonly referred to, collectively, as State Systems for Accounting and Control (SSACs). An effective SSAC can both deter terrorist activities and provide for their early detection. The IAEA Action Plan is taking several steps to strengthen SSACs, through training, assessment services, and the coordination of equipment upgrades.

The security of radioactive sources is a specific area that needs improvement in some states; indeed, in a few states, controls are close to non-existent. To protect the public and the environment from the radiological effects of inadvertent exposure to these sources—as well as from their use in possible terrorist acts—improved security is needed in the acquisition, use, and disposal of radioactive sources, as well as in the transport of radioactive material. Moreover, the large number of "orphan" sources need to be located, secured, and disposed of to reduce the risk of their being used to perpetrate malicious acts. Under its Action Plan, the Agency intends to provide advisory services and guidelines to assist states in establishing national programs to ensure the security of significant radioactive sources. IAEA will also assist states and encourage their efforts to identify, locate, secure, and dispose of orphan sources.

Another important area is the detection of malicious activities involving radioactive materials. Theft, illicit possession, and smuggling of radioactive material are matters of international concern. States need to have in place the means to detect such incidents. There is currently no service available to assist them in evaluating their national detection capabilities, nor any internationally accepted guidelines for such detection capabilities—at borders or elsewhere—against which states can evaluate their national systems. In addition, the existing technology for the detection and monitoring of illicit trafficking needs to be advanced and the staffs of law enforcement organizations need to be trained in the use of such technology. The Action Plan includes activities to provide, on request, assessment services, training, and technical support, and to coordinate the development by member states of state-of-the-art detection instrumentation.

Should any malicious act be carried out, it is vital that states be able to respond in an effective way to mitigate any possible radiological emergencies. Experience has shown that not all states have adequate response capabilities or procedures, and the potential for terrorism underscores the need for strengthening these. The IAEA is upgrading its own Emergency Response Centre to improve its ability to assist states in responding to such incidents and to more quickly and more reliably communicate with counterparts in member states. The Agency also intends to strengthen the radiological emergency response of member states through training, improved guidelines, and technical support.

Finally, an important aspect of improving nuclear security is the development and implementation of international agreements and standards. Under IAEA auspices, many such instruments relevant to protection against nuclear terrorism—both legally binding conventions and non-binding guidelines—have been negotiated; to be fully effective, however, the scope of some instruments must be broadened and universal adherence and implementation are necessary. The Convention on the Physical Protection of Nuclear Material is one important such instrument and efforts are already underway to strengthen and broaden its scope. Under the Action Plan, the Agency will be working to bring about adherence to this Convention and to other relevant instruments by a significantly increased number of states. We believe this can best be achieved through targeted missions to governments and by finding solutions to existing national barriers such as inadequate legislation or regulatory structures.

The total cost of implementing the Action Plan has been estimated to be on the order of $11 million per year.[4] To get underway quickly, IAEA initially shifted some program priorities so that it could start immediately on a number of activities that had already been approved but had not been initiated due to lack of funding.

In summary IAEA expects to achieve the following outcomes through implementation of the Action Plan:

- comprehensive evaluation by all states of possible threats to their nuclear facilities and nuclear material;
- effective physical protection systems in all states;
- improved overall capabilities of nuclear facilities to withstand acts of extreme violence;
- high standard of SSACs in all states;
- enhanced control and regulatory oversight of radioactive sources in all states;
- strengthened border monitoring for nuclear and other radioactive material installed at key border crossings;
- a strong system of international emergency response in the event of a radiological emergency caused by a malicious act; and,
- international agreements and guidelines established for the safety and security of nuclear and other radioactive material in use, storage, and transport, along with universal adherence to these standards.

By achieving these outcomes we will not only strengthen protection against nuclear terrorism, we will also ensure that work can continue on the other side of the balance, where nuclear technology can contribute so significantly to human health, agriculture, hydrology, and clean electricity generation. If we can minimize the risks of terrorism, we can secure the continuation of the benefits of nuclear technology for future generations.

4. As of February 2004, $27 million had been pledged by 24 states plus the Nuclear Threat Initiative and some 20 states had made in-kind contributions.

The Role of the Military

Pierre Conesa°

One should not overestimate the part played in France by the military authorities in the development of civilian nuclear energy. Yet this part is very important when it comes to the security and safety of the equipment.

September 11 and the Homeland Security Architecture

The September 11, 2001 attacks in New York and Washington, DC and the subsequent US anthrax crisis had several impacts on those responsible for national defense globally. France, however, had to face a specific challenge with the explosion of the AZF factory in Toulouse several days later, which had similar dramatic echoes and intensified French reflections about effects and causes of accidents or terrorist attacks. Once the first emotional mood subsided, a wider and more global discussion began about the role of the Ministry of Defence. What are the real risks and dangers? Which of them are acceptable? In what proportion?

In terms of strategy, the main lesson of the attacks is that conventional military superiority is a guarantee outside, but not inside, national borders. The true weakness of western democracies is inside their own territory as shown by the Twin Towers events.

The attacks also revealed a suddenly widened risk at potentially dangerous sites and means for “hyperterrorism”:

- The use of civilian means for massive destruction (e.g., commercial planes used as weapons against a nuclear plant);
- The preparation of attacks with non-conventional weapons (e.g., anthrax or a dirty nuclear bomb);
- The risk that some military or dangerous civilian installations might be misdirected from their current use towards criminal goals (e.g., militarization of anthrax stolen from a lab or the AZF plant’s explosion).

French Ordonnance 59-147 of January 7, 1959—the spirit of which remains current today—establishes a concept of defense organization as “global and permanent.” The ministry of defense is just one actor among others. The role of the army is clear and exclusive outside French borders but is partial inside. When it comes to the safety of civilian nuclear installations, especially, the military authorities must work with the Home Office, the Ministry of Industry, and firms such as Electricité De France (EDF).

The role and power of the military authorities is specific to the nature of each crisis. A civilian nuclear crisis does not create a specific situation for miltary authority under the law.

The risk of a potential attack against a nuclear power plant—in terms of victims and duration of consequences—must not be underestimated. Nevertheless, the Ministry of Defence has to examine the possibility of other non-conventional attacks that could have similarly dramatic impacts: the spraying of anthrax on a city; the poisoning of drinkable water; a smallpox attack. In France, for example, there are 13 dangerous chemical installations around Lyon, where more than one million people are living. The area, called the “valley of chemistry,” is near the A7 motorway, where 5,000 trucks pass every day.

The first lessons after September 11 show that civilian nuclear installations are safer than one might think—more so than chemical and industrial sites, which are also at risk. A terrorist attack with conventional weapons on a nuclear site would be more difficult than one on a chemical or bacteriological installation, and it would be less easy to provoke an explosion of a nuclear power station. Nonetheless, the damage from a successful attack would be more serious and would endure longer.

Some of the safety structures implemented by EDF have to be copied by other firms. During the 1980s, EDF signed two conventions with the Gendarmerie Nationale, including one with the GIGN, a military unit dedicated to commando operations to free hostages. These conventions permanently ensure that EDF will have hundreds of soldiers ready to prevent threats at its nuclear sites.

An inventory of the nuclear installations (137 sites, including about 20 EDF nuclear power stations) led to

° These are the personal views of the author and not the official policies of the French government with regard to civilian and military nuclear strategy.

contrasting, but rather reassuring, results in terms of security and safety. The nuclear military installations were the safest. Some of the protections dedicated to military sites could be replicated for civilian sites.

The risks taken into account until now (eg, sabotage) in the security program of the civilian nuclear industry are still less serious than the risk of a major attack such as that on September 11. The consequences of a plane crash on the reprocessing plants of La Hague and Sellafield, as examined in a WISE-Paris study,[1] seemed unlikely before September 11, but suddenly became real.

No system can guarantee 100% protection. Recall that a small tourism plane landed in the middle of Red Square in Moscow during the Cold War. Nevertheless, there are at least three ways to further reduce the risks at dangerous facilities:

- improve security when designing nuclear power stations by, for instance, integrating automatic safety systems in power stations as is done in submarine nuclear reactors;
- improve security systems and contingency planning to protect people and the environment;
- analyze the methods of potential terrorists in order to improve the active protection of sites (as encouraged in the WISE-Paris study).

Military protection of nuclear sites remains very hard to organize because it requires an immediate political decision at the most complex moment.

Determining the responsibilities of the different actors (i.e., public authorities, the army, the police, facility operators) is a difficult task. Problems of civil liberty also emerge. In France, for example, armed guards and police are forbidden to shoot without some specific pre-emptive rules.

Military protection of the sites (eg, by planes and missiles) remains very hard to organize because it requires an immediate political decision at the most complex moment. Who decides when to shoot? Are we sure the plane is going to crash on the site? Should we shoot it down above a city? Everything has to be done, therefore, to avoid being placed in such a situation. A global security system has to be implemented, taking into account airport security, no fly zones, and other measures.

In all the cases imagined by the authorities, no scenario allows the army to take full responsibility for these decisions. All the power remains in the hands of civilian authorities. There is thus no need to fear a dramatic scenario where the army would govern. On the contrary, the privatization of the security at dangerous EDF sites, where the firm works with the Gendarmerie, is an interesting model that could be applied elsewhere.

Two laws adopted in France on February 13, 2002 created a general nuclear safety authority and an institute on radiation protection and nuclear safety, both of which are supposed to be more independent than the Institut de Protection et de Sécurité Nucléaire, which appeared to be quite dishonest during the Chernobyl crisis.

Relations Between Civilian and Military Nuclear Programs

France is the only country where nuclear military sites are under civilian control. “Nuclear society,” therefore, does not necessarily mean “military society.” There is no automatic relation between the development of nuclear energy and the French deterrence force. Three things should be borne in mind:

- Plutonium stockpiles for military needs are sufficient to ensure our deterrence credibility.
- Like other nuclear weapons states, France is reducing its nuclear arsenal with the removal of Hades nuclear short-range missiles and ICBMs at Albion.
- France has ratified the Comprehensive Test Ban Treaty, which forbids nuclear tests. France has also dismantled the Mururoa nuclear test site.

At the same time, some changes could be worrying. Today, it is the US that is withholding support from the CTBT and other treaties. Strategic thinking in the US not only rejects the CTBT, but also envisions the use of “mini-nukes” against some kinds of underground bunkers.

Conclusion

The aim of this analysis is not to explain or justify the French nuclear energy program, but to explain how the Ministry of Defence has been involved after September 11 in taking into account the new strategic framework. In view of the wide range of risks, terrorism, whether or not it is directed against nuclear energy facilities, could lead us to a militarization of society. The main enemy today is not nuclear energy but terrorism.

Reference

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Rethinking the Role of Government and Industry

Reactor Safety

The Role and Importance of the Swiss Nuclear Safety Authority

Wolfgang Jeschki

Switzerland's federal constitution establishes a number of ground rules and, hence, constraints on government action. Fundamental is the separation of legislative and executive, of the making and exercising of the law. The Federal Assembly (parliament) passes law-defining decrees in the form of federal acts of parliament. These federal laws are subject to optional referendum (ie, the electorate can demand a vote on whether a law is adopted or rejected). For changes to the federal constitution, a plebiscite (compulsory referendum) is obligatory.

The Federal Council of seven ministers is the supreme directive and executive body of the Federation. It has the right to initiate legislation by submitting draft laws to the Federal Assembly for debate and decision. The Federal Council also acts judicially in the form of statutory orders, provided the constitution or the terms of federal laws give it the power to do this. It sees that the laws are executed. The Federal Assembly is responsible for verifying that the measures taken by the Federation to implement the law are effective.

The constitution also makes provision for popular initiatives. The electorate, if 100,000 of them so wish, can petition for a total or partial change to the constitution. For a popular initiative to succeed, it must receive a majority both of votes cast and of cantons. Since 1976, the Swiss people have used popular initiatives six times in order to regulate more strictly or prohibit the operation and building of nuclear power plants:

1) Popular initiative "for the preservation of people's rights and of safety in the construction and operation of atomic installations," submitted on May 20, 1976; put to the vote on February 18, 1979; narrowly defeated (965,927 to 920,480, 14 to 9 cantons);
2) Initiative "for a cessation of the atomic energy programme" of June 1980. This failed to achieve the number of signatures needed before an initiative can be voted on;
3) Twin initiative "for a future with no new nuclear power plants" and "for a safe, economical, and environmentally appropriate power supply." Both were turned down by voters on September 23, 1984 (a. 931,245 to 762,702, 17 to 6 cantons; b. 916,916 to 773,767, 17 to 6 cantons);
4) Initiatives to "stop atomic power plant construction" (moratorium) and "for the abandonment of atomic energy" submitted in 1987. The vote was on September 23, 1990. The moratorium was passed (946,077 to 789,209, 19 to 3 cantons); the abandonment initiative was thrown out (915,739 to 816,289, 16 to 7 cantons).
5) The initiative "MoratoriumPlus—for prolongation of the ban on building atomic power plants and for limitation of the nuclear risk"; and
6) The initiative "electricity without the atom—for an energy rethink and the phased closure of atomic power plants," both submitted in 1999. Both were turned down by voters in May 2003 [MoratoriumPlus: 1,341,512 to 955,593 and 22 to 1 cantons; phased closure: 1,540,164 to 783,718 and all cantons beside Basel Stadt).

In Switzerland, therefore, certainly since 1976, the use of nuclear energy has repeatedly exercised people's minds. The operation of nuclear power stations has always been allowed during this time, while during and after the ballots public attention has focused on the importance of close scrutiny to ensure safety.

The constitution also spells out rules concerning the work of the administration and, hence, the job of the Nuclear Safety Authority (HSK). Article 5 lays down the principles of government action. According to this, the foundation and constraint for government action is the law. Government action must be in the public interest and proportionate. Article 9 says that everyone has the right to be treated by the organs of government with discretion and in good faith.

These rights of the people, on the one hand, and the rules for the administration, on the other, make sure that in Switzerland decisions can be taken democratically about the operation of nuclear power plants as well as other matters.

Relevance of the Constitution to the Safety Authority

Switzerland's Federal Constitution prescribes the separation of legislative from executive and it allows wide-ranging involvement in any alteration of the constitution and in the drawing up of federal laws. The functions of the HSK in this include the following:

- participation in the preparation of draft laws and statutory orders;
- membership on committees of both chambers of parliament as expert informant during the consultative process;
- implementation of laws and statutory orders relating to the safety and radiation protection of nuclear installations; supervision of nuclear installations;
- informing the general public with regard to safety and radiation protection in nuclear installations.

Participation in Drafting of Laws

As already mentioned, the Federal Council has a right of initiative. To enact a new law or to change an existing law the Federal Council presents a draft proposal, a bill, to parliament. This bill is first worked on by the responsible ministry (department). For nuclear energy this is the Department of Environment, Transport, Energy and Communications (DETEC), which sets up a working group involving specialists from the ministry in charge (the Federal Office of Energy, in the case of nuclear power), lawyers, and experts from other concerned ministries.

While the act is being drawn up, the safety authority contributes its expertise and at the same time can state its wishes on matters that need dealing with at the level of a law in order to make its supervisory function easier. Its influence on lawmaking, however, is in general not very great. The judiciary lays down rules as to what merits a law and what does not. Laws should cover only fundamentals; they are not the place for technical details. The working group's draft then goes to sectional consultation, during which other interested sections of government can express their views on the bill. This is followed by a version squared among the different ministries and then consultation with interested circles, in particular with the cantons, the political parties, and other interested or affected organizations and groups. Depending on the outcome of the consultations, the bill is then either shelved because consultation has failed to produce a solid consensus and there is no prospect of getting the bill through parliament and through a referendum, or it is tidied up and passed by the Federal Council to parliament with an invitation to debate it. Since this procedure involves so many stakeholders, the technical watchdog plays a fairly minor role and has no great influence on the formative process.

The situation is different in the case of preparing the text of statutory orders. The law provides for a delegation of authority; the Federal Council is summoned to list specific demands concerning articles of a law ("the Federal Council decrees the necessary provisions") or it is left to the Federal Council whether it wants to create stipulations defining an article more precisely ("the Federal Council can decree additional provisions"). With orders, too, the responsible ministry or government office establishes a working group. Since statutory orders contain regulations on technical matters, the role and influence of the safety authority is considerable here. The HSK's representatives played a prominent part in drawing up the radiation protection order, for example, and to a large degree helped decide its form. This will also be the case with the nuclear energy order that will have to be created to accompany the Nuclear Energy Act.

Committees As Expert Informants

The Nuclear Energy Act (KEG) was dealt with in 2001 and 2002 by the upper and lower chamber's committee on environment, planning, and energy (UREK).] Representatives of the administration, among them a representative of the nuclear safety authority, the HSK, attend to provide information. The role of the HSK here is to explain complicated technical matters to non-experts in a way that allows a political opinion to be formed and, ultimately, a decision taken.

The HSK has to listen to what topics of concern are raised by the parliamentarians, try to understand concerns not always crisply formulated in technical terms, and then present them clearly with the importance of the topic for the wording of the law. The HSK again has some influence here, since it can consider, or disregard, concerns expressed imprecisely.

In my view, the plan to allow parliamentarians to have assistants is very much to be welcomed. Many parliamentarians will then be able to go more deeply into their intentions on a law's wording, gather background material for a bill, and in debate come up with proposals that are better defined and argued.

Implementation of Laws and Statutory Orders; Supervision of Nuclear Installations

As the body supervising the safety and radiation protection of Switzerland's nuclear power plants, the HSK plays a major role in enforcing the relevant laws and statutory orders. Legislation on radiation protection was added to in 1994, when the Radiation Protection Act (SR 814.50) and the related Radiation Protection Order (SR 814.501) came into force. Subsequently, a great many activities became subject to other statutory orders. These included the Order on Dosimetry of Persons (SR 814.501.43), the Order on Training and Permitted Activities (SR 814.501.261) and the Order on Handling of Open Radioactive Radiation Sources (SR 814.554). All these are vital to radiation protection in and around nuclear power plants, and the HSK has to see they are adhered to. In the radiation protection sphere, the Nuclear safety Authority has very little leeway for interpretation where enforcement is concerned; the rules laid down in the statutory orders go into a lot of detail.

What is the situation regarding nuclear safety? Here there is the Atom Act of 1959 (SR 732.0), the Federal Resolution on the Atom Act of 1978 (BBatG, SR 732.01), the Atom Order of 1984 (SR 732.11) and the

Order concerning the Supervision of Nuclear Installations of 1983 (SR 732.22). These acts and orders all contain very little in the way of technical stipulations. It has therefore always been the task of the HSK to set down the necessary technical requirements in guidelines. This is done partly in conjunction with the Swiss Federal Nuclear Safety Commission (KSA). The HSK uses 34 guidelines in its work that have been issued to date. These guidelines are made public and can be obtained on the Internet (www.hsk.ch).

The Nuclear Energy Act has passed the parliament, and there was no referendum against it. In 2003 and 2004 the Nuclear Energy Order is established. The law and the order will be put in force in 2005.Many of the safety regulations at present to be found in guidelines will be incorporated in the Nuclear Energy Order. The HSK plays a major role in drawing up this order, so its influence on the form of the order is correspondingly great.

Informing the General Public

The HSK must not engage in policy making. It must, however, provide the bodies and organizations that influence and are involved in the federal constitution and federal laws with all the information they need to do their job. The informing function of the HSK is of ever growing importance, especially after September 11, 2001. It includes:

- an annual report on safety and radiation protection at nuclear installations in Switzerland;
- a homepage on the internet, with the organization of the HSK, media releases, publications, etc.;
- regular discussions with organizations critical of nuclear energy, such as Greenpeace and the Swiss Energy Foundation (SES);
- publishing the HSK guidelines and bulletins on how the HSK does its supervising.

This transparency of the HSK's work has steadily increased in recent times. After September 11, one must see whether the Nuclear Safety Authority can provide more information to shape the opinions of public and politicians. In the past, for example, the effects of a plane crashing on a nuclear power plant had been examined only in broad terms. The low probability of less than once in 10 million years was justification for not studying these accidents any further. After September 11, the situation has changed. The consequences of a plane crash must be known in order to be able to decide whether the nuclear power plants can be allowed to go on operating. Studies to this end are under way. When all the facts are available and the statements can be verified, there will be better opportunity for everyone to exercise the rights of participation enshrined in the federal constitution. Operators, safety authority, and, finally, the politicians will then have to act accordingly.

The importance of furnishing information is further illustrated by the fact that the HSK has appointed a full time information officer who maintains contacts with the media and interested bodies. The HSK has also built up a quality management system. This process-oriented system shows how the authority is performing its duties and how it deals with operators, the public, and other clients. As a result, the work of the HSK is highly transparent. The quality management system was certified in accordance with ISO 9000/2000 at the end of November, 2001.

But even then there will still be no incontrovertible answers to the question "how safe is safe enough." There is no such thing as complete safety. Although the likelihood of a very serious accident occurring is very low, the effects of one can be devastating. How one is to go about living with these facts is ultimately a matter for the politicians and the people. The tools needed to make decisions are available in Switzerland and have already been used a number of times. So long as the law permits the operation of nuclear power plants, the HSK will implement this law to the best of its knowledge and belief. It is not for the HSK, however, to make operation impossible.

Safety Authority and Operators

The supervisory authority has essentially two tasks:

1) To enforce the laws, statutory orders, licences, etc. This is supervising in the narrower sense: there must be no influence exerted by the operators; the HSK must arrive at its supervisory decisions strictly according to the word of the law.
2) To foster and apply the current state of the art and knowledge. Making sure that the HSK is always up to date with the latest technology and knowhow requires not only perusing the literature and attending conferences, but also talking with the operators. Working together like this is the only way to ensure that the HSK knows what is possible, what is feasible, and what is reasonable. Then it has solid grounds for demanding retrofits if the operator has not already done them itself.

Summary

Switzerland has all the instruments of democracy, on the one hand, to answer the question "nuclear energy yes or no?" and, on the other, to keep a clear watchful eye on its nuclear installations. Important points are:

- The making of laws lies with parliament and with the people, hence so does the decision as to whether nuclear power plants can or cannot be operated in Switzerland.
- The people have had a number of opportunities to decide about the operating of nuclear power plants in Switzerland. Most of the initiatives were turned down. The moratorium initiative, which provided for a ten-year halt to construction, was approved.
- The new Nuclear Energy Act and Order

will be put in force in 2005. So many requirements for nuclear safety will then have a higher legal importance as it was the case with the guidelines.

• The safety authority enforces the laws. It does not decide whether nuclear power plants can be operated or not. It decides whether the plants are operated within the bounds of the law, and commands action to be taken if necessary.

• Clear and comprehensive information is required so that parliament and people know the facts when making their decisions. As an objective organization not tied to any lobby, the HSK contributes substantially to this information. The informing function and transparency of the HSK's work have been constantly improved in recent years. The events of September 11, 2001 have underlined the importance of straight information and transparency.

Terrorism on a Nuclear Installation

Are Nuclear Operators Liable and Insured?

Tom Vanden Borre

Without the terrorist attacks on New York City and Washington, DC, 2001 would have been an average loss year for the insurance industry. Estimates indicate that the insured losses due to the attacks of September 11th, 2001 on the Twin Towers of the World Trade Center amounted to US $19 billion in property and business interruption policies[1]—the highest property loss ever in the history of insurance. The estimates of the overall insured loss amounted to $50 billion—much higher than the $21 billion insured losses incurred by Hurricane Andrew, the second largest insurance event in history and the $3 billion insured losses incurred by Piper Alpha, the largest human-caused property insurance loss prior to the attacks on the Twin Towers. The total economic damage is much higher still than the figures for insured losses—an estimated $90 billion.

The September 11 attacks have alerted the nuclear industry as well, prompting the International Atomic Energy Agency (IAEA) to make additional efforts to combat nuclear terrorism.[2]

According to the IAEA, the risk for nuclear terrorism can be divided into three categories:

> a. nuclear facilities: the primary risks associated with nuclear facilities would involve the theft or diversion of nuclear material from the facility, or a physical attack or act of sabotage designed to cause an uncontrolled release of radioactivity to the surrounding environment;
> b. nuclear material: this risk implies that terrorists would obtain nuclear weapons;
> c. radioactive sources: terrorists could develop a crude radiological dispersal device using radioactive sources commonly used in everyday life.

The international legal framework of the IAEA addresses the various aspects of the risk of nuclear terrorism. Several international conventions have been drafted by the IAEA:[3] the Convention on the Physical Protection of Nuclear Material (1979); the Treaty on the Non-Proliferation of Nuclear Weapons (1968); the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency (1986), among others. The IAEA has also developed safety regulations such as the Nuclear Safety Standards (NUSS) for nuclear power plants, as well as Regulations for the Safe Transport of Radioactive Materials. Although all those measures existed prior to the September 11 attacks, the IAEA approved an action plan on March 19th, 2002 designed to upgrade worldwide protection against acts of terrorism involving nuclear and other radioactive materials. As Mr. Mohamed ElBaradei, IAEA Director General, said: "Many of our programs go to the heart of combating nuclear terrorism, but we now have to actively reinforce safeguards, expand our systems for combating smuggling in nuclear material and upgrade our safety and security services."[4]

This paper addresses the consequences of the events that occurred on September 11th, 2001 for the civil liability and insurance of nuclear incidents in nuclear installations,[5,6] with a focus on the first category

1. "Terrorism—dealing with the new spectre", Focus Report, Swiss RE, 2002, and "Natural Catastrophes and man-made disasters in 2001: man-made losses take on a new dimension", available on www.swissre.com.
2. The IAEA is a UN specialized organization for scientific and technical co-operation in the peaceful use of nuclear technology. Its task is both to promote and to control the use of those technologies. The IAEA Statute provides that "the Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose." More info on the website of the IAEA at www.iaea.org/worldatom.
3. El Baradei M., Nwogugu E, en Rames J. International law and nuclear energy: Overview of the legal framework. IAEA Bulletin 1995/3:16-25.
4. For more details on the strengthened policy of the IAEA, see Nilsson A.. Security of material. The changing context of the IAEA's programme. IAEA Bulletin 2001;4312-15; Goldschmidt P. Strengthened safeguards. Meeting present and future challenges. IAEA Bulletin 2001;43:6-11; Bunn M, Bunn G. Nuclear theft and sabotage. Priorities for reducing new threats. IAEA Bulletin 2001;43:20-29; Gonzalez AJ. Security of radioactive sources. The evolving new international dimensions. IAEA Bulletin 2001;43:39-48.
5. We indeed use the word "nuclear incident" because this is

of nuclear terrorism, defined as an attack or an act of sabotage on a nuclear installation or on a vehicle transporting nuclear material over land. [The consequences on maritime transport of nuclear substances, for which separate conventions exist, are not addressed here.]

A discussion of the existing international nuclear civil liability conventions will be followed by analysis of the reaction of the insurance industry (both the conventional and nuclear insurance industries) to the events of September 11 and by a brief overview of some alternative ways for finding additional coverage and/or capacity.

International Liability Conventions

Overview

Liability and insurance is only one aspect of dealing with nuclear terrorism. Measures preventing terrorist attacks on nuclear installations and transports (physical protection, safeguarding of nuclear material, etc.) are at least equally important.

From a liability and insurance perspective, however, there are two international nuclear civil liability regimes: the Nuclear Energy Agency (NEA)[7] and the International Atomic Energy Agency.[8]

The NEA regime consists of:

- the Convention on Third Party Liability in the Field of Nuclear Energy of July 29, 1960 ("Paris Convention") and
- the Convention of January 31, 1963 Supplementary to the Paris Convention ("Brussels Supplementary Convention").

The NEA-regime was slightly modified by two Protocols in 1964 and 1982.[9]

Whereas the Paris Convention states the principles of liability in case of a nuclear incident, the Brussels Supplementary Convention provides for additional compensation for damage in case the liability coverage of the operator under the Paris Convention is inadequate or insufficient.[10] The additional compensation provision basically consists of State funds from the installation State and from the different Contracting Parties.[11]

In February 2002, 15 countries were member of the Paris Convention: Belgium, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Portugal, Slovenia,[12] Spain, Sweden, Turkey, and the United Kingdom. Except for Portugal, Greece, and Turkey, all member countries of the Paris Convention are also member of the Brussels Supplementary Convention. Slovenia has indicated its intention to seek accession to the Brussels Supplementary Convention.

The IAEA regime, comprising basically the same principles as the Paris Convention, consists of the Vienna Convention on Civil Liability for Nuclear Damage of May 21, 1963.

In February 2002, the following 33 countries were parties to the Vienna Convention: Argentina, Armenia, Belarus, Bolivia, Bosnia Herzegovina, Brazil, Bulgaria, Cameroon, Chile, Croatia, Cuba, Czech Republic, Egypt, Estonia, Hungary, Latvia, Lebanon, Lithuania, Mexico, Niger, Peru, Philippines, Poland, Republic of Moldova, Romania, Saint Vincent & the Grenadines, Slovakia, Slovenia, the Former Yugoslav Republic of Macedonia, Trinidad and Tobago, Ukraine, Uruguay, and Yugoslavia. From November 12, 2002 onwards the Vienna Convention ceased to apply to Slovenia.

Mainly due to the Chernobyl accident, both regimes have been revised and modernized.[13] The first result of the modernization process was the adoption of the Joint Protocol linking the two regimes. The second result was the modification of several provisions of the Paris

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exactly the phrase used in the civil nuclear liability Conventions.

6. About the proliferation of nuclear weapons, see inter alia Vanden Borre, T. and Carchon, R., "Preventing the Proliferation of Nuclear Weapons: 50 Years of Atoms for Peace", Nuclear Law Bulletin, vol. 57, 1996, pp. 23-52.

7. The Nuclear Energy Agency (NEA) is a specialised agency within the Organisation for Economic Co-operation and Development (OECD), an intergovernmental organisation of industrialised countries, based in Paris. The mission of the NEA is to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally friendly and economical use of nuclear energy for peaceful purposes. For more information, see the website of the NEA at www.nea.fr.

8. For a useful overview on nuclear law, see, inter alia, OECD/NEA, Liability and Compensation for Nuclear Damage: An International Overview, Paris, OECD-NEA, 1994.

9. The Protocol to the Paris Convention of 28 January 1964 adjusts some of the definitions and imposes liability on the operator for damage to the means of transport; the Protocol to the Paris Convention of 16 November 1982 changes the unit of account into SDR and increases the liability amounts of the three tiers from initial 120 million up to 300 million SDRs. In this respect, see, inter alia, Lagorce, M., "Bilan et analyse critique de la Convention de Paris et de la Convention complémentaire de Bruxelles après les Protocoles de 1982", in Nuclear Third Party Liability. Status and Prospects, Munich Symposium, Paris, 1985, pp. 24–42.

10. Bette A, Didier JM, Fornasier R, Stein RM. La Réparation des Dommages Nucléaires en Europe. Régime instauré par la Convention de Bruxelles du 31 janvier 1963, Brussel, 1965, p. 10; for a critical analysis see Doeker G, en Gehring T. Private or international liability for transnational environmental damage – the precedent of conventional liability regimes. Journal of Environmental Law 1990;2:1-16.

11. According to Article 3 of the Brussels Supplementary Convention, the total amount of compensation for damage arising from a nuclear incident will be composed of different tiers: the first, with a minimum of 5 million Special Drawing Rights (SDRs), will be provided by the operator's liability; the second, between this amount and 175 million SDRs, will be provided by the State on whose territory the installation of the liable person is situated; a third, between 175 million and 300 million SDRs, will be provided by the Contracting Parties to the Brussels Supplementary Convention, a ratio of the GNP and the thermal capacity of the reactors.

12.The accession of Slovenia became effective on 16 October 2001.

13. See, inter alia, Lamm, V., "Status of the Revision of the Vienna Convention", in Nuclear Accidents. Liabilities and Guarantees, OECD, Paris, 1993, pp. 170-180; Reyners, P., "Le Régime International de Responsabilité civile Nucléaire. Prespectives d'évolution", in L'option Nucléaire. L'Ethique et le Droit, May 1994, Société Française d'Energie Nucléaire, 1994, pp. 245-269 ; Horbach, N.L.J.T., "Lacunae of International Nuclear Liability Agreements", in Horbach, N.L.J.T. (ed.), Contemporary Developments in Nuclear Energy Law. Harmonising Legislation in

Convention, the Brussels Supplementary Convention, and the Vienna Convention.

Originally, the Paris and Vienna Conventions operated entirely independently from each other. If a victim suffered damage in the territory of a Contracting Party to the Paris Convention as a result of a nuclear incident occurring in the territory of a Contracting Party to the Vienna Convention, the victim could not make a claim for compensation in the country where the incident occurred. The Joint Protocol of Vienna of September 21, 1988, which entered into force on April 27, 1992, solves this shortcoming by linking the territorial application of both Conventions. Only a few countries have ratified the Joint Protocol, however, which considerably reduces its importance.[14,15]

The revision process also aimed at modernizing the nuclear civil liability conventions. Although the exercise is basically finished, none of the revisions is in force yet. The negotiations of the revision of the NEA-regime ended early in 2002; the contracting parties will adopt a Protocol to both the Paris and the Brussels Supplementary Convention at a diplomatic conference to be convened.° The revision of the IAEA-regime had already been formally concluded with the adoption at a diplomatic conference on September 12, 1997 of the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage and the Convention on Supplementary Compensation for Nuclear Damage.[16] So far, neither the Protocol nor the Supplementary Funding Convention have entered in force.

Although the revision of both regimes changes some important provisions of the Conventions, the basic principles as mentioned above remain the same.

° Editor's note: The Amending Protocols, shifting the liability burden from governments to industry and setting new limits on liability, were signed in 2004 but have not yet been ratified by the EU Council. For more information, see Uranium Information Centre, Melbourne: www.uic.com.au/nip70.htm.

Basic principles

The Paris and the Vienna Conventions have the same principles regarding liability in case of nuclear incidents:

a. strict liability of the nuclear operator;
b. channelling of all liability to the nuclear operator;
c. limitation of liability in amount and in time;
d. compulsory insurance coverage up to the liability limit;
e. competence of only one court per country.[17]

Article 3 of the Paris Convention holds the operator of a nuclear installation liable for all damage that it causes to persons or to property, with the exception of damage to the installation itself, to other nuclear installations located on the same site, and to any other property located on the same site that is used or is to be used in connection with any such installation.[18] Due to the complex techniques used during the production of nuclear energy, proving the existence of fault was considered too difficult.[19] The victim must prove his damage as well as the causal link between his damage and the nuclear incident. The conduct of the nuclear operator is irrelevant: he will be unable to escape liability (e.g., by saying that he respected all safety regulations). Article 3 of the Paris Convention thus introduces what is commonly referred to as strict liability.

Article 6 of the Paris Convention channels all liability to the nuclear operator:

> "The right to compensation for damage caused by a nuclear incident may be exercised only against an operator liable for the damage in accordance with this Convention....Except as otherwise provided in this Article, no other person shall be liable for damage caused by a nuclear incident...."

This definition contains two elements.[20] First, the

CEEC/NIS, Kluwer Law International, Den Haag, Boston, 1999, pp. 43-85.

14. In September 2001, the following 24 countries were Party to the Joint Protocol: Bulgaria, Cameroon, Chile, Croatia, Czech Republic, Denmark, Egypt, Estonia, Finland, Germany, Greece, Hungary, Italia, Latvia, Lithuania, the Netherlands, Norway, Poland, Romania, Saint Vincent & the Grenadines, Slovakia, Slovenia, Sweden and Ukraine.

15. See, inter alia, Pelzer N. "Inadequacies in the Civil Liability Regime evident after the Chernobyl Accident: The Response in the Joint Protocol of 1988", in Nuclear Accidents: Liabilities and Guarantees, Paris, OECD, 1993, p. 162; Von Busekist, O., "Le Protocole commun relatif à l'application de la Convention de Vienne et de la convention de Paris: Une passerelle entre les deux Conventions sur la responsabilité civile pour les dommages nucléaires", Nuclear Law Bulletin, 43, June 1989, p. 16.

16. See inter alia, Schwartz, J., "Diplomatic conference convened to adopt a protocol to amend the Vienna Convention on civil liability for nuclear damage and to adopt a Convention on supplementary compensation for nuclear damage", in Le droit nucléaire: du XXe au XXIe Sciècle. Nuclear Inter Jura '97, Société de Législation Comparée, Paris, 1998, pp. 427-429; Lamm, V., "Le Protocole d'amendement de la Convention de Vienne de 1963", Bulletin de Droit Nucléaire, N° 61, 1998, pp. 7-26, Reyners, P., "Modernisation du régime de responsabilité civile pour les dommages nucléaires: révision de la Convention de Vienne et nouvelle Convention sur la réparation complémentaire des dommages nucléaires", Revue Générale de Droit International Public, 1998/3, pp. 747-763.

17. There are some difference between the texts of both regimes, primarily that in the NEA-regime, the Brussels Supplementary Convention introduces an international layer providing additional compensation for victims. The latter Convention also offers the possibility to the installation States, to provide for additional funds.

18.This regime is applicable upon the condition that it can be proved that the damage was caused by a nuclear incident occurring at that installation, or by nuclear material originating in that installation involved in the incident. For the definitions of these concepts, see Article 1 of the Paris Convention.

19. Exposé des Motifs, Motif 14.

20. See Vanden Borre T, "Channelling of liability: a few juridical and economic views on an inadequate legal construction", in Horbach, N.L.J.T. (ed.), Contemporary Developments in Nuclear Energy Law. Harmonising Legislation in CEEC/NIS, Kluwer Law International, Den Haag, Boston, 1999, pp. 13-39; Vanden Borre T, Efficiënte preventie en compensatie van catastroferisico's.

operator can, in case of a nuclear incident as defined pursuant to the Paris Convention, only be held liable under the conditions of the Convention and, secondly, no one else but the operator[21] is liable for the damage. This means that the Paris Convention constitutes the only legal basis for a victim to claim compensation for damage suffered as a result of a nuclear incident.

Another consequence of channelling liability is that the operator of a nuclear installation has, in principle, no right of recourse for the compensation paid by it or its insurer to victims of a nuclear incident. There are two exceptions to the channelling principle. First, the operator possesses, pursuant to Article 6(f), a right of recourse with respect to the person who, by his or her conduct (act or omission), intentionally caused damage by a nuclear incident. Second, the operator has a right of recourse if and to the extent that it is so provided expressly by contract.

According to Article 7 of the Paris Convention, the maximum operator's liability is limited to 15 million Special Drawing Rights (SDRs) [21.46 million euros].[22,23] This limitation was considered necessary in order not to jeopardize the development of the nuclear industry.[24] A Contracting Party can, however, decide within its national legislation either to increase or decrease this amount, provided that the minimum amount is not set lower than 5 million SDRs (7,15 million euro).

The liability of the operator is also subject to a time limit. According to Article 8 of the Paris Convention, the right to claim compensation will be extinguished if an action is not brought within 10 years from the date of the nuclear incident. The Contracting Parties, nevertheless, have the option to establish a period longer than 10 years, provided that the operator's liability is insured.[25]

According to Article 10 of the Paris Convention, operators are required to have and maintain insurance or other financial security up to the amount of their limited liability (the so-called congruence principle, meaning that all liability should be covered). Although the Convention clearly gives operators a choice as to the kind of financial security, they have opted for insuring their liability. This mandatory coverage guarantees that victims will be compensated for damage suffered—or, through the limitation of the available amounts, part of the damage. The national authorities have the responsibility to determine the nature and conditions of the insurance or other financial security that an operator needs to obtain.

Finally, jurisdiction over claims concerning nuclear incidents lies exclusively with the courts of the Contracting Party in whose territory the nuclear incident occurred (Article 13(a) of the Paris Convention). The main reason for establishing one exclusive competent court seems to be to ensure that the maximum amount of liability will not be exceeded: a fair distribution of the available amount for compensation would result in insoluble problems if the claims with respect to one nuclear incident could be made before different courts. Ensuring unity of jurisdiction is intended to prevent the sum of awards of compensation by various courts from exceeding the operator's liability and also promotes equitable adjudication of various claims.[26]

Both the Paris and the Vienna Conventions also apply to the transport of nuclear substances (Article 4 of the Paris Convention and Article II.b of the Vienna Convention).

The Contracting Parties of these Conventions have adopted a specific nuclear liability law in order to introduce these principles into their national legal systems. One must therefore consult that specific law in order to know, for example, to what amount the operator is liable. The Conventions, indeed, offer some flexibility in the adoption of the principles.

Before analyzing the liability of the nuclear operator in case of a nuclear incident caused by an act of terrorism, it is important to answer the question whether the principles discussed above apply only to nuclear installations for peaceful purposes or also to nuclear installations for non-peaceful purposes. This is relevant, since a terrorist attack might hit either type of nuclear installation.

Nuclear Installations For Peaceful and Non-Peaceful Purposes

Under both regimes, there is some uncertainty as to whether the Conventions only apply to nuclear installations for peaceful purposes or whether they also apply to nuclear installations for non-peaceful purposes. The Paris Convention and the Vienna Convention are completely silent on this issue.

In the NEA regime, the Brussels Supplementary Convention does contain a specific provision in this respect. Article 2(a) reads that the Convention "shall apply to damage caused by nuclear incidents, other than those occurring entirely in the territory of a State which is not a Party to this Convention: for which an operator of a nuclear installation, used for peaceful purposes, situated in the territory of a Contracting Party to this Convention...and which appears on the list established and kept up to date in accordance with the terms of Article 13, is liable under the Paris Convention" [emphasis added].

The Brussels Supplementary Convention, therefore, explicitly states that it applies only to nuclear installations for peaceful purposes. This does not mean, however, that the same is true for the Paris Convention.[27] The Paris

Het voorbeeld van schade door kernongevallen, Intersentia, Antwerpen, 2001, p. 225 ff.

21.The person appointed by the competent authorities as the operator of a nuclear installation. See Paris Convention, Article 1(a).

22. 21.46 million euro.

23. Note that under the revised Paris Convention, the operator will at least be liable to 700 million euro.

24. Exposé des Motifs of the Paris Convention of 16 November 1982, at Motif 45. The reason for this limitation was, therefore, purely economic: the liability of the operator was limited to the amount for which the insurance market was able to provide coverage.

25. Also this article will be replaced once the Protocol to the Paris Convention will enter into force: a distinction will be made between damage to persons (30 years prescription period) and damage to property (10 years prescription period).

26. Note that for the Member States of the European Union, there are currently some questions related to this principle, given the (similar) provisions of the Council Regulation N° 44/2001 of December, 22nd, 2000 on jurisdiction and the recognition and enforcement of judgments in civil and commercial matters, OJ, L 12/1, 16/01/2001. The Regulation entered into force on March, 1st, 2002.

27. See Bette A, Didier J.M, Fornasier R, Stein RM. "La Réparation des

Convention deals with the liability of the nuclear operator, whereas the Brussels Supplementary Convention introduces supplementary compensation (basically State funds). Given the different nature of these two Conventions, one can argue that the State funds may only be used for civil nuclear installations whereas the liability of the operator can apply to both civil and military nuclear installations. There is, indeed, no explicit provision in the text of the Paris Convention stating that the Convention only applies to nuclear installations for peaceful purposes. Moreover, a military nuclear installation falls within the scope of the definition of a "nuclear installation" under the Paris Convention.[28]

The same conclusion is valid for the IAEA regime. The Vienna Convention does not explicitly deal with military nuclear installations either. But the Protocol to the Vienna Convention does add a specific provision in this respect. Article 3 of the Protocol introduces Article IB in the Vienna Convention, according to which the Convention shall not apply to nuclear installations used for non-peaceful purposes.

Contrary to the IAEA regime, the Contracting Parties of the Paris Convention decided at one of the first meetings concerning the revision of the Convention in April 1998, that there was no need to adopt a similar provision as in the Protocol to the Vienna Convention, excluding nuclear installations for non-peaceful purposes from the scope of the Convention. The Contracting Parties decided that the scope of the Convention should not be restricted and that the Parties should be able to choose to include or exclude military nuclear installations from their national nuclear liability laws. Therefore, under the Paris Convention, the Parties are free to make their nuclear civil liability provisions applicable to nuclear installations for non-peaceful purposes. Some countries, such as France and the Netherlands, have indeed chosen to include military installations in their national nuclear liability laws. The nuclear liability laws of other countries (e.g., Belgium) are silent on this matter. One can assume that this implies that the law also applies to military nuclear installations—if the country has such installations.

In order to have a correct answer to the question whether nuclear liability provisions also apply to nuclear installations for non-peaceful purposes, one should first look at the national nuclear liability law. This law can say either that it shall only apply to nuclear installations for peaceful purposes, or that it is also applicable to nuclear installations for non-peaceful purposes. The law can also be silent on this issue. In the latter case, one can argue that in the current state of the international nuclear liability conventions, the conventions (and the national law implementing them) also apply to nuclear installations for non-peaceful purposes. In future international nuclear liability law, this conclusion will still be valid for the NEA regime whereas, in principle, the countries member of the revised Vienna Convention will exclude such installations from their national nuclear liability laws.

Terrorism in the Nuclear Civil Liability Conventions

Article 9 of the Paris Convention is important in answering the question whether the nuclear operator is liable in case of a nuclear incident caused by an act of terrorism. This article states that:

> "The operator shall not be liable for damage caused by a nuclear incident directly due to an act of armed conflict, hostilities, civil war, insurrection or, except in so far as the legislation of the Contracting Party in whose territory his nuclear installation is situated may provide to the contrary, a grave natural disaster of an exceptional character."

As Article 9 gives a list of events exonerating the nuclear operator from liability, the textual interpretation of this provision seems to indicate that it is an exhaustive list. This means that the only exonerations allowed are those listed in the text. This interpretation is confirmed by the "Exposé des Motifs" of the Paris Convention. The Exposé des Motifs on this article reads:[29]

> "The absolute liability of the operator is not subject to the classic exonerations such as force majeure, Acts of God or intervening acts of third persons, whether or not such acts were reasonably foreseeable and avoidable. Insofar as any precautions can be taken, those in charge of a nuclear installation are in a position to take them, whereas potential victims have no way of protecting themselves.
>
> "The only exonerations lie in the case of damage caused by a nuclear incident directly due to certain disturbances of an international character such as acts of armed conflict and hostilities, of a political nature such as civil war and insurrection, or grave natural disasters of an exceptional character, which are catastrophic and completely unforseeable, on the grounds that all such matters are the responsibility of the nation as a whole. No other exonerations are permitted. The national legislation of the operator liable may, however, provide that he is to be liable even in the

Dommages Nucléaires en Europe. Régime instauré par la Convention de Bruxelles du 31 janvier 1963", lc, 24 ff.

28. According to article 1,(a),(i) of the Paris Convention, a nuclear installation means: "reactors other than those comprised in any means of transport; factories for the manufacture or processing of nuclear substances; factories for the separation of isotopes of nuclear fuel; factories for the reprocessing of irradiated nuclear fuel; facilities for the storage of nuclear substances other than storage incidental to the carriage of such substances; and such other installations in which there are nuclear fuel or radioactive products or waste as the Steering Committee for Nuclear Energy of the Organisation (hereinafter referred to as the "Steering Committee") shall from time to time determine; any Contracting Party may determine that two or more nuclear installations of one operator which are located on the same site shall, together with any other premises on that site where radioactive material is held, be treated as a single nuclear installation."

29. Motif n° 48.

case of a grave natural disaster of an exceptional character." [emphasis added]

Also the "Exposé des Motifs" indicates that the only exonerations allowed are international war-like conflicts, national grave political disturbances, and natural disasters.

A complete analysis of the international civil liability conventions, also requires a brief discussion of the meaning of Article 6, (c),(i),(1) of the Paris Convention, which says that nothing in the Convention shall affect "the liability of any individual for damage caused by a nuclear incident for which the operator, by virtue of Article 3(a)(ii)(1) and (2) or Article 9, is not liable under this Convention and which results from an act or omission of that individual done with intent to cause damage." Thus, there are some scenarios, according to the Convention, where a person other than the nuclear operator is liable for a nuclear incident. The scenarios referred to are damage to the nuclear installation [Article 3 (a) (ii) (1)], damage to on-site property [Article 3 (a) (ii) (2)], and cases of force majeure (Article 9). If, for example, a nuclear incident is directly caused by an insurrection, the nuclear operator will not be liable and the Paris Convention does not affect the liability of the persons having caused the incident.

Finally, brief attention should also be given to the provision of Article 6, (f) (i) of the Paris Convention, according to which the operator shall have a right of recourse only if the damage caused by a nuclear incident results from an act or omission, done with intent to cause damage, against the individual acting or omitting to act with such intent. The right of recourse is limited to a right against the individual physical person who acts or omits to act with intent to cause damage. From a theoretical viewpoint, this scenario can be applied to the persons responsible for a terrorist attack on a nuclear installation or on a transport of nuclear material. Of course, it is highly questionable whether the person(s) will be identified. In suicide attacks such as those on the Twin Towers and the Pentagon, for example, the persons having caused the damage will presumably be dead. If they are not dead, and can be caught, it still is uncertain whether the person(s) responsible for an attack will have enough assets to pay for the damage. Therefore, we can conclude that the right of recourse seems to be of limited help to the operator and his insurer in trying to recover the compensation they had to pay due to a nuclear incident caused by an act of terrorism.

Clearly, terrorism is not a ground for exoneration under the existing nuclear liability conventions (Paris and Vienna Convention), because terrorist acts of the kind committed on September 11, 2001 cannot be considered acts of armed conflict, hostility, civil war, or insurrection. Consequently, the operator of a nuclear installation is liable for damage due to acts of terrorism. This is certainly the case if a terrorist attack hits a nuclear installation (or a transport) used for peaceful purposes, whether the national law explicitly provides for it or is completely silent on this matter. This conclusion will also be valid if a terrorist attack hits a nuclear installation used for non-peaceful purposes.

This conclusion is not much different in countries that are not members of one of the Conventions. Indeed, several countries that are not members of any of the Conventions, such as the United States and Switzerland, have nevertheless adopted more or less the same principles as the Conventions.

In the United States, nuclear liability is governed by the Price-Anderson Act, which imposes strict liability for nuclear incidents and limits the operator's liability to $9.4 billion.[30] The Price-Anderson Act covers anyone liable for public liability. Public liability is defined as "any legal liability arising out of or resulting from a nuclear incident or precautionary evacuation."[31] There are three exceptions to that rule: claims arising out of an act of war; worker's compensation claims; and claims for damage to on-site property at a licensed nuclear facility. Thus, according to the Price-Anderson Act, a nuclear operator would be liable were a nuclear incident caused by an act of terrorism.

In Switzerland, the liability of the nuclear operator is unlimited and almost absolute. Still, the Swiss nuclear liability act contains a remarkable provision stating that a Swiss operator is not exonerated from liability if the nuclear incident is directly due to an armed conflict, a natural disaster, or unlawful conduct by third parties. Even if the Swiss operator is liable, the damage caused by war or grave natural disasters is covered by the State.

Compared to other civil liability mechanisms, the nuclear civil liability system is quite severe because it only gives limited defenses to the nuclear operator. Given the restricted number of exonerations available to the operator, this liability is also referred to as "absolute liability."[32] For example, in the proposed European Directive on environmental liability with regard to the prevention and remedying of environmental damage,[33] the cases of force majeure are larger than those in the nuclear civil liability conventions.[34] If a terrorist act were to cause environmental damage, it seems that the different Member States—not the operator of the dangerous activity—should ensure that the damage is remedied. The proposed Directive will not be applicable to nuclear incidents covered by the nuclear civil liability conventions discussed above.

30. 42 US Code Sections 2014, 2210.

31.42 US Code Section 2210(w).

32. Boyle, A.E., "Nuclear Energy and International Law: An Environmental Perspective", British Yearbook of International Law, 1989, vol. 60, 303.

33. European Commission, 23 January 2002, COM (2002), 17 final.

34. Article 9, (1) of the Proposal reads: "Subject to Article 10, this Directive shall not cover environmental damage or an imminent threat of such damage caused by: (a) an act of armed conflict, hostilities, civil war or insurrection; (b) a natural phenomenon of exceptional, inevitable and irresistible character; (c) an emission or event allowed in applicable laws and regulations, or in the permit or authorisation issued to the operator; (d) emissions or activities which were not considered harmful according to the state of scientific and technical knowledge at the time when the emission was released or the activity took place." Article 9,3,(a) reads: "Subject to Article 10, an operator shall not be required to bear the cost of preventive or restorative measures taken pursuant to this Directive when the environmental damage or imminent threat of such damage occurring is the result of: (a) an act done by a third party with intent to cause damage, and the damage or imminent threat in question resulted despite the fact that appropriate safety measures were in place."

Insurance of Nuclear Risk

Before analyzing the reaction of the insurance industry—particularly the nuclear insurance industry—to the events of September 11, 2001, one has to bear in mind the specific way nuclear risk is insured.[35] Studies carried out in the 1950s and early 1960s indicated that the capacity of the insurance companies was insufficient to cover nuclear risk. Similarly, there was no experience in covering these types of risks.

Therefore, national insurance pools have been created. This implies that, in a given country, several insurance companies have joined forces in order for each to cover a small part of the third party liability of an operator. As a consequence of the fact that those pools are organized nationally, a Belgian operator can only buy third-party liability insurance with the Belgian nuclear pool, a Dutch operator with the Dutch pool, etc.

Every pool member declares each year the amount at which it is willing or able to provide insurance coverage. The capacity of the pool is therefore equal to the contributions of all its members. In case payments had to be made, each member of the pool would have to contribute a ratio of its participation as contractually agreed with the pool. Re-insurance of the nuclear risk will take place among pools; a separate member of the pool cannot take care of reinsurance itself. That is why a large number of insurance companies worldwide had to intervene as reinsurers following the Three Mile Island accident in 1979.[36]

According to the insurers, this strategy results in a double advantage. Since every member of the pool knows exactly for what amount it will responsible, members are willing to insure a much larger part of the nuclear risk than they would conventional industrial risks. Moreover, reinsurance is directly established among the different national pools without intervention of third parties, which minimizes the costs. There is no commission for reinsurance among the pools; only a part of the costs will be calculated—7.5% on average compared with commissions averaging 30% on the conventional reinsurance market.

Those nuclear insurance pools are still effective today; they offer coverage not only for the third party liability of the nuclear operator but also for property damage, worker's compensation, etc.

Additional schemes exist for the insurance of property damage to nuclear installations. In the US and in Europe, the nuclear operators have created their own (so-called captive[37]) insurance formulas, basically to insure property damage —Nuclear Electric Insurance Limited (NEIL) in the US and European Mutual Association for Nuclear Insurance (EMANI) in Europe. Both NEIL and EMANI, however, also insure, directly or indirectly, the third-party liability of nuclear operators. In doing so, they are able to offer additional capacity to the pools and they can also act as a competitor of the traditional pools.

During the last few years several pools have lost a part of their market to the captives, although the American nuclear insurance pool (American Nuclear Insurers, ANI) certainly works closely together with NEIL. NEIL in fact, is an important reinsurer of ANI. The captives are not alone in their willingness to take some of the market share of the nuclear insurance pools; traditional insurers also seem more and more willing to provide coverage (e.g., worker's compensation of nuclear operators).

Reaction of "Conventional" Insurance Industry to September 11

Prior to the events of September 11, fire insurance policies covered fire and explosion damage, regardless of the cause. The only exception concerned cases where the damage was caused by (civil) war or civil commotion. In most countries terrorism was not mentioned in war exclusion clauses and, therefore, fire or explosion damage resulting from a terrorist attack was covered.

As insurance companies call upon reinsurance companies for spreading their risks, the attacks put a major pressure on the world's reinsurance market. The biggest reinsurance companies felt compelled to terminate the coverage of terrorism risk. As a consequence, the insurance companies also stopped covering terrorism risk. Terminating those contracts obliged the different parties involved to negotiate in order to find a solution to the problem. Insurers have reviewed their risk acceptance positions and have reduced and limited their coverages in order to safeguard their own positions.

The question as to whether terrorism risk is insurable at all has been reviewed.[38] The attacks on the Twin Towers and the Pentagon mainly influenced the assessment of the probability and severity of the risk. Several authors have indicated that problems in assessing the probability of a very high potential damage do not make a risk uninsurable as such.[39] Given the acute demand for covering terrorism risks, the insurance and reinsurance industries now seem ready to offer insurance for terrorism risk to a certain extent. It seems that terrorism coverage is or will be made available on a limited, selective basis and against the payment of an additional premium reflecting the individual risk.

35. See, inter alia, W.E. Besler, "Über die Zweckmäßigkeit der Poolung von Atomrisiken", 18 Versicherungswirtschaft, 14 Jahrgang (September 1959), pp. 572–584; J.C. Dow, Nuclear Energy and Insurance, London, Witherby & Co., 1989; Nuclear Power: Insurance and the Pooling System, Special Edition of the Nuclear Pools' Bulletin, 1992); S.M..S. Reitsma, "Nuclear Insurance Pools: History and Development", in Nuclear Accidents: Liability and Guarantees, INLA Helsinki Symposium, 1992, p. 346.

36. J.C. Dow, "The Organisation and Development of International Liability Capacity and National Market Pools with Special Reference to New Nuclear Countries", in Nuclear Third Party Liability and Insurance: Status and Prospects, München Symposium IAEA/NEA 1984, Paris, IAEA/OECD, 1985, pp. 172–182.

37. A captive is, in fact, a company aiming at insuring or re-insuring all or part of the risks of an affiliated company. See Bawcut, P.A., Captive Insurance Companies. Establishment, Operation and Management, 3th edition, Woodhead-Faulkner, New York, 1991.

38. According to SwissRe, the criteria for the insurability of risks are: assessibility, randomness, mutuality and economic feasibility.

39. Faure, M. and Hartlief, T., "Remedies for expanding liability", Oxford Journal of Legal Studies, vol. 18, 1998, 681-706; Faure, M., "The Limits to Insurability from a Law and Economics Perspective", The Geneva Papers on Risk and Insurance, 1995, n° 76, 454-462.

The major problem today is the lack of capacity for the coverage of such risks. In the US, for example, the insurance industry said it would need four years to develop the necessary means to cover terrorism. Given the current lack of capacity on the one hand and the urgent and huge demands for terrorism coverage on the other, temporary solutions combining private and public resources have been set up. This is the case in the aviation industry, to which the private insurance market currently offers an airline liability policy with a US $50 million limit. The member States of the European Union act as an insurer for amounts exceeding this—up to $1 billion. The airlines have to pay a premium for this coverage and the European Commission evaluates the need for State intervention from month to month.

In the meantime, solutions are being worked out in different countries. In France, for instance, a pool for terrorism exposure—GAREAT (Gestion de l'Assurance et de la Réassurance des Risques Attentats et Actes de Terrorisme)—was established as of January 1, 2002. The French State provides for a state guarantee for the pool. The business ceded to the pool consists of material damage and loss of profit from fire and engineering insurance. This solution combines a specific mechanism for generating more capacity (pooling) and a State guarantee. In other countries, negotiations are proceeding on possible solutions.

Reaction of Nuclear Insurance Industry to September 11

Due to the possible magnitude of a nuclear incident, the consequences of terrorist attacks on nuclear installations or on the transport of nuclear material can be even more troublesome than those on "conventional" targets. In the nuclear industry, the positions of both the insurance industry and the nuclear operators are quite difficult. As indicated, the nuclear operator is liable if a terrorist attack on a nuclear installation (or on a transport over land) causes a release of radiation and if this release causes damage to a third party. Should the nuclear insurers cancel terrorism risk in the existing liability policies, then the nuclear operators are in principal obliged to provide for another means of financial security (e.g., bank guarantees, State guarantees). Otherwise they would violate the congruence principle of the Paris Convention (and of the domestic law provision implementing this principle).

Some nuclear insurance pools have argued that since they have their own reinsurance scheme (reinsuring each other instead of reinsuring on the common reinsurance market), they were more or less able to continue providing coverage, including terrorism risk. The American nuclear insurance pool (ANI), for example, decided to continue providing coverage but it imposed an industry-wide aggregate limit of $200 million. ANI will increase its premium by 20% to cover terrorism.

Other pools wanted to terminate the civil liability policies but were unable to do so. The European nuclear pools had no alternative but to continue to provide terrorism liability coverage through 2002. Most nuclear reinsurance contracts run from January 1 of each year, but require a four or six months notice of changes. Therefore, it was not possible to change coverage that began on January 1, 2002. So far, it is not clear how terrorism coverage will be addressed as from January 1, 2003.

The traditional nuclear insurance pools are under increased pressure due to the increasing competition on the market. Both traditional insurers active in insuring worker's compensation and the nuclear captives have become real competitors of the pools.[40] Therefore, some of the pools were and are reluctant to terminate contracts or to change premiums dramatically.

The least one can say is that there is and was some nervousness in the market. In a first reaction after the attacks, the Swedish nuclear pool terminated coverage of terrorism risks; only a few weeks later, it reconsidered its position and provided coverage for terrorism risk. Similarly, it remains to be seen whether those nuclear pools that actually still provide coverage for terrorism risk will continue to do so should a loss occur. Some pools, indeed, have indicated that they will seriously consider terminating coverage for terrorism risk in their third-party liability policies, should a terrorist act hit a nuclear installation causing a nuclear incident.

Most pools have principally excluded terrorism risk from property damage coverage in their policies, but they offer the possibility to provide coverage if an additional premium is paid.

EMANI, the European captive of nuclear operators, continues to provide terrorism coverage up to 100 million euros in its property damage policy. In EMANI's view, an industrial captive must protect the interests of its members. The American captive of utilities covering all American nuclear insurance property, NEIL, imposed a single-loss aggregate for terrorism claims in a twelve-month period.

The reaction of the players in the nuclear insurance market is thus different from country to country. Currently, some of the players are working out self-insurance schemes covering only the nuclear terrorism risk; others seem to be trying to convince the national authorities to act as a reinsurer or guarantor. Whether the nuclear operators in the European Union will be able to convince the European Commission of the need for State intervention is quite unlikely. Although the Commission approved that different member States would act as insurer of the civilian airline industry, it has been clear from the beginning that the Commission's approval was limited in time.

Possible Alternatives

Pooling insurance companies—within the nuclear insurance pools, for example—is an alternative way to insure certain risks. But pooling is not only used in nuclear liability insurance. As already indicated, GAREAT, a pool covering terrorism risk, was created in France. Note that GAREAT also applies to damage

40. For a critical analysis of these pools see Faure, M en Van den Bergh, R., "Restrictions of competition on insurance markets and the applicability of EC antitrust law", Kyklos, vol. 48, 1995, pp. 65-85.

caused by a nuclear incident. Basically, those pools enable the generation of more insurance capacity.

Similar pools exist to cover environmental damage. In the Netherlands, for instance, the Nederlandse Milieupool (or Dutch environmental pool) is effective. Whereas this pool initially provided for environmental liability insurance, it now issues an environmental damage insurance (MSV or milieuschadeverzekering),[41] providing an integrated coverage of all the environmental damage that occurs on or from the insured site. The prerequisite is that it concerns pollution of the soil or of the water. The whole idea is that this coverage constitutes a direct insurance. In other words, the insured site is insured even when cleanup costs have to be made on the site of a third party. Coverage takes place as soon as the site of a third party is polluted as the result of the insured risk, irrespective of who is or can be liable for the damage. The trigger for compensation under this policy is, therefore, no longer tort law but the insurance policy. Therefore, this is called a first party insurance or a direct insurance. It is, indeed, not the victim who purchases liability insurance (although the insured may be the victim), but someone who has responsibility for a site on or from which water or soil pollution may occur. The policy hence benefits third parties as well.

Some [insurers] have indicated that they will seriously consider terminating coverage for terrorism risk should a terrorist act hit a nuclear installation causing a nuclear incident.

An alternative to pooling by insurance companies is risk pooling by plant operators. Faure and Skogh have proposed a risk pooling by nuclear operators, a risk sharing agreement as an alternative compensation scheme that could provide higher amounts of coverage to deal with nuclear risk.[42] A kind of pooling of nuclear operators already exists in the US. According to the Price-Anderson Act, a nuclear operator is obliged to have an individual liability coverage of $200 million; if the damage exceeds this amount, the nuclear operator needs to pay a retrospective premium of $83.6 million per nuclear installation. Thus, the total compensation available in the US consists of two layers: first, the liability insurance of the individual nuclear operator; second, the collective layer of all licensed nuclear utilities.[43]

Sharing agreements are well-known in other fields of liability risk. For instance, marine oil pollution is insured by the so-called Protection and Indemnity (P&I) Clubs, which offer both liability and property coverage. The members of P&I clubs, which function as a mutual insurance company, are the tanker owners. Profits and losses are shared among the members.[44]

Such risk-sharing agreements are often created by way of a captive. It might be worthwhile to consider the establishment of a nuclear captive covering only terrorism risk. In the airline industry, captive alternatives are being worked out. The US Air Transport Association (ATA) supports an alternative solution in creating a captive war risk insurance company, to be called Equitime. The International Civil Aviation Organization (ICAO) proposed a scheme creating a non-profit special purpose insurance company to provide war risk insurance. This proposal is being supported by the Association of European Airlines (AEA).

Another alternative is the creation of a so-called damage fund; the creation of such a fund is often proposed as a means of covering environmental liability.[45] In fact, several types of funds can be distinguished: a limitation fund, an advance fund, a guarantee fund, and a fund replacing liability and insurance.[46]

41. See inter alia Drion, P.J.M., “Milieu onder één dak: milieuschadeverzekering (MSV)”, Verzekeringsrechtelijke Berichten, 1998/2, 19-21; Janssen, C.A., “Aansprakelijkheid voor milieuschade en financiële zekerheid baar toekomstig recht: nieuwe oplossingen. Nederlands recht”, in Deketelaere, K. en Wiggers-Rust, L.F. (red.), Aansprakelijkheid voor milieuschade en financiële zekerheid. Een vergelijking van Nederlands, Belgisch en Europees recht, Die Keure, Vermande, Brugge, 1998, 111-112.

42. Faure, M., en Skogh, G., “Compensation for damages caused by nuclear accidents: a convention as insurance”, The Geneva Papers on Risk and Insurance, vol. 17, n° 65, 1992, pp. 499-513.43. For more details see Heimann, F.F., “The U.S. Liability protection system for nuclear power plants”, in Nuclear Accidents. Liabilities and Guarantees, OECD/NEA-IAEA, Helsinki, 1993, 418-424; Brown, O. F. II, “Nuclear Liability Coverage Developments in the United States of America”, Nuclear Inter Jura ’93, AIDN/INLA, Rio, II.5.6-2; Brown, O.F., “Recent Developments from the Perspective of the United States”, in Horbach, N.L.J.T. (ed.), Contemporary Developments in Nuclear Energy Law. Harmonising Legislation in CEEC/NIS, Kluwer Law International, Den Haag, Boston, 1999, pp. 481-488; Vanden Borre T., “Dekking van het nucleaire risico op nationaalrechtelijke basis of via internationale Verdragen: de Verenigde Staten versus Europa”, Deketelaere, K., Faure, M. en Verhoossel, G. (red.), Grensoverschrijdende milieuproblemen: uitdagingen voor de nationale en de internationale rechtsorde, Intersentia, Antwerpen, Groningen, 1998, pp. 443-490.

44. See about the P&I Clubs: Aspden, P., “Oil Pollution Legislation and its consequences. A P&I Club View”, Shipping Law Faces Europe: European Policy, Competition and Environment, Maklu, Antwerpen-Apeldoorn, Bruylant, Brussel, 1995, pp. 135-154; Coghlin, T.G., “Protection and Indemnity Clubs”, Lloyds Maritime and Commercial Law Quarterly, 1984, pp. 403-416; Dieryck, C., Van Havre, P., “Les assurances P&I(Protection and Indemnity Clubs)”, in L’Assurance Mutuelle en Belgique, Academia, Bruylant, Bruxelles, 1999, pp. 373-395.

45. Bocken, H., “Alternatives to liability and liability insurance for the compensation of pollution damages”, Tijdschrift voor Milieuaansprakelijkheid, 1987/4, 83-87 and 1988/1, 3-10; Bocken, H., “Complementary compensation mechanisms. A general environmental damage fund? ” , in Bocken, H. en Ryckbost, D. (ed.), Verzekering van milieuschade, Gent Story Scientia, 1989, 427-437; Bocken, H., “Systèmes alternatifs pour l’indemnisation des dommages dus à la pollution”, Revue Générale des Assurances et des Responsabilités, 1990, 11.698 en 11.714.

46. Faure, M.G., and Hartlief, T., “Compensation Funds versus

Other proposals tend to solve the capacity problems of the insurance market by looking for alternatives in the capital market. These so-called Alternative Risk Transfer (ART) Mechanisms use insurance derivatives such as swaps and options. One of these alternative mechanisms is the Act of God Bond where the return payment of the investment highly depends on the realization of certain events (called catastrophic risks).[47] Some of these financial products are already in effect [e.g., the CATEX (Catastrophe Risk Exchange) in New York where packages of catastrophic risks are being exchanged].[48] A proposal has also been made to address the capital market concerning nuclear risk.[49]

A detailed discussion of the advantages and disadvantages of each of these alternatives is beyond the purpose of this article. The point to keep in mind is that a great variety of mechanisms already exist and that negotiations are taking place both in the conventional and the nuclear insurance industries.

Conclusion

The major problem for nuclear operators is that under today's legal principles they are liable for damage caused to third parties, even if the nuclear incident was caused by an act of terrorism. It seems very unlikely that the existing international nuclear civil liability conventions will soon be changed in that respect. The revision of the Vienna Convention has been terminated by the adoption, in 1997, of the Protocol to amend the Vienna Convention and of the Supplementary Funding Convention. According to both instruments, the nuclear operators are liable if a nuclear incident has been caused by an act of terrorism.

Soon after the events of September 11, the Contracting Parties of the Paris Convention decided it was not appropriate to address the issue of terrorism at that point. Consequently, the revision process that had already gone on for several years was terminated without changing the fact that nuclear operators are liable if a nuclear incident is caused by an act of terrorism.

Therefore, it will be quite difficult for the countries that are members of the Paris or Vienna conventions to change their domestic laws concerning terrorism: if they should change the national nuclear liability provisions by accepting terrorism as an exoneration for the nuclear operator, the provisions of the Conventions would be violated.

It is thus quite unlikely that nuclear civil liability principles will be changed. Theoretically, a country that is not a member of the Conventions could do so more easily than member countries. Whether this will be politically acceptable remains to be seen. Even if the nuclear liability conventions were changed by excluding the terrorism risk, the question of who would have to pay for the damage due to terrorism would still have to be resolved.

In the past, coverage of terrorism was not much of an issue in the (nuclear) insurance industry. The events of September 11 dramatically changed this situation. Some policies were or are to be cancelled; in other the cases, the premium has gone up. Several players have changed the magnitude of the coverage they offer (lower amount insured, introduction of aggregate limit etc.). Therefore, the only solution for nuclear operators seems to be in finding additional coverage for the terrorism risk.

Nuclear insurance pools might advisedly verify their real capacity. In the recent past, some of the nuclear pools have lost some market share (especially in covering property damage) to the captives (EMANI and NEIL). Consequently, they might have some free capacity available for covering the terrorism risk.

Apart from increasing the capacity of the nuclear insurance pools or using all available capacity, several other possibilities exist: international pooling of terrorism risk amongst insurance companies; pooling of operators in captive insurance schemes; partial and/or temporary public funding; creation of damage funds; and others. It is impossible to tell which scenario will eventually prevail.

Although it might be prudent not to delay for too long, implementing alternative mechanisms might take some time, given the complexity of the issues involved and given the magnitude of the interests at stake. One should also have in mind the difference in insurance laws even within the European Union—liability law as well as the willingness of the State to act as an insurer or reinsurer. The different business approaches of the different insurance markets do not make these discussions any easier. It is quite unlikely that there will be one "miracle solution"; it seems more reasonable to assume that a combination will eventually be worked out and become effective.

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Rethinking the Role of Citizens in Democracies

Nuclear Energy in a Democratic State

Who Decides? The Minister, Top Civil Servants, or Industrialists?

Jean-François Collin

A number of actors who may also have an important role to play in decision making for a country's energy policy are missing from the question raised in the title of this paper. I am thinking of the citizens themselves as well as Members of Parliament, who would surely have something to say on the matter.

The French situation, whether or not it is exemplary, is certainly exceptional in several respects. Compared to other countries that have chosen to use nuclear energy, France is in a rather unusual position, which could be characterized as "the dual French exception."

The first of these exceptions has to do with the proportion of electricity generated by nuclear reactors as a proportion of total electricity production: nuclear energy produces nearly 80% of all electricity generated in France, as against 35% in Germany, 35% in Japan, 29% in the UK, 20% in the US, 14% in Canada, and none in Italy. This very unusual position—the result of very deliberate decisions taken three decades ago—has a particularly strong influence on any debate in France on these matters.

The second exception is the "public"—or, rather, "state-dominated"—nature of the nuclear industry in France. All the major bodies and companies that are involved in this sector—the Commissariat à l'Energie Atomique (CEA) for research, Electricité de France for electricity generation, AREVA for the production of nuclear fuels and reactors, l'Agence Nationale des Déchets Radioactifs (ANDRA) for radioactive waste, to name the most important amongst them—depend directly on the State budget, or have the State as their sole or majority shareholder.

This State domination is partly explained by the origins of the civilian nuclear industry and the fact that nuclear energy was initially used for military applications. Another decisive element is related to the decisions made regarding administrative organization. The CEA initially accommodated all areas of responsibility, from design right through to controls and safety, for both civilian and military ends. Pierre Guillaumat—the Administrator-General of the CEA from 1951 to 1958, who then became Defence Minister under Charles de Gaulle before returning to the CEA and then becoming the head of EDF—is a perfect illustration of how these civilian and military applications have been so closely intertwined.

A third French exception could be added to the previous two: the domination of a specific branch of the civil service—the engineers of les Mines—in the French nuclear sector. Having been picked from the best of the Ecole Polytechnique, one of France's most prestigious establishments of higher education, these engineers have played a major role in the nuclear field. The career of one of them illustrates the special place that this small group of people has occupied in the nuclear industry. Mr Syrota was a Director at the Industry Ministry before being named Chairman of COGEMA, which did not prevent him from being the top man within the body that manages the careers of all Mines engineers in the very original system used to organize the civil service in France. Today, he is Chairman of the electricity industry's regulatory body, the Commission de Régulation de l'Electricité.

Decisions are taken within this framework. It is, in fact, important to distinguish two types of decision: 1) strategic and guideline decisions that carve out the future; and 2) everyday management decisions to do with the nuclear sector. The same actors are not involved in these two types of decision, nor do they follow the same procedures. I will concentrate here on the first type.

Major strategic decisions are taken, at the end of the day, by the Prime Minister and the President of the Republic, once the ground has been prepared by the relevant ministers. Lobbies, which have considerable influence in France, bring pressure to bear. But this does not alter the fact that only the top political office has the power to decide, in the final analysis, and nothing in the law allows us to derogate from that.

When Pierre Messmer, Prime Minister under President Pompidou, announced his plan to equip France with nuclear power stations as a response to the 1973 oil crisis, he took the decision alongside the President. This choice was perfectly suited to the EDF's corporate culture and they used it to further their domination, but the decision itself was not taken by the EDF.

When Francois Mitterrand, very shortly after his election, authorized the construction of the factory at The

Hague for the reprocessing of nuclear fuels in 1981 despite the pledges he had made during his presidential campaign, a political choice was made. This choice was subsequently confirmed in October 1981 by Prime Minister Mauroy in a highly pro-nuclear speech made to the Parliament, the Assemblée Nationale. But to get the process through to that point, an intense political war had been waged within the ranks of the Socialist party, which was opposed at that time to the development of nuclear energy.

When Lionel Jospin decided to stop and dismantle the rapid neutron reactor, "Superphénix", his decision was taken despite opposition from most of those in favor of the development of nuclear energy and, indeed, against the advice of his Industry Minister.

There is at least one point that is common to the three major decisions to which I have just alluded: the Parliament is never consulted. The executive power decides in this field in France, or such has been the case to the present. To be fair, this makes quite a lot of sense since the vast majority of MPs and Senators are favorable to using nuclear energy and accept as dogma the need to use this energy source to ensure our "energy independence." At the same time they profess blind confidence in the ability of our administrations and our companies to control this technology.

Citizens have not been directly consulted either. Polls suggest that public opinion is highly divided on the subject, although there is no majority call for ceasing nuclear activity immediately.

In each instance the political authorities have taken one decision from among several possible alternatives; there has never been one single alternative on the table. Even the pro-nuclear camp is divided. When the decision was taken to equip the country with nuclear power stations, the CEA defended the natural uranium and the graphite-gas options, which it had developed itself, while the EDF was in favor of the enriched uranium and pressurized water solution developed by the Americans, which, in EDF's view, was economically more efficient. The government eventually opted for the latter choice, despite the blow to national pride.

When Jospin won the approval of the Greens with the closure of Superphénix, it is conceivable that EDF was not itself displeased, since the decision freed them of the burden of a high-risk facility that had never worked very well and had cost them a great deal of money. Even so, the nuclear lobby mobilized strongly against the decision for symbolic reasons and because it feared the potential consequences on the nuclear fuel-reprocessing industry, for which Superphénix recycled the most hazardous waste.

Other decisions taken by Lionel Jospin's government in the nuclear energy field illustrate the role that each party has to play in their preparation. The main subjects that were on the table in 1997 were as follows:

a) the role of nuclear energy in French energy production and a possible diversification of sources of electricity production;
b) miscellaneous questions concerning the downstream end of the nuclear cycle: the operating conditions governing the plant at The Hague and the conditions under which nuclear waste was stored;
c) the setting up of an organization that could guarantee independent expertise and controls in the field of nuclear safety;
d) whether or not to launch the construction of a new generation of nuclear reactors.

Certain questions have produced answers or the beginnings of an answer; others have not.

The Role of Nuclear Energy in French Energy Production

Although not prepared to abandon nuclear usage, the Jospin government has stressed its will to diversify the sources of electricity production and to control energy consumption. In order to achieve this, two major decisions have been taken. The first was to increase the level of public funding—almost non-existent in 1997—for research and experimentation programs to encourage the development of renewable energies. Funding in the amount of 80 million euros in 1998 and almost 160 million euros by 2000 financed programs set up by a public body controlled primarily by the Ministry of the Environment. A program for enhanced energy efficiency was launched in the autumn of 2000 after the mini oil crisis of that autumn. Dominique Voynet's protests against the concessions made to road haulage companies, which brought into question the decisions taken on the matter of aligning diesel and petrol levy regulations, were also a factor. All these decisions were reached after very lengthy inter-ministerial debates pitting the Minister of the Environment against the Industry and Finance ministers.

The most important decision taken in this area was to fix a preferential price for the purchase of electricity generated through renewable means—wind, solar, biomass, or hydraulic. By imposing a statutory purchase price higher than the market price for renewable forms of electricity on the EDF for a period of five years, the government created the conditions for this new sector to take off. Beyond the reservations of the EDF and of certain areas of government—in particular the Ministry of Finance, Economy and Industry—the government had to deal with opposition from the electricity regulation committee, which found the guaranteed prices to be too high and which also criticized the very principle of the mechanism, preferring instead a tender-type approach that they felt was more suitable to the market economy. Nevertheless, the government stood firm, confirming the notion that in the final analysis—and whenever they choose—the political powers do make major energy policy decisions in France.

The Downstream End of the Nuclear Cycle

Looking at the downstream end of the cycle, two questions arise: what are we to do about nuclear waste and what conditions should be imposed upon the operation of the COGEMA reprocessing plant—now called AREVA—in The Hague?

As is the case for all countries that use nuclear energy, we have a problem with nuclear waste. Reprocessing is not a miracle solution, primarily because it produces waste, too: at the end of reprocessing, fission products and actinides remain and must be packed in high-specification confinement bottles. There is also the problem of reprocessing uranium and unused plutonium, to say nothing of what we should be doing with MOX, which is extremely difficult to "reprocess," and with all the other radioactive waste.

Low- and medium-radioactive wastes are stocked at two surface sites managed by ANDRA. Long term highly radioactive waste is in storage, awaiting a more permanent solution. Therein lie the real problems.

One of the rare laws voted in Parliament in the nuclear field (1991) opened up three research channels in the search for a solution for these categories of waste:

- the reduction in radioactivity of waste through separation and transmutation (transforming long-term radioactive elements into short-term elements through neutron bombardment);
- long-term surface storage;
- burial in deep geological beds, making best use of the geologic barrier.

In practice, all efforts have been directed towards the creation of laboratories to prepare future deep waste burial sites, although no one is capable of saying what progress has been made on the other research channels.

From a political point of view, the debate has been about the need to ensure that choices can be reversed once they have been made at a given moment in time, which means we need to be able to recover the waste that has been disposed of, however deep down it might be, in order to subject it to another form of processing if necessary. This was one of the conditions obtained by Voynet when the underground laboratories came into being. The other condition was to ensure that progress on the different solutions explored moved at the same pace. Voynet prevailed on this point and the government decided to undertake works immediately on the underground laboratory in Bure in Lorraine, in argillacious ground. The procedure undertaken to identify another site in granite beds failed on account of the popular revolt that followed each movement of the mission responsible for looking at possible sites. Very large and sometimes violent demonstrations occurred in each of the communities chosen along the route. This shows that the citizen can also take a role in the decision making process and step in to change some of the decisions taken by government.

The plant at The Hague operates under conditions established by very old authorization decrees that are no longer suited to modern requirements. The level of emission of radionuclides into the environment that is tolerated by these decrees is much higher than real levels and higher than what would be considered acceptable in today's terms. Over a period of five years, the government has not been able to undertake a review procedure on these authorization decrees because they have been unable to arbitrate between opposing positions. On one side, COGEMA, with the backing of the Industry Ministry, looks to seize this opportunity to obtain authorization to reprocess fuels with much higher enrichment and combustion levels than existing fuels as well as MOX fuels in its new fuel plants. On the other side, the Minister of the Environment is demanding that new authorizations for waste should be, at most, equal to current waste levels, combined with commitments to progressively reduce waste volumes in compliance with the undertakings made by France within the framework of the OSPAR Convention. These requirements clearly made it impossible to give satisfaction to COGEMA.

In this instance, we could be forgiven for asking "who doesn't decide" rather than "who decides." The Environment Minister, although very much isolated within the government, nevertheless had real political clout and was able to prevent certain decisions being taken, though she was unable to hold sway.

Transparency, Independence of Expertise, and Controls on Nuclear Safety

Since Chernobyl, lack of credibility and public scepticism have clouded the pronouncements of authorities who seriously wanted us to believe that the radioactive cloud resulting from the accident had stopped at the French border and that our country was free of any contamination. The question of free and honest information about nuclear issues and independent expertise is on the table.

Initially, the government imagined that it could answer this question by proposing a law that would create an independent administrative authority responsible for nuclear safety and information on nuclear risk. Two questions thereby became one: that of information and public debate on nuclear issues and that of the administrative organization of equipment control and safety. There was a debate on this subject in France, to the extent that the department made responsible for it was answerable to two ministers: Environment and Industry. Many observers found it abnormal that the Industry Minister, part of whose job it was to promote the nuclear industry, should also be in charge of controlling it.

Again, not wanting to arbitrate between the two ministers, the Prime Minister proposed a solution that failed to solve anything: an independent administrative authority. But the State Council, to whom the government is required to submit any white paper for its opinion before presenting it before Parliament, gave an extremely negative opinion about this proposal, judging that the government could not unload its responsibility for ensuring the safety of nuclear facilities onto an independent authority and that if an accident were to happen everyone would inevitably turn to the government. For once, the State Council shared the position of the Environment Minister and the government finally reneged on this white paper.

The reform carried out since then, however, has not solved the problem. A new administration, with responsibilities for both the safety of nuclear reactors and radiation protection, is now under the control of three Ministers: Environment, Health, and Industry.

Independent expertise has evolved with the creation of a public establishment that is independent of the CEA, even though it has had to overcome some fierce opposition and delaying tactics used by those seeking to protect the general scope of influence of the CEA.

Timing of the Launch of a New Generation of Nuclear Reactors

This is a thorny issue for the nuclear industry. Since the halting of the American nuclear plan and overcapacity in French production, the future is not very bright for the industry. Pressure is being applied at regular intervals for the launch of the so-called EPR reactors.

Voynet managed to secure the condition that government decisions should be based on a thorough analysis of the economics of the nuclear business that would be able to stand up to the closest scrutiny. This analysis was made the responsibility of Mr. Charpin, the Commissaire Général au Plan, Mr. Dessus, an economist from the CNRS scientific research institute, and Mr. Pelat, who is the head of the CEA. The real interest of this work was this plurality of interests, but the report produced by this group failed to further the public debate.

The report does contain a number of interesting conclusions, such as the idea that nuclear energy has given France no economic advantage over its partners; that the problem of the renewal of nuclear facilities will not arise until 2020; that the most beneficial energy scenarios include vigorous efforts in energy control, including electrical energy, and not "all-nuclear" options; and, finally, the idea that the reprocessing of used fuels provides no obvious benefit from an environmental point of view, that there is a big price tag on it, and that this business is not a profitable one.

Even though very little used, it may be that the report has contributed to modifying the balance of power within government. And we see through this example that expertise is not a passive element of the mechanism, but also an important component of the decision making process.

Conclusion

In conclusion, the answer to the question raised at the beginning of this paper is not quite as simple as it might first appear. The power of decision regarding the major strategic choices is clearly in the hands of the public authorities. But a government is not a monolithic block and the situation is made all the more complicated when there is a situation of "cohabitation," with a Prime Minister and a President of the Republic not sharing the same opinions.

Citizens who have opposed the setting up of a waste burial center have influenced one set of decisions, while a judicial body, such as the Conseil d'Etat, has contributed to the failure of a government initiative. Independent auditing has had a role to play in other instances. There are also power struggles among the parties of the governmental majority. All of this plays out against a backdrop of lobbies and the wranglings of the administrations concerned. This balance of influence often results in paralysis, although in this instance, it has to be said that inaction is not always a bad thing.

One thing is certain: even though the citizens are still often being kept at arm's length, the nuclear debate in France is still a very volatile affair, much more so than other issues that are just as important. From the secrecy of the past and decisions taken by the executive without the least consultation—naturally for the good of all—we have inherited a very particular style for dealing with nuclear matters, characterized by rigidity, brutality, and confrontation of dogmas rather than reasoned argument. The arrival of the Greens in high positions of responsibility has not rid us of this particular style of government, nor has it rid us of nuclear energy itself.

From Referendum to Constitutional Prohibition of Nuclear Energy

The Austrian Experience

Klaus Renoldner

When Austria obtained its status of neutrality in 1955, the new constitutional law of the country included the prohibition of nuclear weapons on its territory but it did not say anything about nuclear energy. Austria signed the Non-Proliferation Treaty (NPT) and became the host country of the International Atomic Energy Agency (IAEA) and, later, for the Canberra Commission and for Comprehensive Test Ban Treaty Organization (CTBTO).

In the 1970s, plans started for the construction of the first Austrian nuclear power plant, in Zwentendorf, situated at the river Danube in Lower Austria. This was strongly supported by the industrial and commercial sectors as well as by a considerable part of the academic community. Both major political parties (Conservative and Social Democrat) pushed for the project. At the same time, critical voices arose from many elements of civil society, as well as within the Acadamy of Sciences and the rather new Green movement. Through public campaigns and various other activities, opposition to nuclear power became stronger. Representatives of the movement declared that the construction of a nuclear power plant would be against the will of the Austrian population.

The Austrian Chancellor at the time, Bruno Kreisky, and his government had drafted a new law for the regulation of the use of nuclear energy in Austria. Around the same time, late in 1978, construction of the plant in Zwentendorf was almost finished. Because of many local demonstrations the plant was continuously protected by strong police forces. With growing opposition to his plan, Kreisky agreed to hold a referendum, which proposed the enactment of a law that would forbid nuclear power in Austria. 50.5% of the population voted in favor. Meanwhile, it had become public that the Zwentendorf plant did not conform to the up-to-date standards of security demanded. The law was settled in the parliament. The unused buildings of the power plant in Zwentendorf remain to this day as a memorial to an undesirable development in technology.

Since then there have been some suggestions of a return to nuclear energy, but none of these has garnered major public support. Opinion polls have continued to show that 70% to 80% of the Austrian population are strictly against the use of nuclear power.

Political circumstances changed when 67% of the Austrian people voted in favor of Austria joining the European Union. The conservative party also lobbied for joining NATO. Austrian intellectuals, peace groups, and the Austrian affiliate of IPPNW foresaw that Austria could lose its neutral status and, once becoming a member of NATO, could easily be obliged to accept the deployment of nuclear weapons on its territory. Therefore we started a campaign for the establishment of a new constitutional law forbidding nuclear power as well as nuclear weapons. We did this knowing that a large Austrian majority is against both and knowing that, were we to succeed, the law could not be changed again easily since constitutional laws need a parliamentary majority of two thirds. We lobbied with a petition to all political parties and, although we feared some resistance, we succeeded. On July 13, 1999 the Austrian parliament passed the "Constitutional Law in Favor of a Nuclear-free Austria," with the following provisions:

> 1) Nuclear weapons may not be produced, stored, transported, or tested in Austria;
> 2) Nuclear power plants (fission plants) may not be constructed or used in Austria;
> 3) Transport of fissile material on Austrian territory is prohibited, with the exception of transport for exclusively peaceful uses, but not for the purpose of the production of energy by nuclear fission.

Nevertheless, with the opening of the free energy market in Europe new questions are arising. Foreign energy companies own parts of the Austrian energy sector. There is a growing interest in selling electric energy produced by nuclear power plants in neighboring countries. There is considerable price competition. But who pays the real bill? The private consumer, of course, cannot distinguish from what source the electric current delivered to his or her home is coming. But civil society groups have started projects that can enable the consumer to decide, as much as possible, the type of energy purchased by his or her energy company. The Austrian law should serve as an example for other countries, in promoting the idea of a nuclear weapon free zone in Europe and a completely nuclear-free Europe in the future.

Democratic Decision-Making in Switzerland

Referenda for a Nuclear Phase-Out

Conrad U. Brunner

The post World War II dream of abundant, cheap, and safe energy supply made possible a technical and ethical conversion of the well known remnants of nuclear war into "atoms for peace." The military-industrial complex joined with the political establishment and with large, university-based research laboratories worldwide to develop a new technology for electricity production. Since the investments were large, so international cooperation was necessary. Actually the founding of the International Atomic Energy Agency (IAEA) in Vienna, just after the Montan-Union, was the result of this joint investment.

What Makes Democracies Change?

Majority rule is the foundation of democracy, and changes in the perception of the majority regarding negative developments—in this case with regard to nuclear energy— went through a sequence of five distinct steps as follows:

Evidence: Individual persons (scientists, operators, physicists, etc.) started to voice early concerns over evidence they had found coincidentally and that normally was kept secret.

Information: A few courageous and independent scientists and others started to gather information and to make it public to the scientific community in personal conversation, in papers, and in books. These publications usually found their way into established print and electronic media only very slowly, and encountered a solid wall of opposing arguments from the dominant group of editors aligned with established perceptions.

Concern: The small numbers of people who had become aware of the information started to voice concern as to the feasibility and safety of nuclear power. First, organized groups started to speak out forcefully in universities and at public rallies near power plant projects. This concern was met by a worldwide industry campaign to promote thousands of "safe" reactors producing heat and electricity at "almost no cost."

Campaign: The political apparatus (governments, parties, parliaments, tribunals, etc.) started to make the subject part of the political agenda. Hearings were organized, funds for research and subsidies were discussed. A taboo was broken with the introduction of the phrase "nuclear phase-out" into the official lexicon.

Decisions: Local, regional, and national referenda for constitutional amendments, etc. started as early as 1979, before the Three Mile Island disaster in Harrisburg, Pennsylvania. National referenda campaigns occurred in 1979, 1984, 1990, and 2003, and a considerable number of local and regional energy-related laws have been the subjects of public debate ever since.

In Switzerland, 51% of the public and a majority of the federal states (13 cantons with the equivalent of 53% to 55% of the vote) are required to pass a constitutional amendment. The effort to get to this stage of decision making in Switzerland is considerable: 100,000 signatures (at a cost of approximately 2 euros per signature) must be collected in the streets within 18 months in order to bring a constitutional amendment to a public vote in a referendum within two to six years. After parliament has decided to allow the referendum, another investment of some two to three euros per vote must be expended for a political campaign in three national languages (German, French, and Italian), in order to ensure the approximately 1,500,000 votes needed for passage. Early funding—seven million euros, or one euro per Swiss citizen)— and the establishment of a wide political coalition of supporting groups are the alpha and omega of success. The stakes are high: over many decades, only 10% of proposed constitutional amendments have won at the polls and have been accepted into law.

Winning a referendum campaign requires the use of professional opinion polls and nationwide communication networks, with participation by both NGO workers and well known faces from the established political parties. Many NGOs have refused to compromise their images and have reflected high ethical and ecological values, which gives them better access to media than commercial backing.

Support by a wide array of groups (scientists, physicians, clergy, wildlife protection groups, etc.) have underscored the movement's alignment with public concerns, not notions of political revolution with which many anti-nuclear movements had previously been associated.

Planning for Change

The process described above does not come about naturally: it must be studied, planned, and implemented. The following four concepts are relevant to building new majorities opposed to nuclear power:

- The cost of producing electricity has been much higher than anticipated. The original cost schemes did not include total cost of operation (TCO), i.e., planning, building the plants, fuel, advanced safety upgrading, lengthy permit procedures (under democratic scrutiny), operating costs, education of personnel, end of use, waste disposal, dismantling, insurance for normal radioactive contamination and for contamination resulting from accidents, etc. Only the persistence of NGOs has made the owners and boards of directors of the plants reveal their TCOs.
- The political end of pipe (nuclear waste disposal and storage) is a crucial factor for the approval procedures. The densely populated Swiss alpine region did not allow the kinds of "desert" waste disposal to which the Russian and US nuclear programs were accustomed. The democratic procedure to define safety standards for nuclear waste and to find local and regional zones with the necessary geological stability required an evaluation program that lasted more than two decades and is still not concluded. In early concessions to public concern, a minor consultation process involving cantons and communities was implemented, particularly among politically active farmers and other rural populations.
- The electricity alternatives have to be studied and publicized using pilot plants and projects. Research and development programs have to be refocused and energy funding has to be reoriented toward energy efficiency and solar energy technologies. Knowledge has to be advanced in several steps:

1. It has to be shown that the rejection of nuclear energy does not mean "going back to the caves" in the way we live and work. A comfortable lifestyle is possible without nuclear energy.
2. The evidence showed early on that large (1,000 MWe) nuclear power plants could not easily be replaced by photovoltaic installations of the same order of magnitude but that millions of 3 kW installations might be necessary. Wind energy at a scale of 100 kW to 5

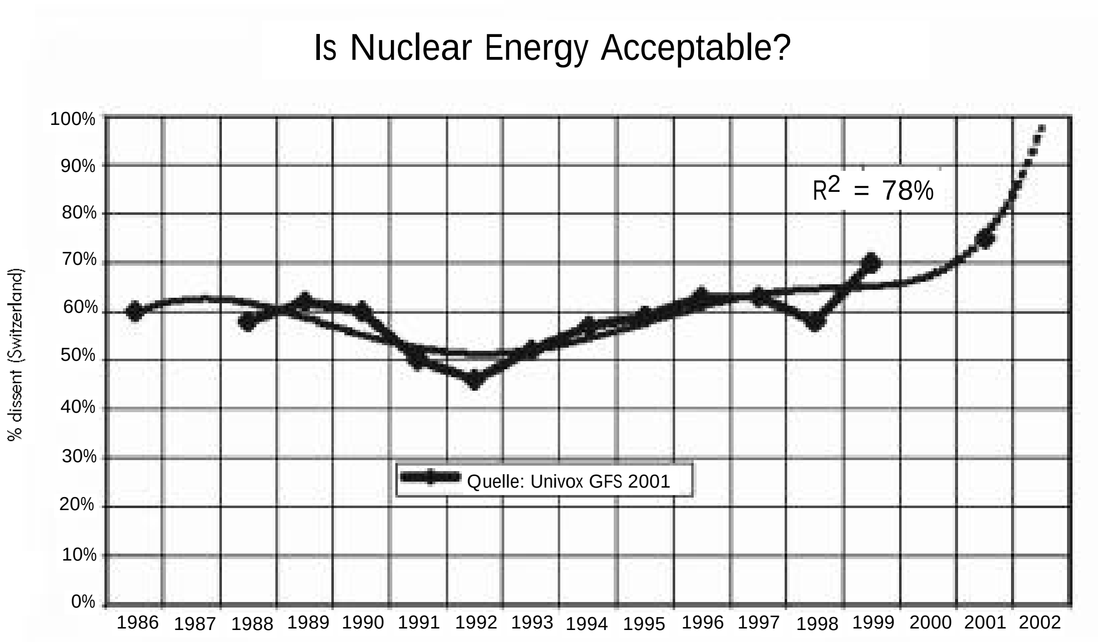


Figure 1. Systematic opinion polls of the Swiss voting population ("angst barometer") show an all time high of 75% of dissenting opinions regarding the use of nuclear energy in 2001 in Switzerland. The trend curve (polynomial with a relatively good fit) gives hope that the upward trend could continue.

MW is already at a market price level to serve as a substitute for nuclear energy and fossil power production.

3. Highly efficient cogeneration and combined-cycle production plants with controlled exhaust fumes are necessary in order to replace nuclear energy with fossil fuel. A 50%-plus coefficient of electrical, along with another 30% to 40% of thermal performance makes a rapid and relatively cheap substitute for nuclear energy possible.

4. Only during the last decade has the evidence accumulated that electricity can be used much more efficiently, i.e. that the largest reservoirs of electricity are not found in newly produced nuclear megawatts, but in "negawatts" found in light bulbs, electrical motors, refrigerators, etc. The establishment of clear, technological, and economical alternatives can be used in an optimal mix of many of the above-mentioned solutions.

• The silent majority has to be given a distinct voice. The 50% to 70% non-voting population has to be engaged and stimulated to establish emotional and economic links between the perils of nuclear energy and their individual well being.

What Could End Nuclear Power Production Sooner Rather Than Later?

The lines of argument advanced to promote the end of nuclear power have developed considerably in the last two decades. There are four major arguments that seem to be widely accepted and that help to gain democratic majorities:

1. Political uncertainties: Many of the power plant owners and producers have shied away from decade-long, uncertain approval procedures for new power plants, and from political fights on all levels.
2. The cost of nuclear energy (TCO) has risen compared with the falling costs of alternatives (efficiency, wind, distributed co-generation, etc.). Ongoing market liberation in the European Union will put pressure on expensive technologies with uncertain completion of their planned life cycle.
3. The public perception of uncertainty, safety problems during normal operation, and failure due to technical defects (or, now, deadly terrorist incursion) has increased the operation costs again: insurance rates are no longer shifted to free state guarantees but have to be paid for at steep commercial rates. Long range costs for waste disposal and dismantling have to be paid now in advance into funds that are not dependent on the economic well being of the owner. (see graph below from the “Angst-Barometer” Univox GfS 1986-2001).
4. Qualified, trained, and emotionally stable operating personnel are scarce. University careers are faltering and many departments are closing their reactor engineer programs due to a lack of students and funding.

Sweden's Missed Phase-Out

Tomas Kåberger

Sweden has an energy-intensive economy. Few countries use more hydropower per capita than Sweden, which also produces more electricity per capita using nuclear reactors than any other country in the world. Still, energy supply is dominated by oil, even though oil dependence has decreased since 1970.

Sweden has been attempting to reduce oil dependence for 30 years. There is also public support for doing without nuclear power. Anti-nuclear arguments have been based on concerns regarding reactor accidents; long term human health effects of exposure to routine emissions of radioactive materials; nuclear waste; and the links between civilian nuclear power and nuclear weapons.

Nuclear policy was the major domestic policy issue during the mid- and late-1970s; the anti-nuclear movement acted like a lightning rod for much of the political opposition to nearly 40 years of uninterrupted Social Democrat governments. The most powerful industrial organizations, however, have been strongly supportive of nuclear power.

Nuclear investments in Sweden were started as part of a weapons project[1,2] and continued with industrial ambitions. As the cost of nuclear power was far higher than electricity prices, however, the nuclear power project became not only an environmental and political problem but also an economic problem to the owners.[3,4]

As some major political parties were internally split, the nuclear power policy could not be managed by the parliamentary procedure. Instead, a national referendum on nuclear power was held in March 1980. The referendum ballot options were worded ambiguously, though the unwritten meanings were well understood by the voters. There were three alternatives, all of which stated that nuclear power reactors should be decommissioned. The winning alternative stated that a maximum of 12 reactors should be built and all of them should be closed after a period of licensed operation. According to a plan published by the campaign, all reactors should be closed within an estimated 25 years of operation.[5]

Swedish nuclear politics are very difficult to describe in a consistent way. Many have tried to describe the political process from sociological or political science perspectives.[6-11,3]

An attempt follows to outline some of the economic interests and rationalities that have influenced nuclear power policy in Sweden. There is also an economic rationality, however, offering policy measures to create market conditions that may harness economic interests for the wealth of society. The most pertinent component is the internalization of reactor accident cost described by Vanden Borre [see page 53].

Swedish Electricity Sector Development

Electricity works were established in Swedish cities and industries during the last decades of the 19th century. Some were based on thermal electricity generation, while others relied on small hydropower plants built in the minor rivers in the more populated, southern half of Sweden. As competition was hard to sustain, the Electricity Act was developed and local electricity companies often became municipality-owned monopolies.

Exploitation of the large rivers, mostly in northern Sweden, began in the early 20th century. Power companies with the economic capacity to take part in this exploitation were formed by industries, by municipalities, and by the state. The exploitation was aided by special legislation.

Transmission lines connecting the large hydropower plants of the north with the population gathered in southern Sweden were built by the state. The local, often municipal, electricity companies, one by one, gave up electricity production and became distributors of electricity bought from the power companies. The "electricity works" turned into pseudo-independent retailers with little or no power of their own.

The hydro-expansion came to an end in the late 1950s. The rivers that could be exploited at low cost had been built out. Those that were left required great investments in relation to the electricity that could be produced. In addition, a rapidly growing public opinion was opposing the complete exploitation of the rivers flowing into the Baltic Sea, increasing the political cost of every new project. As a consequence, the increasing demand for electricity could no longer be met by new hydropower and attention turned to thermal power.

Thermal power offered municipal energy companies in the cities of southern Sweden the opportunity to recover independence. Steam turbines, employing district-heating systems to utilize cooling water, could be operated to generate electricity. Revenues from district heating would give these municipal systems a competitive advantage over the power companies, which did not have access to district heating grids and would have to set their electricity price high enough to cover all the power-plant costs. As a result, local energy companies could take back market-shares lost during the hydropower era.

Such new competitors threatened the position of the power companies to control both electricity price and the national power grid. In the battle that followed, the State-owned power company, Statens Vattenfallsverk, now Vattenfall, had significant market power. Vattenfall could stop municipal companies from selling surplus electricity to neighboring cities and demanded exorbitantly high rates for power to be supplied in case of power shortages in a city that had dared to build co-generation.[12,13]

In this situation, if the power companies could present nuclear power as being able to produce electricity cheaper than co-generation from fossil fuels, their strategic vision would prevail.

The first reactors built in Britain and the USA did not offer evidence of low total costs of nuclear-generated electricity. The first small Swedish reactor at Ågesta should have been ready in 1961 at a cost of 40 M SEK. It was ready in 1964 at a cost of 205 M Swedish kröne (SEK). It operated at a loss despite the government writing off most of the investment cost until the reactor was closed in 1974.[10]

Electricity-intensive industries had developed in Sweden under market conditions set by hydropower, with high investment costs and low marginal costs. Nuclear power, too, appeared to provide low marginal costs despite the high total costs due to high investments. For industrial customers, such technology may provide low power prices if, and only if, there is overcapacity. Once the plants are built, electricity will be produced at prices as low as the short term marginal costs.

Proponents of nuclear power also anticipated that the plants would become cheaper to operate as more plants were built. If a series of reactors could be build, according to this belief, the costs of each reactor would be reduced enough to make nuclear power plants economically competitive. In order to be able to build series of reactors, perceptions of a large future demand for electricity were needed.

When asked by the power companies, the industrial customers had an interest in providing exaggerated estimates of future energy demand in order to create overcapacity and, thereby, to get low electricity prices. Power companies, on the other hand, saw such estimates as signs of support of their visions for large series of nuclear reactors. During the period around 1970, projections were made that turned out to be far from realistic. In 1972, CDL, the organization co-ordinating the projections for the electricity producing industry, projected a need for 24 reactors by 1990.

Cost Concepts to Describe the Economics of Nuclear Power

Marginal cost of production: The cost avoided if power output is reduced during the coming hour or day. It is mainly the cost for fuel and, possibly, some waste-management costs. For a nuclear reactor the marginal cost of production can be on the order of 0.005euros/kWh.

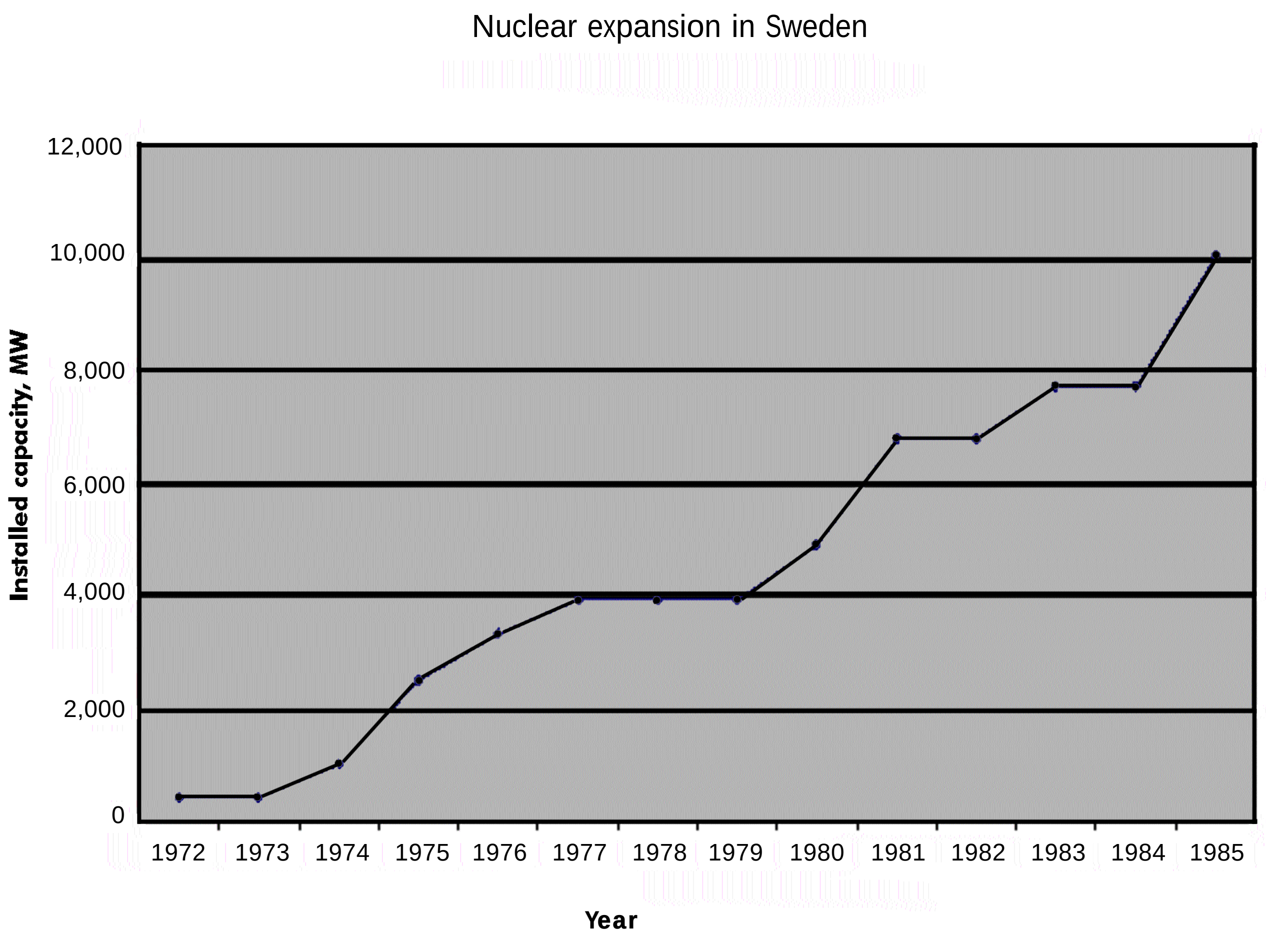
Avoidable costs: The costs avoided if a decision is made to close a plant permanently. These include the cost of fuel, staff, other operation and maintenance costs, and re-investments. Among old, small reactors one may find avoidable costs in the range 0.015-0.035euros/kWh, while the best modern reactors during their best years may produce electricity at avoidable costs of 0.010-0.015euros/kWh.

Total production costs: The costs of building and operating a reactor and the costs for decommissioning and waste management. Calculating the capital costs of building a reactor, one must decide what rate of return on investment is to be demanded. In the nuclear sector, government involvement has often resulted in lower rates used than those found in other energy sectors. Removing subsidies and introducing competition into the electricity sector has resulted in the use of higher rates of return in these calculations. Total production costs of 0.03-0.06euros/kWh

(All the figures given here are found in the reports of the nuclear operators. The costs of routine emissions and nuclear accident risks are therefore not fully included.)

Another factor encouraging the electricity industry to provide high estimates of future energy demand was the opposition of environmentalists to nuclear power starting in the 1970s. The anti-nuclear movement favored wind power, solar energy, and biomass. Wind power and biomass were within economic reach, but the nuclear industry contended that only atomic power could meet the projected demand for electricity—if projections were high enough.

In 1974, a governmental commission on energy projections,[14] relying heavily on information provided by the industries producing and consuming electricity, described an electricity consumption of 350 TWh by 2000—real use turned out to be less than 145 TWh.



The vision of rapidly growing electricity demand and large-scale expansion of nuclear generation had been turned into government policy.

The overinvestments in nuclear reactors that followed may be understood from this context of individually rational responses conditioned by economic situations and interests. Electricity-intensive industries gave too high a figure of future electricity need. The managers of the power companies did not critically analyze their figures because the resulting projections fitted their aims so well. The projections justified the idea to build large numbers of reactors to bring down investment costs and the rapid demand growth showed that renewable energy was not sufficient.

Before the last Swedish reactors were built after the referendum in 1980 it was already clear to many people that the demand could not justify electricity prices that would pay the total production costs of the reactors planned.[15,16] Some years later, researchers concluded that the low–power energy plan of the anti-nuclear movement fitted real demand better than the official projection, even though none of the measures to reduce energy use had been taken.[17]

The last reactors built after the referendum, most clearly Oskarshamn III and Forsmark III, commissioned in 1985, have not recovered the capital costs to their owners. (See table 1) But at least before competition was introduced, all reactors appeared to cover their avoidable costs, (fuel, staff, and maintenance). Before competition was introduced, however, electricity trade already included markets for marginal power offered at prices much below average price. Assuming all such sales were priced around 0.1 SEK/kWh to the older nuclear reac-

Table 1: The Swedish nuclear reactors

REACTOR	NET-POWER / MW	STARTED / YEAR
Barsebäck 1*	600	1975
Barsebäck 2	600	1977
Forsmark 1	970	1980
Forsmark 2	970	1981
Forsmark 3	1,155	1985
Oskarshamn 1	445	1972
Oskarshamn 2	605	1974
Oskarshamn 3	1,160	1985
Ringhals 1	835	1976
Ringhals 2	875	1975
Ringhals 3	920	1981
Ringhals 4	920	1983

* Barsebäck 1 was closed November 30, 1999.

tors, one may construct an analysis yielding the opposite result. Despite low-priced marginal electricity, production was limited to prices above the short term marginal costs of nuclear fuel alone. And often demand was too low even at that price, forcing operators to turn down output of the reactors.

This was the situation in the early 1990s when the oldest reactors approached 25 years of operation and were to be shut down according to the promises made before the referendum and the parliamentary decision thereafter. The minister for Energy and Environment, Birgitta Dahl, made an "irrevocable" commitment to close the first reactors in 1996. A well-funded campaign against her and the commitment was launched. In the campaign, the industrial trade unions were mobilized against the social democratic government. The role of the nuclear reactor industry and the power companies was limited to providing "low-key information"[18] leaving the battle to the electricity-intensive industries and trade unions.[19]

The main actors in this campaign were the electricity-intensive industries of the mining, steel, chemical, and pulp and paper sectors. The companies involved were few and they perceived their economic interest to be strong. Thus they were easily organized and formed the Swedish Electricity Refining Industry (Sveriges El-förädlande Industrier) to run the campaign.

Together they consumed 31 TWh of electricity per year. Overcapacity of electricity generators made it possible for them to buy electricity at 0.15 SEK/kWh (approximately 1.5 EUR cent/kWh). The belief expressed—by industry as well as in government reports at the time, was that if two reactors were shut overcapacity would disappear and the price would rise until new power plants could be built. Electricity from any new power plant that could be built was said to be double the cost, 0.3 SEK/kWh. The business idea of the campaign was that if it just managed to delay nuclear decommissioning by one year, the price increase would also be postponed by one year. Electricity-intensive industries, buying 31 TWh per year, thus would save 31 TWh * (0.3-0.15) SEK/kWh = 4.65 GSEK ≈ 480 million, as a result of only a one -year delay in decommissioning.

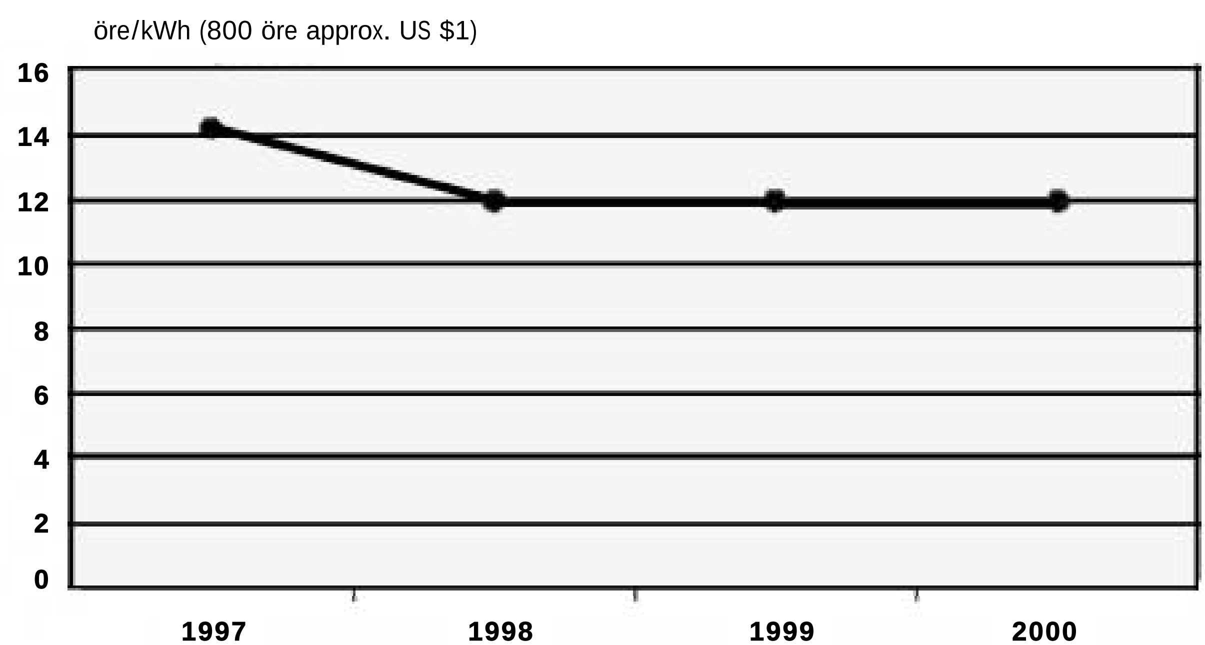
Judging from the visible organized activities and their publications, the campaign budget appears to have been on the order of 10% of this amount.

At a meeting with the German Atomic Forum, the success of the campaign was described by Lennart Fogelström, at that time the executive director of Asea Atom.[19] Fogelström concluded that the trade union leaders, among them Rune Molin, were impressed by the arguments. Molin was given a post in government as minister of industry and was given the energy portfolio from Birgitta Dahl, who was left with only the environment. The "irrevocable decision" became a vague ambition and the economic result of the industry campaign appeared satisfactory to those who financed it.

The losers were the power companies, who failed to recover their investments and who lost the profits of their hydropower plants that could have been harvested had market equilibrium prices prevailed instead of overcapacity. At the time, the power companies were about 4/5-owned by taxpayers and retirement funds.

The electricity market was re-regulated in 1995 in order to introduce competition among producers. The result of the reform was a falling electricity price. The price for the three years 1998-2000 was around 0.12 SEK/kWh— approx. 0.015/kWh (cf. Figure 1). As a result, all nuclear reactor companies published production costs well above the market price. For the newest reactors, this was due to remaining capital costs, but the oldest reactors were not even able to cover avoidable

Figure 1. Average electricity spot market in Sweden (1997-2000)/Source: NordPool 2001



costs at market price.

In 1997 there was a decision by a negotiated parliamentary majority to close one of the oldest reactors, Barsebäck I, and to pay compensation to the owner, Sydkraft. At the same time the decision to close all reactors after 25 years of operation was revoked. In the days following the decision, share values of all power companies increased but the value Sydkraft increased more than the others.[20] The economic settlement that followed forced taxpayers to pay approximately 1 billion to the reactor owners.

To understand the political success of this settlement, one must see how the decision affected the interested parties:

Only the power industry profited. One of several reactors that had avoidable cost far above the electricity price was closed. No power company lost anything due to the deal. All electricity producers expected to benefit from a marginally increasing electricity price. The nuclear power companies won. The decision to close all reactors at 25 years of age was removed and, most important, the companies were given compensation for closing reactors, even for the first and oldest reactor, which had avoidable costs above market price.

Shortly afterwards, Peter Nygårds, the vice minister for energy who handled the decision, was given the job as managing director of SKB, a waste management company owned by the Swedish nuclear reactor owners collectively. This appointment indicates that the power industry was at least not disappointed by the political settlement.

The power-intensive industries may be threatened by the risk of a short term marginal price increase due to reduced overcapacity. With the integrated Nordic electricity market, however, the effect of closing one minor reactor was small. More important was the decision not to close all the other reactors after 25 years of operation; such a capacity loss would have been large enough in relation to transmission capacity in northern Europe to have an effect on prices in Sweden.

Many active nuclear opponents celebrated the start of decommissioning: footage of Greenpeace activists opening a bottle Champagne was a frequent TV illustration of the event. In their political rhetoric, government spokesmen made successful efforts to support this image of the deal.

The direct losers were the taxpayers, who had to compensate the reactor owners. A large number of individuals each lost a moderate sum of money. Such stakeholders are difficult to organize well enough to understand—let alone be able to defend—their interests.

In the above description of the outcome, the focus has been on monetary transactions. The energy sector, however, has significant external economic effects that are lost in such analysis. The extended operation time of the remaining reactors will lead to a net increase in nuclear operation. Some of the expected external costs of extended operation are the following:

* An increased number of expected cancer cases and genetic risks will occur from routine emissions of radioactive material, mostly from uranium mining. These costs affect mainly people in other countries and in future generations. Cancer is nowadays possible to treat successfully for those who have capacity to detect their cancer early and who have economic resources to pay for treatment. Rational economic men of power in present industrial societies may value these effects low. A socio-economic analysis giving equal appreciation of cost regardless of where and when people suffer from such effects, however, may assess these costs as significantly larger.

* More reactor years of operation will contribute to reactor accident risks. The significance of such risks is difficult to quantify. The costs have been lifted off the shoulders of the operators and placed on taxpayers and potential accident victims by special legislation on nuclear liability. In this case, a large number of people carry a low probability of a significant cost.

* More waste will be produced. Nuclear waste management is believed to pose external costs only to coming generations. Members of these generations cannot influence present decision making. In economic theory, though not necessarily in politics, however, consequences are important even if they do not have well organized interest groups to give them attention. The general principle is that those who cause environmental costs also shall pay the costs. If they do not pay the victims directly, then they should pay the cost as a tax.[21] This is the position taken not only by environmentalists but also by economists and by international organizations in documents such as Agenda 21 and the Report of the World Energy Council.[22]

In Spring 2002 the government presented a proposition to the parliament on future energy policy.[23] The title is "Co-operation for safe, efficient and environmentally friendly energy-supply." This proposition contains two minor legislative changes with little relevance to nuclear policy, but in it the government also asks the parliament to support a government effort to reach a decommissioning agreement with the power industry, with the German agreement as a blueprint.

The nuclear industry is interested and repeats its claim to have fair "competitive conditions." The interpretation of this situation is that the government will possibly agree with the power companies that they will close the reactors in the distant future on the condition that parliament immediately remove all remaining taxes—approximately 150 M per year—on nuclear reactors and their operation.

The tax removal is immediate and has economic implications. The commitment to close reactors is long term and has no economic implications—it may be revoked before having any impact.

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Referendum Shifts Japan's Nuclear Policy

Kazuyuki Takemoto

My hometown, Kariwa village, is the site of the world's biggest nuclear power station. Tokyo Electric Power Company (TEPCO) operates seven nuclear reactors with a total output of 8,212 MW at the Kashiwazaki-Kariwa nuclear power station. The Kashiwazaki-Kariwa station is located on the boundary of Kashiwazaki city, with 90,000 residents, and Kariwa village, with 5,000 residents.

I was born in a peasant family, three kilometers from the nuclear power station. I have been opposing nuclear power since the project was first announced in 1969.

Kariwa village held a referendum on May 27, 2002 regarding the Pluthermal project, MOX fuel use in light water reactors, and the impact of the project on the entire nation.

On March 5, 2002, the reactor 1 at Kashiwazaki-Kariwa had an accident in its recirculation pump, and it was manually stopped. In that year alone, there were 15 accidents at Kashiwazaki-Kariwa. Many accidents are a result of the aging of the reactors, operator errors, and the negative influences of a "cost-effectiveness-first" policy. Whenever an accident is reported, distrust and anxiety mount among the residents in the surrounding area.

Police stand guard in front of the nuclear power station's gate 24 hours a day. Patrol boats remain on the surrounding sea, and helicopters brought by the boats fly overhead. The security has been like this since September 11, 2001, which brought even more anxiety to the residents.

In the referendum on the introduction of the Pluthermal project, the opposition won the majority, and the plan is now suspended. Neither the Japanese government nor TEPCO, however, have given up the plan yet.

Japanese Nuclear Power Plants and the Pluthermal Project

Japan has been planning to use plutonium in a fast breeder reactor (FBR) and constructed Monju, a prototype FBR. On December 8, 1995, however, sodium leaked from a ruptured coolant pipe and this caused a fire. The operation of Monju has been suspended since the fire, and there is no prospect of resumption of its operation. Because of this, a huge amount of plutonium, which is convertible to nuclear weapons, has accumulated. In order to consume this excess plutonium, the Japanese government planned to fabricate MOX fuel to burn in light water reactors. In the original plan, Kansai Electric Power Company (KEPCO) planned to burn MOX at Takahama 3 and Takahama 4 in Fukui prefecture, and Tokyo Electric Power Company (TEPCO) at Fukushima I-3 and Kashiwazaki-Kariwa 3. By 2010, the Pluthermal plan was going to be implemented by each utility company at a total of 18 to 20 light water reactors.

In the midst of the uproar caused by the JCO accident, MOX fuel was being shipped from the UK and France to Fukui and Fukushima. The fuel planned to be loaded into Takahama 4, however, had to be returned to the UK due to a scandal surrounding the falsification of inspection data.

In Fukushima, nobody knows when the MOX will be loaded since the prefectural governor's Energy Policy Review Committee is still underway. At the third candidate site, also in Kashiwazaki-Kariwa, there is no knowing when the plan could actually be implemented. The governor stated, "As long as the residents' decision does not change, we cannot go on," referring to the result of the referendum showing that the majority of Kariwa villagers opposed the plan.

There is no prospect at all that MOX will be loaded into a reactor in Hamaoka operated by Chubu Electric, because of the accidents involving a pipe rupture and water leak from the Hamaoka 1 reactor vessel. The electric companies themselves may not want to go ahead with the Pluthermal plan, since it will suppress the liberation of the electric market and will lead to higher costs.

The Japanese population of 125 million lives in an area of 378,000 square kilometers. The 10 electric companies that have divided up Japan among them provide electricity to each area under regional monopolies. Nine electric companies, as well as the Japan Atomic Power Co., operate 53 nuclear power plants [29 boiling water reactors (BWRs), 23 pressurized water reactors (PWRs), and one advanced thermal reactor (ATR)] with a total capacity of 46 GW.

As of the end of 2000, the world total was 430 plants with a total capacity of 363 GW, of which Japan's share was one eighth, in both the number of plants and

Table 1. Nuclear power plants in the world.

Country	Number	Output MW	Population (million)	Area (1,000km 2)	Population ratio kW/person	Area ratio kW/km 2
US	103	101,171	226	9,364	0.38	11
France	57	62,920	58	552	1.08	114
Japan	52	45,082	125	378	0.36	119
Germany	19	22,365	82	357	0.27	63
Russia	29	21,556	148	17,075	0.15	1
Korea	16	13,716	45	99	0.30	139
UK	33	13,531	59	244	0.23	55
Ukraine	13	11,818	51	604	0.23	20
Canada	14	10,615	29	9,971	0.37	1
Sweden	11	9,822	9	450	1.09	22
Spain	9	7,798	39	506	0.20	15
Belgium	7	5,995	10	31	0.60	193
Taiwan	6	5,144	22	36	0.23	143
Bulgaria	6	3,760	8	111	0.47	34
Switzerland	5	3,352	7	41	0.48	82
Others	50	24,698	4,810	95,822		
Total	430	363,343	5,768	135,641		

capacity. The first Japanese nuclear reactor was a gas-cooled reactor imported from the UK, construction of which began in 1960, and which operated for 32 years from 1966 to 1998. That plant is now being decommissioned. From 1969 to 1997, on average, two US type reactors, both BWRs and PWRs, have been constructed each year. Between 1997, when Kashiwazaki-Kariwa reactor 7 and Genkai 4 began operating, and January 2002, when Onagawa 3 commenced its operation, no new reactors had been started up. Currently, only three reactors are being constructed. Thus, even in Japan the construction of nuclear power plants has slowed down.

The arguments made on behalf of nuclear energy have been based on need, economy, and safety:

- Necessity: Japan's energy consumption expands each year. Japan has scarce sources of energy and oil will soon be depleted. Nuclear energy is an infinite source of energy and, thus, we need nuclear energy.
- Economics: Nuclear energy is more economical than fossil energy such as oil, coal, and natural gas, or than hydro energy.
- Safety: We do not have to worry about the catastrophic consequences of Hiroshima and Nagasaki. There is no health risk incurred by low-level radiation. Nuclear energy, when under control, is safe.

When the nuclear energy era arrived, those who rejected nuclear energy were said to deny the progress of society. Such slogans were widespread when all the nuclear power plants were constructed in agricultural or fishing villages far away from the consumers' locations. In regions with nuclear power plants, people were persuaded that their towns would become rich through tax cuts and other financial rewards for their support of nuclear facilities.

The first reactor was made by the UK; all the others were BWRs and PWRs that were copied from the US and built by Japanese companies. Japan has become the third largest nuclear energy country: the US is first with 103 reactors with a total output of 101 GW; and France is second with 57 reactors with an output of 63 GW (see Table 1).

Liberalization of the Electricity Market and Decentralized Small Scale Generation

The Japanese utility fee is quite expensive compared to other advanced countries—approximately 2.5 times that in the US and two times those in European nations (see Table 2).

This is a result of regional monopoly and the comprehensive cost system, in which the profit can be decided in accordance with the electricity cost, and thus is a convenient system for the Japanese electric companies. Currently, liberalization of electricity is being promoted.

All over the world, nuclear energy is becoming less and less popular. Nuclear energy needs enormous amount of capital investment, and no future prospect is yet to be seen regarding disposal of the waste even without accident. Moreover, an irreversible catastrophe could occur if a severe accident happened. Some European countries have chosen to withdraw from their nuclear policy, based on their rational thinking. For economic reasons, the US has also stopped siting new

Table 2. Comparison of electricity fees by country (1997) US cent/kWh

Countries	Industrial	Domestic
Australia	5.6	8.0
United States	4.4	8.5
Sweden	3.4	10.1
UK	6.5	12.5
France	4.9	13.4
Italy	9.4	15.9
Germany	7.2	16.1
Japan	14.6	20.7

nuclear power plants since 1980. Japan, on the other hand, has been promoting nuclear power.

But now, electric companies are in deep trouble, saying, "Without the government's incentives, we cannot maintain our cooperation with nuclear policy." Until today, the pro-nuclear government and the electric companies have stood shoulder to shoulder. Now disagreements are seen on both sides.

Anti-Nuclear Referenda: Democracy Shifts Nuclear Policy

When many candidate sites for nuclear power plants were revealed, the anti-nuclear power plant movements started. In response, the government and the electric companies conducted promotional activities and bought up the land and surrounding seas at exorbitant prices. As a result, construction was forcibly carried out. There are still some places where the purchase of land and sea could not be secured, and where the plans were finally given up due to long-sustained movements. Yet even now, in some places, electric companies have not given up their plans and anti-nuclear citizens' movements continue.

All Japanese nuclear power plants are built on the coasts far away from the cities. After World War II, urbanization progressed rapidly, causing overpopulation in cities and depopulation in agricultural villages. The electric companies proclaimed that local economies would be boosted if they accepted nuclear power plants; people could enjoy prosperous lives just like in cities. In Japan, lands are privately owned and fishing rights are rendered to fishermen's unions. Assemblymen elected in their regions are able to decide regional policies. In order to build and operate a nuclear power plant, the electric company must purchase the construction site, obtain the renunciation of fishing rights in the area to be affected by hot waste water, and secure the agreement of the mayor and the assembly.

Under the slogan "Nuclear power is a state policy, so you should be cooperative," the lands and the seas were sold at dozens of times higher than regular prices. Municipal officials were made to agree, after being persuaded that the region would be enriched by the government's incentives for building nuclear power plants. In fact, compared to regions without nuclear power plants, enormous subsidies and donations were allocated; public buildings were constructed; and roads and ports were renovated.

Mayors and assemblymen are elected by the voters. Nuclear policy is just one among many election issues. Mayors and assemblymen generally belong to, or at least support, political parties. This means that most of them are on the pro-nuclear side and support the Pluthermal plan. As a result, in many cases, the opinions of a majority of voters' conflict with those of their mayor or assemblyman over the issues of siting nuclear power plants and implementing the Pluthermal plan. In villages with nuclear power plants, citizens' anxiety or outright opposition has not been reflected in important decision-making processes.

During the 1960s, when the atomic energy plan was initially announced, Japanese democracy was not mature. Women had been given the right to vote for the first time only in 1946, and people did not insist on their own rights so much. As one way of overcoming such a situation, referenda, in which voters can express their own will, have been proposed and implemented. The first referendum held in Japan, on August 4, 1996, was on the approval of the construction of a nuclear power plant in Maki town, Niigata prefecture. Since then, there have been a number of referenda over such issues as an industrial waste disposal site, a military base, and others.

According to Japanese laws, establishment of an ordinance can be proposed directly by 1/50 of the voters, but without the motion of the assembly, that ordinance cannot be passed. The direct proposal for a referendum on the Pluthermal plan in Kariwa village was submitted to the assembly for the first time by Kariwa and Kashiwazaki in January 1999. The claim was dismissed, however, on March 23. After that, the JCO criticality accident took place, followed by the exposure of the data falsification of MOX fuel for the Takahama nuclear power plant owned by KEPCO, and the scandal concerning slush spending on Rapika, which had been built with government subsidies for promoting areas adjacent to nuclear power plants. Due to this series of incidents, the referenda were finally undertaken.

Both in Maki and Kariwa, promoters of nuclear energy expressed their opposition to referenda, insisting that referenda were unnecessary. There were indescribable difficulties on the way to the implementation of the referenda both in Maki and Kariwa.

On the other hand, a referendum to approve the siting of a nuclear power plant in Miyama town, in Mie prefecture, was planned and implemented by the promoters. Nuclear promoters in Maki and Kariwa used to insist, "Nuclear energy is a state policy, which does not go along with referenda," "Referenda deny the parliamentary democracy." But after the referendum in Miyama, which was implemented by nuclear promoters, they can no longer criticize referenda using this logic. That people should decide important issues, such as the building of nuclear power plants, by direct voting can no longer be disputed.

Voter turnout for the referenda was almost 90% in the three municipalities. This high turnout shows the will-

Table 3. Results of referenda on nuclear policy								
	Date	Population	# of voters	# of votes	Turnout	Opposition	(%)	Support
Maki	04/08/1996	30,011	23,222	20,503	88.29%	12,478	(60.9)	7,904
Kariwa	27/05/2001	5,027	4,090	3,605	88.14%	1,925	(53.4)	1,533
Miyama	17/11/2001	10,400	8,748	7,754	88.64%	5,215	(67.3)	2,512

Table 4. Claims for Referenda in Japan

A result of a referendum regarding nuclear policy is not legally binding. Yet, the mayors of the municipality should take the result into consideration. The following are the results of claims submitted to municipalities seeking an ordinance for implementing a referendum related to nuclear policy.

Date of claim	Municipalities	Issues	Result	Date of Referendum
May 85	Aomori prefecture	Siting of nuclear fuel cycle facility	Dismissed	
June 85	Kisei town (Mie)	Advance environmental assessment for siting Ashihama nuclear power plant	Dismissed	
May 86	Togi town (Ishikawa)	Siting of Shika nuclear power plant	Dismissed	
Sep. 90	Tomioka town (Fukushima)	Resumption of Fukushima II-3's operation	Dismissed	
Feb. 93	Nanto town (Mie)	Siting of nuclear power plant (Revised on 95.3)	Passed	
Oct. 93	Kushima city (Miyazaki)	Siting of nuclear power plant (Revised on 95.9)	Passed	
Dec. 93	Tsuruga (Fukui)	Construction of new nuclear power plant	Dismissed	
Dec. 93	Rokkasho (Aomori)	Receiving high level waste	Dismissed	
March 95	Nanto town (Mie)	Advance environmental assessment for siting nuclear power plant	Passed	
June 95	Maki toen (Niigata)	Siting of nuclear power plant (Revised on 95.10)	Passed	08/96
Dec. 95	Kisei town (Mie)	Siting of nuclear power plant	Passed	
Dec. 99	Takahama town (Fukui)	Loading of MOX	Dismissed	
March. 01	Kariwa village (Niigata)	Loading of MOX	Passed	05/01
Aug. 01	Miyama town (Mie)	Siting of nuclear power plant	Passed	11/01

ingness of the citizens, who want to participate in important decision-making processes of their regions. All the results showed opposition to the construction of a nuclear power plant or the loading of MOX fuel, which has led to a freeze, suspension, or cancellation of the respective target plants (see Table 3).

In Miyama town, the siting plan for a nuclear power plant had already been underway. In Maki, most of the land for constructing a nuclear power plant had already been purchased. In Kariwa, one fourth of the village's households have been dependent on the salary from the nuclear power station. Yet it was proven in Japan that we can stop the promotion of nuclear energy if we resort to democratic referenda.

The referenda proved to be an effective democratic procedure by which residents could recapture control of their own governments and administrative matters. The first referendum, held in Maki on the issue of whether to disapprove construction of a nuclear power plant, helped the spread of referenda nationwide. The central government, for example, has given instructions to promote merging small sized municipalities into bigger ones, to simplify administrative work. Referenda are expected to take place on this issue as well. Accordingly, referenda will become a more common practice, which will become an advantage for the anti-nuclear referendum movement. There will be a day in the future when it is said that the people of Japan successfully shifted nuclear energy policy by referenda (see Table 4).

Joint Movements By Citizens Nationwide For New Regional Societies

After the Kariwa referendum, citizens from organizations against nuclear power plants in Kariwa village and Niigata prefecture were invited to report about the referendum and they expressed gratitude to those who supported their action. People who live in candidate areas for siting facilities such as nuclear power generation plants, interim storage sites for spent fuel, reprocessing plants, or geological disposal sites for high level waste, were as pleased with the result as if it were their own victory. People who had been supporting anti-war and anti-nuclear weapons movements also joined the celebration. They have made a renewed pledge for establishing a nuclear-free society.

Miyama town, in Mie prefecture, had its own referendum on the issue of constructing a new nuclear power plant after the referendum in Kariwa village. The victory went to the anti-nuclear citizens' side. If we, the Kariwa villagers, indeed made some contribution to the result of the Miyama town referendum by telling them the situation in the pro-nuclear town Kaswhiwazaki-Kariwa, we believe that it was the best return gift to all the people who supported us nationwide.

In Kariwa village, the "Society for Talk about Kariwa in the Future" was established. The Society was established to have a discussion about the lives of local people who have been forced to accept the existence of nuclear power plants. The meetings are also for talks with pro-nuclear people.

Efforts By the Government and Electric Companies to Undermine the Result of the Referendum

On March 8, 2002, ignoring the result of the referendum of Kariwa villagers, TEPCO announced that it had placed an order for the next shipment of MOX fuel to COGEMA, and that the fabrication was underway. Behind the scenes, we can assume that electric companies are trying to execute their old contracts and that the nuclear industries are trying to reinvigorate their industry, which is on its deathbed.

After the referendum, the government and electric companies have expanded their nuclear promotion activities, including pro-nuclear energy education from an early age, excursions to nuclear power plants, exchange programs between the regions that produce and con-

History of Nuclear Technologies

1895 Roentgen discovers X-rays

1898 Madam Curie discovers radium

1903 Rutherford establishes theory of decaying radioactive elements

1905 Einstein establishes Special Theory of Relativity

1938 Hahn and Strassman discover uranium nuclear fission

1942 Fermi creates nuclear fission chain reaction

1945 A-bombs dropped on Hiroshima and Nagasaki

1953 US President Eisenhower advocates "Atoms for Peace" at the United Nations

1966 Tokai nuclear power plant (GCR 166MW) commences operation

1969 Tokyo Electric announces plan for Kashiwazaki-Kariwa nuclear power plants

1970 Tsuruga nuclear power plant (357 MW) commences operation

1979 Accident at US Three-Mile Island nuclear power plant 2

1985 Tokyo Electric commences operation of Kashiwazaki-Kariwa 1

1986 Accident at Chernobyl nuclear power plant 4 in former Soviet Union

1995 Sodium fire accident at Monju

1996 Maki town in Nigata holds referendum on siting nuclear power plant

1997 Tokyo electric commences operation of Kashiwazaki-Kariwa 7

1999 JCO criticality accident in Tokaimura

2001 Referenda in Kariwa (on Pluthermal plan) and in Miyama (on siting nuclear power plant) sume electricity, and increased regional subsidies.

Right after the referendum, the government established an Inter-Ministerial Coordination Committee for Promoting Pluthermal. The Atomic Energy Commission has also been trying to conciliate local people by meeting with citizens in Kariwa village and saying, "We have listened to the voices of people who are against nuclear power." Even the pro-nuclear people in Kariwa were discontent, saying, "We are not getting visible support from the government." Responding to this, the government dispatched some personnel who would listen to the voices of the residents in Kariwa. Yet, what the pro-nuclear people really think was represented by the statements from the governor of Tokyo, who said "Taxpayers' money from cities paved the roads on which only bears would cross at night." In addition, the director of the Inter-Ministerial Coordination Committee for Promoting Pluthermal said, "Kariwa should be thankful to nuclear power plants, which brought prosperity to the village."

Electric companies have been continuously conducting a campaign for promoting the Pluthermal plan. With "Seeing is Believing" as their slogan, they initiated a campaign called "Let One Million People Visit Nuclear Power Plants," the size of which is three times bigger than the previous campaign. In addition, they are using TV and newspaper advertisements. For the first time in more than 30 years, since the announcement of the construction of a nuclear power plant in Kariwa village, TEPCO carried out visits to all the local households. In addition, they have tried to regain trust by sending applications to join Japanese cricket clubs that mainly consist of senior citizens, and by providing donations to local festivals.

The promotional activities by the government and the electric companies remind us of a furtive stalker trying to undermine the endeavors of the residents who have already decided to reject the Pluthermal plan. It is not an acceptable practice for a single private company to interfere in a local community to this extent.

The Future Perspective

After the industrial revolution, urbanization progressed all over the world. In the case of Japan, it started in 1867, the year of the Meiji Restoration, and the movement became all the more rampant after WW II. Urbanization brought overpopulation in big cities, and depopulation in agricultural and fishing villages, which made both cities and villages run-down. In Japan, population in primary industries, such as agriculture, forestry, and fishing diminished, and shifted to secondary and tertiary industries. Since that time, urbanization has been a worldwide trend, which has promoted the division of labor to achieve higher efficiency.

In the old days, large-scale electricity generation systems and long-distance transmission were considered effective and thus they were promoted. The typical example of this was nuclear power stations. The efficiency of nuclear energy (conversion of heat energy to electric energy) is only one third. The loss of electricity through long-distance transmission is almost 10%. Thus, the energy that can actually be used at consumers' locations is only 30% of the initial amount produced at the source.

On the other hand, decentralized, small-scale generating systems, such as fuel cells or micro gas turbines, generate electricity at consumers' locations and provide hot water along with electricity. The efficiency of these energy forms is said to be between 70% and 80%. It is quite obvious that more efficient systems will be selected in the future. Small-scale, decentralized systems will not only affect the electricity generation system, but also the social system as a whole. They will help bring to realization a society where diverse cultures and values are recognized while the self-sufficiency and independence of many regions are maintained. This kind of society should be the framework for the 21st century.

The referendum in Kariwa village, with only 5,000 people, became the turning point in Japan's nuclear policy. The state can no longer ignore the will of the villagers. In this regard, the meaning of the referendum was more than we had expected. It was at the end of 19th century, approximately 100 years ago, when the principles of atomic energy were discovered. It has been half a century since atomic bombs were dropped on Hiroshima and Nagasaki. Since then, atomic energy has spread all over the world, with the issues of waste disposal and control remaining unsolved.

I consider that the choice of nuclear energy as an industry was a wrong decision by human beings in the 20th century. The nuclear industry is a negative legacy, which burdens us with worries about catastrophic accidents, occupational exposure, and genetic damage during the whole process of the nuclear fuel cycle, from uranium mining to disposal of high-level waste that will have to be overseen for many centuries to come. I believe that in a future history book, nuclear energy will be noted as a foolish technology, chosen by people living in advanced societies in the latter half of the 20th century.

Postscript: Earthquakes and Nuclear Power Plants

80% of the world's earthquake energy is concentrated on the Circum-Pacific Earthquake Belt; 20% on the Himaraya Mediterranean Earthquake Belt. 15% of the world's earthquake energy is released under the Japanese archipelago, whose land and surroundings are less than 0.1% of the world's entire area. Seismic activities in and around the Japanese archipelago have alternated between active and inactive periods. But since the Great Hanshin Earthquake in 1995, Japan is now said to have entered a seismically active period.

There are 53 operating nuclear power plants in Japan. Although a large earthquake has not yet hit a nuclear power plant anywhere in the world, a catastrophic disaster caused by destruction of a nuclear power plant in a great earthquake is highly probable. The whole world has to think seriously about the nuclear plants built on seismically active belts.

In March 2002, a lawsuit was filed seeking an injunction on the operation of the Hamaoka nuclear power plants, which are located directly in the area where the Great Tokai Earthquake is expected to occur.

The Citizen Science Concept

The Role of Independent and Counter Expertise

Mycle Schneider

WISE-Paris was established as an information service and consultancy in 1983. Its activities, on the one hand, are clearly journalistic in nature, while, in parallel, it has an expertise, research, and consultancy dimension. The original idea was very simple: if I do in-depth research, investigation, and analysis, I can elaborate from the result a TV documentary, a press article, or a research report. In the end, the research—the underlying work—is identical, though the outcome—the "product"—takes a different format. WISE-Paris has been trying to do this right from the start. Therefore, the media are among its regular clients. To give an example, between September 11, 2001 and the end of February 2002, WISE-Paris received inquiries for information from more than 110 journalists from 14 different countries, including representatives of 16 television and 14 radio stations.

On the other hand, WISE-Paris's consulting and analysis activities and information services go to clients ranging from Greenpeace International to the International Atomic Energy Agency (approximately 180° of the possible opinions on nuclear issues); from local citizen groups to international organizations such as UNESCO; from government institutions and individual governments to the European Commission and the European Parliament.

WISE-Paris is independent. What does independent mean? The term "independent expert" has often been called into question. Essentially, the point is very clear and is not actually controversial. An independent expert or scientist is a specialist in a particular field who is—as far as possible—free of conflicts of interest for a specific task. In other words, the outcome of a specific expert exercise cannot have an impact on his or her professional career or private situation.

Of course, there are levels of independence beyond that. But the basic definition is clear. The "controversy" over the definition basically aims to denigrate the role of the independent expert rather than to serve the advancement of pluralistic approaches toward scientific and technical issues.

At any point in time, through what amounts to bribery, one can transform an independent scientist or expert into one who is no longer independent. I have undertaken many expert missions in the nuclear field, but the only times I have been offered money directly were in two cases where I have been in charge of expert studies on chemical projects. In those two cases, I was directly offered money if the outcome of the "counter expert's" studies of the two industrial projects matched the expectations of the industries involved.

More fundamental than lengthy debates about definitions of "independence" is the question of what qualities or qualifications an independent scientist or counter expert needs. First, there is a matter of values and, second, the question of working methods.

The citizen science concept, as such, was developed in the US in the early 1970s and came out of Ralph Nader's approach, in the legal arena, to what he called "public interest law." A number of physicists around Princeton University—Frank von Hippel in particular—developed this approach into "public interest science"—the term that was given to citizen science at the time. In 1974, von Hippel and Joel Primack published a book entitled "Advice and Dissent: Scientists in the Political Arena"[1] in which the term "citizen science" was used, probably for the first time.

In late 2000, on the basis of the last will of Japanese nuclear scientist Jinzaburo Takagi, a Japanese foundation was started—the Takagi Fund for Citizen Science. The life of Jinzaburo Takagi provides an outstanding example of someone who came from the industry and turned toward independent expertise and independent science. He was a superb nuclear chemist, was a young associate university professor, and had a quite clear-cut career in the nuclear industry, which he quit in the early 1970s to create the Citizens' Nuclear Information Center (CNIC) in Tokyo.

As a board member of the Takagi Fund, I was asked to define what Citizen Science could mean today and I offered the following definition:

> "Citizen science can be defined as the participatory and combined effort in research, analysis, and public education that strictly follows the guiding principle of striving

1. Frank von Hippel and Joel Primack, "Advice and Dissent: Scientists in the Political Arena", Basic Books, New York, 1974

> towards collective well being of present and future generations of human beings all over the planet and the biosphere. The citizen scientist, through particular skills in independent research and analysis, shall assist to protect society from industrial, economic, and social development patterns that are placing State or corporate interest above collective sustainable benefit. The Citizen Scientist is the counter-expert par excellence."

Part of the key orientation is to be sufficiently outside, sufficiently independent of state or corporate interest, to be able to actually do analysis on behalf of the collective interest. The Takagi Fund issues grants to support young scientists in research that is independent and is meant to remain independent from government funding or from industry. For example, a student from the Graduate School of Asia-Pacific Studies, SEDAN University, has received a grant to carry out a survey of atomic-bomb victims on the Ailuk Atoll in the Marshall Islands. The grants cover not only nuclear issues, but also other energy, environmental, and social issues. One project by an individual researcher, for example, aims to analyze and evaluate the present situation of material flows and recycling systems in Japan.

Study and training encouragement is also given to individuals aiming to engage in citizen science, because one of the key aims of the Takagi Fund is to support the development, training, and growth of a network of independent scientists. For that reason, training of young Japanese scientists in other countries will be supported. In the first round of grants one project is situated in Denmark, one in China, one in Germany. The German project, for example, is an investigation into Germany's policy for phasing out nuclear power. This research could bring some interesting results of the controversial readings of Germany's phase-out policy to Japan. Some grants will be given for surveys and research, meetings, and communication of research results by organizations. There is, for example, a survey of the effects on the environment of US military bases in Okinawa and a critical study of the geological disposal concept for high-level radioactive waste. The latter is a research association of various groups including the Tokyo-based CNIC.

These grants given by the Takagi Fund for Citizen Science are small compared with grants by many US foundations. This is an entirely new approach in Japan, where there are very few foundations that support such work. Takagi Fund programs total about 75,000 euros (10 million Yen) per year; individual projects range between 1,700 and 17,000 euros.

To turn back to the conceptual side, the key message is very simple: the goal is to always place the collective before individual or corporate interest. One of the biggest problems for an independent consultant is, of course, to actually acquire information: if one is not inside the industry and not inside the government, one has to access information somehow.

The nuclear industry, especially, has championed using the term "transparency." Yet no industry is less transparent than the nuclear industry. It is fundamental to distinguish between communication and information. Clear rules for access to information, on a legal basis such as that provided by the Freedom of Information Act in the US, are needed. While not perfect, this approach could be kept in mind for many other countries.

We need to develop an analysis capacity. If one has access to information but has no analysis capacity, one will not go very far with big piles of documents. We need to develop a mechanism that guarantees that independent or counter expertise can have an influence on the decision making process. A lot of expert studies, a lot of reports, and a lot of analyses are being done that never have real influence. It is important to think the whole process through to the end and not consider only one piece of the mechanism.

A few words on working methods: the objective of collective sustainable benefit requires more ambitious methodology than individual, corporate, or even state-benefit approaches. Citizen science needs to be international, it needs to be systemic, and it needs to be dynamic. An analysis that provides only a still photograph of a given situation is not sufficient; worse, it is often misleading. What we need is to look at the entire film, to identify tendencies and developments. That is a key challenge.

On the educational side, it is clear that currently no specific academic curriculum leads to becoming a citizen scientist. We have to look at whether this should be developed as a particular approach.

Independent expertise is still often considered as being a kind of volunteer work, done by a kind of evening scientist or a weekend expert. Independent expertise and citizen science will be entirely professional, will be on a very high level, will always be—or attempt to be—better than corporate or state-expertise, or it will not be at all.

Rethinking Nuclear Energy and Democracy after September 11, 2001

Mitsuhei Murata

In January 1997, when I was the Ambassador of Japan to Switzerland, I sent a personal message to Japanese leaders, pleading that they organize a simulation of a nuclear accident, as had been done in Switzerland a few months earlier. In doing so, I broke a sort of taboo, because in Japan there is a peculiar atmosphere that makes you think that referring to nuclear dangers in a way that insinuates an anti-nuclear attitude is to be avoided in order not to invite serious trouble and disadvantages. Two months later, a reprocessing plant in Tokai-mura exploded. A year and a half after that, at the JCO uranium processing plant in the same village, a single milligram of uranium-235 reached critical mass due to improper handling and a serious accident took place.

Since my retirement two and a half years ago, I have been arguing in Japan and abroad for the denuclearization of the globe: a total ban on the use—be it military or civilian—of nuclear energy.

When I presented this argument at the Silver Jubilee Conference of the Tata Energy Research Institute in India two years ago, former US Secretary of Defense Robert McNamara, who was present at the Conference, ardently appealed for the earliest possible total ban on nuclear arms, stressing the high risk of human errors leading to catastrophic accidents. The September 11, 2001 terrorist attacks, the accident caused by a US nuclear submarine sinking a Japanese training ship in the Pacific Ocean, and the collision between a Chinese and an American warplane over the Taiwan Straits, all seem to justify these arguments. The legislature of the State of New York unanimously decided, on March 19, 2002, to start examining the possibility of closing down the Indian Point nuclear plant.

Japan has not learned the right lessons from the many serious accidents that have occurred, and continues to promoting nuclear energy as a matter of policy. That Japan, the only victim of atomic bombs, is doing this is a great irony. With 53 nuclear plants, Japan has become extremely vulnerable from the viewpoint of national security.

In a recent book entitled “A Plea for a New Civilization—Dedicated to Future Generations,” I pointed out that Japan, the victim of the military use of nuclear energy, is treading a path toward becoming the victim of the civilian use of nuclear energy. I first used the term “the sickness of Japan” in this book to explain this peculiar phenomenon. I pleaded for a new civilization, based on ethics and solidarity, that respects the environment and the interests of future generations. Such a new civilization calls for a conversion from material to more spiritual priorities, and brings about a less energy-consuming society.

In my second book from the ASAHI newspaper, the title of which is “Nuclear Energy and the Sickness of Japan,” I point out that this sickness is the outcome of a lack of three senses: the sense of responsibility, the sense of justice, and the sense of ethics. The world is also suffering from this sickness, if to a lesser degree. I attribute all this to a lack of sensibility that is the source of compassion and imagination.

I further ague that nuclear energy and the sickness of Japan could destroy the world and I cite, in particular, two cases. The first concerns four nuclear plants in Hamaoka, built at the very center of an area where a magnitude 8 class earthquake is predicted. The second concerns the reprocessing plant in Rokkashomura, in the Aomori prefecture, where radioactive waste materials equivalent to one million Hiroshima atomic bombs are to be accumulated.

Should the worst happen, the damages could by far surpass those suffered in the last war. Nevertheless, Japanese society totally lacks awareness of this horrible danger due to a self-restraint tacitly imposed on reporting the subject. This reminds us of the atmosphere that existed in Japan prior to the last war. In this book, I call for the immediate closing down of the Hamaoka nuclear reactors.

The nuclear policy of Japan helped society cope for some time with the shortage of energy resources. But after witnessing the fatal pitfalls of giant technology, more and more people recognize the necessity for change. Japan, however, still faces unimaginable difficulties in changing the course of its nuclear policy. Doing so will require the involvement of civil society. The best approach, under present circumstances, is to have civil society groups influence local autonomies so that these may in turn move the national parliament. The government cannot but be influenced by these moves.

Civil society plays a vital role in the decision making process regarding nuclear policy. This reflects a dawning shift of importance as regards the determining factors of human society: from intelligence to sensibility, from power to philosophy, from technology to intuition, and from experts to citizens. A sensible citizen endowed with good intuition and a sense of philosophy could defy the experts and declare that it is totally impossible to assure, over time, the safety of a reprocessing plant with 1,500 km of pipes and more than 400,000 welded joints.

The international community has three important tasks:

- A basic fact about nuclear energy must be wiudely disseminated: when the price paid by the consumer takes into account all the costs needed to assure safety, the civilian use of nuclear energy cannot be commercially viable. There is no reason to take such serious risks by depending upon it. Exporting nuclear plants should be out of the question.
- Controls over the safety of existing nuclear plants must be strengthened. Sovereignty can no longer serve as a pretext for rejecting interventions by other countries, since a fatal accident in one country could have terrible consequences for many others.
- There must be dialogue among civilizations. The problem of nuclear policy must be tackled with a view to changing our lifestyles so that we consume less energy. This can best be done within the framework of the dialogue among civilizations. Because of the grave consequences nuclear accidents could bring about, countries that do not possess nuclear installations should be involved and consulted concerning the measures to be taken by those that do.

The problem of nuclear energy boils down to the question of ethics and responsibility. Is it ethical to export nuclear installations to other countries, fully aware that they are dangerous and not commercially viable? Is it ethical for decision makers to import such installations, fully aware of the dangers and the costs?

Is it not a lack of the sense of responsibility to allow the continued functioning of more than 430 nuclear reactors in 36 countries without knowing how to dispose of waste materials or how to suppress an eventual accident that requires the mobilization of hundreds of thousands of people?

To do nothing to eliminate the obvious seeds of such catastrophes reflects a sheer lack of the sense of justice. We are faced with two choices. The first is to start the denuclearization of the globe as a preventive measure. The second is to be eventually forced to do so by a catastrophic disaster.

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