THE CASE AGAINST NUCLEAR POWER

GORDON TAYLOR
2011-06-06

SUMMARY

The critical issue for nuclear power is the consequences of a major radioactive release. These were predicted in the Sandia CRAC-2 study as 42,000 to 100,000 early deaths. They were confirmed empirically by Chernobyl, which contaminated huge areas of the Ukraine, Belarus and Russia as well as 40% of Europe, with an eventual death toll put variously at 10,000 up to 1.8 million. Due to the high population density, Fukushima has been predicted to cause up to 210,000 excess cancer deaths. The probability of any size of radioactive release is not just unknown but unknowable, so must be taken as 1 - i.e. inevitable. This was understood by the worldwide insurance industry from the start and by some involved in the Reactor Safety Studies as well as by independent analysts. If insurance was fully paid, the cost of nuclear power would increase by e.g. 45 to 348 p/kWh. Other countries are adopting safer, sustainable and infinitely cheaper solutions for supplying electrical and other energy services so there is no need to add to our already huge nuclear risks and debts. Moreover the consequences of a major radioactive release are completely unacceptable, so all existing nuclear plants should be phased out forthwith.

1. THE CONSEQUENCES OF RADIOACTIVE RELEASES

1.1 ASSUMED RELEASES, ESTIMATED CONSEQUENCES

1.1.1 Two early U.S. Reactor Safety Studies were WASH-740 of 1957 and WASH-1250 of 1965 (published in 1973). These looked at the consequences of a major radioactive release from a single nuclear power plant - the 'maximum credible accident'. They showed that it could kill thousands of people and render large areas uninhabitable.

The best-known Reactor Safety Study is known variously as 'The Rasmussen Report', NUREG-75/014 and WASH-1400, of 1975.[1] By the time this was carried out, 100 nuclear power plants – of differing designs and higher outputs - had been built in the USA.

The consequences of major nuclear releases were estimated in each of the above U. S. Reactor Safety Studies. [2] [3]

1.1.2 In the Swedish Reactor Safety Study of 1978, the best estimate of the long term fatalities is about 200,000 while the average contaminated area is 10,000 to 100,000 km2. [4] [5] For comparison, the area of Belarus contaminated by Chernobyl was 144,000 km2 and the area of the UK is 244,000 km2.

1.1.3 In the German Reactor Safety Study, Phase A, of 1979, the maximum early fatalities were 14,500 and the maximum late fatalities about 100,000. [6]

Table 1

Major Accident Consequence Estimates			
Source	**Consequence**		
	Fatalities	**Injured**	**Property Damage**
U.S. R.S.S. WASH-740	3,400	43,000	$ 7 billion
U.S. R.S.S. WASH-740 Update	45,000	70,000	Not available
U.S. R.S.S. WASH-1400	3,300 Prompt	45,000	$ 14 billion
	45,000 Long Term	248,000	Not available
Swedish Reactor Safety Study	200,000 Long Term		
German Reactor Safety Study	14,500 Early, 100,000 Late		

The consequences found in the Swedish and German studies are higher than those of the US studies. This is due to the higher population densities in Europe and the use of the Linear No Threshold risk model, as recommended by the ICRP. [7]

1.1.4 Sandia National Laboratory, under contract to the Nuclear Regulatory Commission, carried out the calculation of reactor accident consequences soon after the nuclear 'accident' at Three Mile Island Unit 2 in 1979. The Calculation of Reactor Accident Consequences (CRAC-2) report was published by Congress November 1, 1982. It was also printed by the Washington Post the same day. Other major media, including the New York Times published it shortly thereafter. [8]

1.1.5 The CRAC-2 report was released 19 years later, in 2001 and very reluctantly, to Greenpeace USA. They published it, in part, as 'Risky Business: The Probability and Consequences of a Nuclear Accident' [9] [10] The figures are based on a core melt down accident in which the reactor containment is breached directly to the atmosphere and all installed safety mechanisms fail. Here is an extract:

EXPLANATION OF CONSEQUENCES IN CRAC-2

In the data released by the House Subcommittee on Oversight and Investigation, the consequences of severe nuclear accident are broken down into four categories:

1. *Peak Early Fatalities*
2. *Peak Early Injuries*
3. *Peak Cancer Deaths*
4. *Scaled Costs*

"Peak" refers to the highest calculated values from the CRAC-2 computer printouts for the Sandia study. However, peak does not mean the worst case scenario. This is due to the uncertainties in the meteorological modeling that have been acknowledged by the authors of the Sandia report. The CRAC-2 model only considered one year's worth of data and does not model for precipitation beyond a thirty-mile radius from the reactor. According to the documents released by the Subcommittee, "(t)his is significant for peak consequences since the highest consequences from accidents are predicted to occur when a radioactive plume encounters rain over a relatively densely populated area."

Peak Early Fatalities

Early Fatalities are deaths that result from radiation exposure occurring within the first year.

Table 2

Peak Early Fatalities				
	Reactor	**Owner**	**Location**	**Fatalities**
1	Salem 1 & 2	PSEG Nuclear	18 miles S of Wilmington, DE	100,000
2	Waterford 3	Entergy	21 miles W of New Orleans, LA	96,000
3	Limerick 1 & 2	Exelon	21 miles NW of Philadelphia, PA	74,000
4	Peach Bottom 2 & 3	Exelon	18 miles S of Lancaster, PA	72,000
5	Susquehanna 1 & 2	PP&L	7 miles NE of Berwick, PA	67,000
6	Indian Point 2 & 3	Entergy	24 miles N of New York, NY	50,000/46,000
7	Catawba 1 & 2	Duke Power	6 miles NNW of Rock Hill, NC	42,000
8	Three Mile Island 1	AmerGen	10 miles SE of Harrisburg, PA	42,000
9	Dresden 2 & 3	Exelon	9 miles E of Morris , IL	42,000
10	Surry 1 & 2	Dominion	17 miles NW of Newport News, VA	31,000
11	Turkey Point 3 & 4	Florida P&L	25 miles S of Miami, FL	29,000
12	Sequoyah 1 & 2	TVA	10 miles NE of Chattanooga, TN	29,000

1.2 ACTUAL RELEASES, ESTIMATED CONSEQUENCES

Evidence on the health effects of a nuclear release arose following that from Chernobyl in 1986.

1.2.1 An early estimate of the consequences of Chernobyl was published by John Gofman in 1994. [11] Here is an extract:

> *My estimate in 1986, based upon releases of various non-iodine radionuclides, was 475,000 fatal cancers plus about an equal number of additional non-fatal cases, occurring over time both inside and outside the ex-Soviet Union.*

1.2.2 The amount of radionuclides released at Chernobyl was given in 'Chernobyl at Ten: Half-lives and Half-Truths', by John M. LaForge, 1997. [12] [13] According to the latter, the Argonne National Lab put it as 30% of the total – 3 billion of an estimated 9 billion Curies. Lawrence Livermore National Lab put it at one-half, Vladimir Chernousenko, the chief scientific supervisor of the 'clean-up' team, put it at 80%, while Joseph Hendrie, former Chair of the U.S. Nuclear Regulatory Commission said 'They have dumped the full inventory of volatile fission products from a large power reactor into the environment. You can't do any worse than that.'

1.2.3 A report 'Nuclear Reactor Hazards' was published by Greenpeace International in 2005. [14] Here is an extract:

The main conclusions are:

- *All operational reactors have very serious inherent safety flaws which cannot be eliminated by safety upgrading;*
- *A major accident in a light-water reactor – the large majority of the reactors – can lead to radioactive releases equivalent to several times the release at Chernobyl and about 1000 times that released by a fission weapon. Relocation of the population can become necessary for large areas (up to 100,000 km2). The number of cancer deaths could exceed 1 million;*
- *New reactor lines are envisaged which are heralded as fundamentally safe. However, apart from having their own specific safety problems, those new reactors would require enormous sums for their development, with uncertain outcome;*
- *The average age of the world's reactors is 21 years and many countries are planning to extend the lifetime of their reactors beyond the original design lifetime. This leads to the degradation of critical components and the increase of severe incidents. The age-related degradation mechanisms are not well understood and difficult to predict;*
- *De-regulation (liberalisation) of electricity markets has pushed nuclear utilities to decrease safety-related investments and limit staff. Utilities are also upgrading their reactors by increasing reactor pressure and operational temperature and the burn-up of the fuel. This accelerates ageing and decreases safety margins. Nuclear regulators are not always able to fully cope with this new regime;*
- *Highly radioactive spent fuel mostly is stored employing active cooling. If this fails, this could lead to a major release of radioactivity, far more important than the 1986 Chernobyl accident;*
- *Reactors cannot be sufficiently protected against a terrorist threat. There are several scenario's – aside from a crash of an airliner on the reactor building – which could lead to a major accident;*
- *Climate change impacts, such as flooding, sea level rises and extreme droughts, seriously increase nuclear risks.*

Unfortunately several of the above have been proved true at Fukushima.

1.2.4 The US National Academies published 'Health Risks from Exposure to Low Levels of Ionizing Radiation', BEIR VII, 2005. The key point is their acceptance of the Linear No Threshold (LNT) risk model. [15] This assumes that every radioactive release causes a proportionate increase in risk and hence consequences in human death and injury.

1.2.5 The IAEA, WHO, and UNSCEAR originated separate reports on Chernobyl, but they came together in the 'Chernobyl Forum', which issued it's own report in 2005. [16] This found that there had been 28 deaths from acute radiation and predicted 4000 additional deaths from cancer.

1.2.6 The Chernobyl Catastrophe: Consequences on Human Health', by Yablokov, A. et al, 2006, was published by Greenpeace. [17]

Here is an extract from the Executive Summary:

The range of estimates of excess mortality resulting from the Chernobyl accident spans an extremely wide range depending upon precisely what is taken into account. The most recent epidemiological evidence, published under the auspices of the Russian Academy of Sciences, suggests that the scale of the problems could be very much greater than predicted by studies published to date. For example, the 2005 IAEA report predicted that 4000 additional deaths would results from the Chernobyl accident. The most recently published figures indicate that in Belarus, Russia and the Ukraine alone the accident resulted in an estimated 200,000 additional deaths between 1990 and 2004.

1.2.7 'The Other Report on Chernobyl (Torch)', by Fairlie, I. and Sumner, D. was also published in 2006. [18] This independent scientific evaluation of the health and environmental effects 20 years afterwards was commissioned by Rebecca Harms, MEP. Here are some extracts from the Executive Summary and Conclusions:

The World Health Organisation (WHO) has estimated that the total radioactivity from Chernobyl was 200 times that of the combined releases from the atomic bombs dropped on Hiroshima and Nagasaki.

The authors have reassessed the percentages of the initial reactor inventories of caesium-137 and iodine-131 which were released to the environment. They conclude that official figures underestimate the amounts released by 15% (iodine-131) and 30% (caesium-137)'.

Extensive surveying of Chernobyl's caesium-137 contamination was carried out in the 1990s under the auspices of the European Commission. The largest concentrations of volatile nuclides and fuel particles occurred in Belarus, Russia and Ukraine. But more than half of the total quantity of Chernobyl's volatile inventory was deposited outside these countries.

Russia, Belarus and Ukraine received the highest amounts of fallout while former Yugoslavia, Finland, Sweden, Bulgaria, Norway, Rumania, Germany, Austria and Poland each received more than one petabecquerel (10^15 Bq or one million billion becquerels) of caesium-137, a very large amount of radioactivity.

In area terms, about 3,900,000 km2 of Europe was contaminated by caesium-137 (above 4,000 Bq/m2) which is 40% of the surface area of Europe. Curiously, this latter figure does not appear to have been published and, certainly has never reached the public's consciousness in Europe. Also 218,000 km2 or about 2.3% of Europe's surface area was contaminated to higher levels (greater than 40,000 Bq/m2 Cs-1379). This is the area cited by IAEA/WHO and UNSCEAR, which shows that they have been remarkably selective in their reporting.

In terms of their surface areas, Belarus (22% of its land area) and Austria (13%) were most affected by higher levels of contamination. Other countries were seriously affected; for example, more than 5% of Ukraine, Finland and Sweden were contaminated to high levels (> 40,000 Bq/m2 caesium-137). More than 80% of Moldova, the European part of Turkey, Slovenia, Switzerland, Austria and the Slovak Republic were contaminated to lower levels (> 4,000 Bq/m2 caesium-137). And 44% of Germany and 34% of the UK were similarly affected.

The IAEA/WHO reports do not mention these comprehensive datasets on European contamination by the European Commission. No explanation is given for this omission. Moreover, the IAEA/WHO reports do not discuss deposition and radiation doses in any country apart from Belarus, Ukraine and Russia. Although heavy depositions certainly occurred there, the omission of any examination of Chernobyl fallout in the rest of Europe and the northern hemisphere is questionable.

The IAEA/WHO reports estimate the collective dose to Belarus, Ukraine and Russia is 55,000 person sieverts, which is the lower end of a range of evaluations reaching over 300,000 person sieverts. The IAEA/WHO restrict their time estimate to 2006, and fail to present estimates for European and worldwide collective doses: these are significant limitations.

The most credible published estimate for the total worldwide collective dose from Chernobyl fallout is 600,000 person sieverts making Chernobyl the worst nuclear accident by a considerable margin. Of this total collective dose, approximately:

- *36% is to the populations of Belarus, Ukraine and Russia*
- *53% is to the population of the rest of Europe*
- *11% is to the population of the rest of the world'.*

The IAEA, in its 5 September 2005 press release "Chernobyl: The True Scale of the Accident" stated that up to 4,000 people could eventually die of radiation exposure from Chernobyl. This figure has been quoted extensively by the world media. However the statement is misleading, as the figure calculated in the IAEA/WHO report is actually 9,000 fatalities.

Depending on the risk factor used (ie the risk of fatal cancer per person sievert), Fairlie and Sumner, in the TORCH Report, estimate that the worldwide collective dose of 600,000 person sieverts will result in 30,000 to 60,000 excess cancer deaths, 7 to 15 times the figure release in the IAEA's press statement.

1.2.8 Another estimate of the deaths from Chernobyl was made in 'Bertell, R. (2006). [19] Here is an extract:

Using conservative methodology based on the external radiation risk factors deduced from the Japanese A-Bomb studies, I would estimate that the eventual death toll from the Chernobyl disaster would be: 290 due to direct radiation damage, 899,310 to 1,786,657 due to fatal cancers, 899,600 to 1,787,000 in total.

1.2.9 A report on the consequences of Chernobyl was produced by Alexey Yablokov and others and published by the New York Academy of Sciences in December 2009. This was based on about 1000 titles from more than 30,000. [20] Here is an extract:

Thus the overall mortality for the period from April 1986 to the end of 2004 from the Chernobyl catastrophe was estimated at 985,000 additional deaths. This estimate of the number of additional deaths is similar to those of Gofman (1994) and Bertell (2006).

1.2.10 John Large and Associates wrote a report for Greenpeace on the Flamanville EPR/PWR in 2007. This highlighted the adverse effects of increased burn-up and of including partial and 100% MOX - including recycled plutonium - as nuclear fuel. [21] Here is an extract:

> *These greatly increase the Consequences of any radioactive release. A serious release could require the evacuation of hundreds of thousands of people, would involve the serious contamination of many thousands of square kilometers and may produce thousands of human fatalities.*

This is especially relevant since this EPR/PWR is what EdF has suggested that it might build in the UK.

1.2.11 'Health risks of nuclear power', by Jan Willem Storm van Leeuwen, November 2010. [22] This is a very thorough report and in particular considers the additional risks from spent fuel. Here are a selection of points from the Summary:

> *The only way to prevent disastrous exposure of the public to human-made radioactivity on unprecedented scale is to immobilize the radioactive waste physically and to isolate it from the biosphere in deep geologic repositories, lasting at least a million of years. To deal with the global radioactive waste at the current rate of generation about every year a new large deep geological repository has to be opened, at an estimated cost of at least Euros 10bn each. To dispose of the existing radioactive wastes from the past, dozens of deep geologic repositories would be required.*

> *Even after a cooling period of a 100 years the specific radioactivity of spent fuel is still at such a high level that about 1 milligram of it ingested or inhaled would mean a lethal dose to a human.*

> *The probabilistic safety analyses done by the nuclear industry cover only a small part of the existing nuclear installations worldwide which have the potential of large-scale accidents.*
>
> *Not all events and factors potentially leading to a severe nuclear accident can be analysed or quantified in a PRA. Two unavoidable and unpredictable factors are:*
>
> - *degradation of materials and constructions (consequences of the Second Law [of Thermodynamics])*
> - *human behaviour and economic pressure.*

> *The nuclear industry has a habit of 'Après nous le déluge' by postponing indefinitively the actions required to deal adequately with the human-made radioactivity. The assertion of the World Nuclear Association, representing the Western nuclear industy, that all safety matters are fully under control is in flagrant contradiction to the practice.*
>
> *[This was written before Fukushima].*

> *Nuclear power is building up immense energy debts by postponing the immobilization and isolation of the radioactive waste from the biosphere, which is the only way to prevent large-scale accidents affecting vast regions. A physical analysis of the activities required to finish the overdue cleanup of the nuclear heritage points to the consumption of massive amounts of energy, materials and human resources and consequently to unprecedented economic efforts. The energy debt has a physical basis that will grow with time instead of depreciating with time; the energy debt cannot be discounted nor written off like common monetary debts. The financial consequences of the nuclear debts in countries like France and the UK are estimated to rise to hundreds of billions of euros, several times the final cost of the entire US Apollo moon project.*
>
> *We may ask ourselves if the future generations will be able to solve the problem we could not. Would the future generations have to their disposal sufficient energy, materials, human resources and economic `ability to cope' to make their living environment as safe as we and they would wish?*
>
> *Liability of the nuclear industry is passed on to the taxpayer. Delayed expenses, for example definitive waste storage and dismantling of nuclear power stations, are systematically passed on to the taxpayer: privatising the profits, socialising the costs.*

1.2.12 Worldwatch reported that, as of April 1, 2011, there were 437 nuclear reactors operating in the world and their average age is 26 years. [23]

1.2.13 The use of MOX fuel has been proposed recently by Sir David King. [24] He overlooks the hugely increased dangers of such a 'plutonium economy' during reprocessing, use and long-term storage, together with the inevitable 'accidental' releases. Due to the depletion of uranium fuel, increased burnup and the use of MOX – containing recycled plutonium - is increasing the lethality of the fuel and hence the 'source term' of any radioactive release. He also fails to mention that the THORP reprocessing plant cost £ 2.3 billion and the MOX Demonstration Facility £ 470 million. Yet they have given rise to a major accident – rated 3 on the INES scale – with the potential to kill hundreds of thousands and the 'MOX Falsification Scandal', that cost £ 133 million in compensation payments to the Japanese customer. [25] While neither plant has ever worked properly, they have increased the volume of nuclear wastes and given rise to radioactive discharges into the Irish Sea, which have even reached the Baltic. [26]

1.2.14 A significant new report 'Health Effects of Chernobyl – 25 Years After The Reactor Catastrophe' has just been published by the German Affiliate of International Physicians for the Prevention of Nuclear War and the Gesellschaft für Strahlenschutz, both based in Berlin. [27] This looks at the human consequences of Chernobyl in terms not only of deaths but also life-shortening injuries, birth defects and the genetic inheritance. Here are some extracts from the Executive Summary:

> *9. Genetic and teratogenic damage (malformations) have also risen significantly not only in the three directly affected countries but also in many European countries. In Bavaria alone, between 1000 and 3000 additional birth deformities have been found since Chernobyl. We fear that in Europe more than 10,000 severe abnormalities could have been radiation induced. The estimated figure of unreported cases is high, given that even the IAEA came to the conclusion that there were between 100,000 and 200,000 abortions in Western Europe because of the Chernobyl catastrophe.*
>
> *10. According to UNSCEAR between 12,000 and 83,000 children were born with congenital deformations in the region of Chernobyl, and around 30,000 to 207,000 genetically damaged children worldwide. Only 10% of the overall expected damage can be seen in the first generation'.*

> *18. A paper published by the Chernobyl Ministry in Ukraine registered a multiplication of the cases of disease of the endocrine system (25-fold from 1987 to 1992), the nervous system (6-fold), the circulatory system (44-fold), the digestive organs (60-fold), the cutaneous and subcutaneous tissue (50 times higher), the muscular-skeletal system and psychological dysfunctions (53-fold). The number of healthy people among evacuees sank from 1987 to 1996 from 59 % to 18%. Among the population of the contaminated areas from 52% to 21% and –particularly dramatic - among the children who were not directly affected themselves by Chernobyl fallout but their parents were exposed to high levels of radiation, the numbers of healthy children sank from 81% to 30% in 1996.*

> *Conclusion*
>
> *Even though the lack of large-scale independent long-term studies does not permit a complete picture to be made of the current situation, a number of trends can be shown: a high mortality rate and an almost 100 % morbidity rate can be observed among people, such as liquidators, who were exposed to high radiation levels. 25 years after the reactor catastrophe cancer and other diseases have emerged on a scale that, owing to the long latency period, might have appeared inconceivable immediately following the catastrophe.*
>
> *The number of non-cancerous diseases is far more dramatic than had ever before been imagined. "New" symptoms, such as the premature aging of liquidators, raise questions that research is still unable to answer.*
>
> *By 2050 thousands more cases of illnesses will be diagnosed that will have been caused by the Chernobyl nuclear catastrophe. The delay between cause and noticeable physical reaction is insidious. Chernobyl is far from over.*
>
> *Particularly tragic is the fate of the thousands of children who were born dead or died in infancy, who were born with malformations and hereditary diseases, or who are forced to live with diseases they would not have developed under normal circumstances.*
>
> *The genetic defects caused by Chernobyl will continue to trouble the world for a long time to come – most of the effects will not become apparent until the second or third generation.*
>
> *Even if the extent of the health effects is not yet clear, it can still be predicted that the suffering brought about by the nuclear disaster in Fukushima is, and will be, of a similar magnitude.*

It finds that the data underlying the original WHO report was understated by factor five in the 'Chernobyl Forum' report. [28] Here is an extract:

> *The press release of the WHO and IAEA stated that in the future, at most, 4000 surplus fatalities due to cancer and leukaemia amongst the most severely affected groups of people might be expected. In the WHO report on which this was based however, the actual number of deaths is given as 8,930. These deaths were not mentioned in any newspaper articles. When one examines the source quoted in the WHO report, one arrives at a number between 10,000 and 25,000 additional fatalities due to cancer and leukaemia.*

Finally, it quotes the estimated consequences of the maximum radioactive release technically possible from a German nuclear power plant, such as that in Biblis.

> *Excursus: Consequences of a super-GAU in Germany*
>
> *Following Chernobyl scientists estimated the consequences of a super-GAU in Germany. The 7-10-fold higher population density was taken into consideration. A risk factor of 500 respective 1,000 cancer and leukaemia deaths per 10,000-person sievert was assumed. In alternative 1, the same radiation exposure as that following Chernobyl was assumed. In alternatives 2 and 3 – based on figures from the German Risk Study of nuclear power stations (phase B) – greater radiation exposure following a super-GAU was assumed (alternatives 2 and 3).*

For Alternative 1, the cancer deaths were 2.4 million, for Alternative 2, 12 million and for Alternative 3, 1.7 million.

1.2.15 Several of the predictions of global health consequences of the Chernobyl accident have been reviewed by Busby. He clarifies the effect of the methodology used, most notably the ICRP and ECRR models.[29] The principal difference is in the weighting of certain internal exposures due to air, water and food pollution. [30]

1.2.16 Following the earthquake and tsunami of 2011-03-11, radioactivity was released from the Fukushima Dai-ichi site, which has four nuclear power plants. A report 'The health outcome of the Fukushima catastrophe – Initial analysis from risk model of the European Committee on Radiation Risk ECRR', by Chris Busby, was published by Green Audit on 2011-03-30. For the 10 million people living within 200 km of Fukushima, the number of excess cancers is approximately 420,000 in the next 50 years.[31] At a mortality to incidence rate of 50%, the excess cancer deaths would be about 210,000 in the next 50 years. [32]

Table 3

Actual Radioactive Release, Predicted Consequences - Chernobyl			
Date	**Source**	**Model**	**Excess Deaths**
1994	Gofman	Gofman	475,000 worldwide
2005	IAEA, WHO	ICRP	4000, 9000 excess cancer deaths for FSU to 2006
2006	Fairlie and Sumner	ICRP	30,000 to 60,000 excess cancer deaths worldwide
2006	Bertell	Bertell	899,600 to 1,787,000 eventual
2009	Yablokov et al	Yablokov et al	985,000 to 2004
2011	IPPNW-GfS	ICRP	10,000 to 25,000
2011	Busby	ECRR	740,000 to 1,480,000 cancer incidence in 50 y
2011	Busby	Tondell	2,450,000 cancer incidence in 50 y
Actual Radioactive Release, Predicted Consequences - Fukushima			
2011	Busby	ICRP	6158 excess cancers within 200 km
2011	Busby	ECRR	210,000 excess cancer deaths within 200 km

The consequences predicted with the ICRP model are already unacceptable and those with the other models even more so.

1.2.17 There is a quantitative difference in the risks posed by coal-fired and nuclear power plants. While both emit small amounts of radioactivity in normal operation, there is no high radionuclide release scenario for coal. However, the release from a nuclear power plant could be up to the full fuel charge, which is about 1000 times that of a nuclear bomb. Moreover, it could be several times that if it includes the contents of the spent fuel store. This last is all too likely because no nuclear power plant operator wants to face up to paying for long term storage elsewhere. The Japanese nuclear power plants have kept almost all the spent fuel in their storage pools for years and if they fill up, the reactor has to shut down. [33] At Fukushima the largest amount is in the storage pool of Reactor 4, so - although it was shut down - it still requires a lot of cooling. The UK is no better. It has the world's largest stock of civil plutonium, separated from spent fuel: 105 tons...of which 26.5 tons are foreign. [34] So the nuclear power industries have blackmailed the governments into passing the costs of re-processing and of storage – many billions of dollars - onto the electricity consumers and the taxpayers respectively.

2. THE PROBABILITY OF RADIOACTIVE RELEASES

2.1.1 The Probability of a major radioactive release must be taken as 1 - that is whatever could possibly happen, will happen sooner or later. This was understood from the beginning by the worldwide insurance industry, whose business depends on judging probabilities. It declared that it would never fully insure nuclear risks. [35] Here are extracts from one such statement:

> *The anticipated extent of loss from a nuclear accident was generally believed to justify a special liability regime. Such a regime would both ensure proper compensation for the public and foster the development of the nuclear power industry, which would otherwise be faced with an overwhelming burden.*
>
> *Accordingly, the operators' interests were secured by limiting their liability in time and amount, and the liability regime was introduced in the Paris Convention on Third Party Liability in the Field of Nuclear Energy [of 1960] and in the Vienna Convention on Liability for Nuclear Damage [of 1963].*

> *The first formal reactor risk assessment (WASH-740) was completed in the U.S. in 1957. It was produced partly to meet the requirements of the Price-Anderson Act of that year, which limited the liability of a utility in the event of an accident and which therefore required some assessment of possible damage sequences.*
>
> *The act came up for extension in 1965 and once again the Brookhaven National Laboratory was asked to provide a risk assessment. [The WASH-740 Update (WASH-1250) study of 1964-65]. This was a less optimistic analysis that neither the nuclear industry nor the Congressional Joint Committee on Atomic Energy (which favoured the industry) wished to be made public, so its publication was suppressed until some six or seven years later. But its ghost haunted the committee which faced another review in the mid seventies. So in 1972 the Atomic Energy Commission asked Norman Rasmussen, a professor of nuclear engineering at MIT, to conduct a thorough and quantitative analysis of the safety of light water reactors. The purpose of this study was to examine one typical pressurised water reactor (PWR) and one typical boiling water reactor (BWR) to determine the most significant sequences of events that could lead to an accident and to estimate both the probability and consequences of each sequence. The consequences were to include prompt fatalities, the induction of latent cancers, genetic damage, and property damage.* [36]

2.1.2 One of the directors of the WASH-740 Update (WASH-1250) study of 1964-65 noted:

> *There is no objective, quantitative means of assuring that all possible paths leading to catastrophe have been recognized and safeguarded or that safeguards will in every case function as intended when needed.* [37]

2.1.3 The WASH-1400 Reactor Safety Study of 1975 adopted the methodology that Risk = Consequences x Probability, where the Probability is estimated by 'Probabilistic Risk Assessment'. This requires tracing all possible chains of events leading to a fault – a given radioactive release - through a tree-structure representing the nuclear power plant – known as 'fault-tree analysis'. However, due to constraints in time and resources, the task was scaled down by looking only at certain pathways, known as 'event tree analysis'. Here is an extract from a history of WASH-1400:

> *In June 1976, the Committee on Interior and Insular Affairs of the US House of Representatives held hearings on the findings of the RSS. Chaired by Representative Morris Udall, the hearings found that RSS seemed to be misleading in the certainty and comprehensiveness of its conclusions. The committee also focused on the worst possible postulated accidents without taking into account the probabilities associated with them compared to less damaging accidents. Rep. Udall suggested that a new executive summary could be written that would solve these problems, and that an outside review panel be formed to take a closer look at how the study arrived at its conclusions. Marcus Rowden, the chairman of the NRC, disagreed that a re-written executive summary would be of much use, but did agree that an outside panel looking at the study would be of value. Commissioner Rowden asked Dr Harold Lewis of the University of California-Santa Barbara to chair the Risk Assessment Review Group. Dr Lewis had also chaired the American Physical Society review of the RSS in 1975.* [38]

2.1.4 The Risk Assessment Review Group produced their report – NUREG/CR-0400 – in September 1978. Among the Findings:

> *It is conceptually impossible to be complete in a mathematical sense in the construction of event-trees and fault-trees; what matters is the approach to completeness and the ability to demonstrate with reasonable assurance that only small contributions are omitted. This inherent limitation means that any calculation using this methodology is always subject to revision and to doubt as to its completeness.* [39]

Probably the most important criticism of the report was not about the report itself, but rather how the report was being used:

> *There have been instances in which WASH-1400 has been misused as a vehicle to judge the acceptability of reactor risks. In other cases it may have been used prematurely as an estimate of the absolute risk of reactor accidents without full realization of the wide band of uncertainties involved. Such use should be discouraged'.* [40] [41]

2.1.5 T.P. Speed – a statistician at CSIRO, Australia – criticised the Probabilistic Risk Analyses in two Reactor Safety Studies. He was reported thus:

> *Among more technical criticisms, Speed [1977] condemned the (WASH-1400) Reactor Safety Study on three elementary grounds:*
>
> *a. Individual probabilities ascribed to events were based upon little or no data and were sometimes purely subjective.*
> *b. There were unfounded assumptions of independence in chains of events which could cause gross underestimates of the probability.*
> *c. Fault tree analysis can only consider the chances of failure from an anticipated cause. It is possible that an unanticipated cause of failure may have a reasonably large probability of occurring.*
>
> *While the [Reactor Safety] study was in Draft form, there was an incident in which the Browns Ferry plant in Alabama was closed down due to a large electrical fire in the control room. The Draft had not even considered such contingencies and had to be modified to include a statement to this effect'.*[42]

2.1.6 In his critique of the Sizewell B Reactor Safety Study, T.P. Speed observed:

> *Is it possible that the members of the Study group identified all accident sequences which could contribute significantly to the risk ? The discussion in the RARG [Risk Assessment Review Group, of 1978 that reviewed WASH-1400] Section III is relevant here, although essentially leaving the question unanswered, but in a footnote we find the opinion:*
>
> *"One of us (F.v.H.) [Frank von Hippel] questions whether, for a system as complex as a nuclear power plant, the methodology can be implemented to give such a high level of confidence that the summed probability of many known and unknown accident sequences leading to an end point such as a core melt is well below the limit set by experience".*
>
> *Experience with actual reactor accidents (Browns Ferry, Three Mile Island) would seem to support this view and it appears to be shared by Critchley (1976, p 18):*
>
> *"No high-risk, major hazard, safety-assured plant like a nuclear reactor should be built unless it is so well designed, constructed and operated that disastrous failure cannot be foreseen in the anticipated circumstances of its existence; that is, such an event must be 'incredible'. Thus, the permitted net chance of occurrence of a catastrophic radiation accident arising from any cause must be vanishingly small. A risk so forecast cannot be true. The true hazard is given by the summation of the occurrence probabilities of all accident-producing causes which includes an almost infinite spectrum of unexpected, unusual or highly improbable though possible happenings or coincidences. At the present time, at least, the task of catching such a large number of rare, random and diverse things is Sisyphean. There is, thus, a severe limitation on the input data which vitiates any quantitative predictions, and such serious accidents as might occur will most likely be 'rogue' events which would not be identified in the quantifier's philosophy".* [43]

2.1.7 The Swedish Reactor Safety Study of 1978 noted:

> *In contrast to the WASH-1400 method, policy makers in evaluating risks where the potential consequences of a major accident are very large, as is true for a nuclear disaster, may make their decision on the acceptability of nuclear technology based primarily on the potential disaster size alone'.* [44]

2.1.8 The German Reactor Safety Study, Phase A, was published by the GRS in 1979. There is a short summary in English. [45] Page 2 mentions:

> *Since this [the identification of all initiating events that potentially could lead to radioactive release to the environment] cannot be done in a theoretically complete sense...'.*

2.1.9 Huge numbers of nuclear accidents have already occurred due to events that were not foreseen. Many are in 'The Greenpeace book of the nuclear age ; The hidden history - the human cost', by John May, Greenpeace Books, 1989. [46] More are in: [47] and [48] Yet more are given in the Wikipedia 'List of civilian nuclear accidents'. This lists 28 major civil nuclear radioactive releases - 17 with INES values from 2 to 7 - in only 60 years. [49]

2.1.10 Nuclear power plants are designed at a certain date using a Probabilistic Risk Assessment with certain assumptions. Then a 'new' failure pathway shows itself, which may be small or large – e.g. a magnitude '9' earthquake and a 15 m high tsunami, as at Fukushima. However, the 'new' failure pathway was always present – just not anticipated. Yet retrofit measures may be either very costly or even completely prohibitive.

Moreover failures could occur at any time. The nuclear emergency at Three Mile Island in 1979 occurred after only one year of operation. As shown by Chernobyl, anything up to the maximum possible release could occur at any time. Nassim Nicholas Taleb cites the Japanese Nuclear Commission, which set a goal for probability of 1 in a million years in 2003, yet failure occurred within only 8 years. [50] This too is because the failure pathway was always present. Even a probability of 1 in a million years does not mean that it won't happen tomorrow – or even today! He has also discussed events that have not happened yet – which he calls 'Black Swan' events - in his book 'Fooled by Randomness'. On page xiv, he writes:

> *logic does not require empirical verification*

and on page 4:

> *It does not matter how frequently something succeeds if failure is too costly to bear.*

Therefore the Probability of the various radioactive releases is always an underestimate, and by an amount that is not just unknown, but logically unknowable. Hence the Probability must be taken as 1 – i.e. inevitable - and the risk assessed only in terms of the Consequences, particularly the health effects - deaths, injuries and genetic.

Also consider what would happen if we started to build more nuclear power plants, and one or more of the 400-odd aging existing plants released yet more radioactivity – in yet another 'Black Swan' event. We would be left with not 'stranded assets' but many 'stranded liabilities'. There would also be a shortage of power.

3. ELECTRICITY AND GREENHOUSE GAS IMPLICATIONS

3.1.1 Mark Lynas claims that phasing out planned nuclear programmes in a number of countries could increase global warming from two to three degrees. [51] I have a high regard for his book 'Six Degrees', but here his premise is false. He can postulate that nuclear power plants would be replaced by coal or gas-fired power plants, but he has not shown them to be necessary. He suggests that nuclear power plants could avoid a ramp-up of 2 to 3 GtCO2/y by 2030. However, Meinshausen et al, 2009 say that for a 50% probability of exceeding global warming of 2 C, the cumulative emissions 2006-2050 require limiting to 1206 GtCO2. [52] But 24 x 2.5/2 + 20 x 2.5 = 80 GtCO2, which – compared with 1206 is only 6.6%, so the real problems – and hence the solutions - lie elsewhere.

3.1.2 Moreover, nuclear power is undermining far more effective measures for reducing greenhouse gas emissions. [53] Money and embedded energy can be invested only once, and as Amory Lovins from the US Rocky Mountain Institute calculates:

> *Each dollar invested in electric efficiency displaces nearly seven times as much carbon dioxide as a dollar invested in nuclear power, without any nasty side effects.* [54]

3.1.3 The 'Energy [R]evolution', a report on a global sustainable energy pathway up to 2050, was commissioned from the DLR Institute (German Aerospace Centre) by Greenpeace and the European Renewable Energy Council (EREC). This assumes that fossil fuels and nuclear power will be phased out and replaced by energy efficiency and renewables. [55] As the technology has evolved, the report has been updated for 2009 and 2010. [56] [57]

3.1.4 Most oil is used in transport, with lesser amounts for heating and petro-chemicals, and almost all gas is used for electricity and heating (though all too rarely in Combined Heat and Power plants). But what is all the electricity used for? Admittedly there are a huge variety of end-uses. However, it is the most expensive form of energy (before taxes) yet very easy to measure and record, so there is no excuse for not knowing where it all goes. Then for each end-use we could say much more about electrical efficiencies - the average, 'best practice' and the thermodynamic limit. For example, lighting - always mentioned as 'keeping the lights on' - probably accounts for about 20% of electricity. In the curious units used, the 'efficacy' of electric lighting in lumens/Watt is on average maybe 40 (between incandescent and CFL), 'best practice' maybe 100 (best linear fluorescent, best current LED) but the thermodynamic limit for white light is at least 330. (It is about twice this for monochromatic light).

> *Although the range in efficacy for commercial LEDs is currently 76 to 132 lm/W, research in a variety of areas, as outlined in this report, can raise the efficacy of LEDs to approximately 230 lm/W.* [58]

The US Department of Energy project that - for the same light output - the electricity used could be reduced by 25% by 2030. [59]

Clearly more detailed analyses of this type must be carried out for every electricity end-use.

3.1.5 As an illustration of what is possible, I installed a high efficiency central heating pump and thus reduced the electricity input to my gas-fired heating system from about 500 to about 100 kWh/y. I have also replaced every light bulb with a CFL and every CRT screen (3 x PCs and 1 x TV) with LCD screens. Overall, I have managed to cut my electricity use from about 3000 kWh/y in 2001 to about 2400 in 2010 - i.e. by 20%.

3.1.6 For Germany, Greenpeace has published a series of reports showing how the German energy system could evolve. Thus 'Der Plan: Deutschland ist Erneuerbar' shows how all electricity could come from renewable sources by 2050. [60] 'Der Atomaussteig bis 2015 ist machbar' shows how nuclear power could be phased out by 2015. [61] 'Berechnung von Ersatzkapazitäten für die Abschaltung der AKW' shows how all coal-fired power plants could be phased out by 2020. [62] 'Klimaschutz: Plan B 2050 – Energiekonzept für Deutschland' shows how greenhouse gas emissions – including from electricity production, transport and heat supply - could be reduced by 90% by 2050. [63]

3.1.7 In the UK, heat is about 50% of final energy, transport fuels about 30% and electricity only about 20%. Of this last, only about 20% comes from nuclear, so supplying only about 4% of the final energy and avoiding only about 6% of the CO2. Worldwide, nuclear supplies only about 2.5% of final energy and so avoids say 4% of CO2. Exactly what do the proponents of nuclear power propose to do about the other 96 to 97.5% of final energy? Before they say 'build 25 to 40 times as many nuclear power plants', they should consider the vast amounts of money and embedded energy that this would require. Those proposing more nuclear power plants almost always forget to take account of the energy embedded in the steel and concrete and the energy cost of producing the nuclear fuel. For an average global uranium ore grade of 0.15%, the specific lifecycle emissions for a uranium-fuelled nuclear power plant total around 135g CO2/kWh, compared with 385 for a gas-fired plant. [64] It has also been examined very fully by van Leeuven. [65] This shows that within the design lifetime of any new nuclear power plant started now, the carbon intensity of the electricity would probably exceed that from gas-fired power plants, so new nuclear would be self-defeating. Moreover in the same time period uranium mining would approach the 'point of futility', where the lifecycle energy expended exceeded that obtained from the power plant. Abbot has shown that – due to limits on the exotic metals used in construction and on the uranium fuel – nuclear power could not be scaled from the present 0.375 TW even to 1 TW. [66] Thus no option based on a depletable fuel can be sustainable, and only energy saving, energy efficiency and renewable energy supply options are sustainable.

3.1.8 I set out a complete and sustainable solution in the presentation '100% Energy From Wind', which I gave recently to an audience of engineers. [67] This is based on current technologies, and well within the abilities of developed countries, such as the UK. After reducing the demand for electricity, the rest can be supplied wholly, more reliably and entirely safely from renewables, notably wind turbines, with the existing gas-fired power plants being fuelled with Renewable Power Methane when the renewable electricity is insufficient. [68]

3.1.9 Audi – part of the VW Group, the largest car company in Europe – has just announced the closely related 'e-gas' project. [69] Green Car Congress reported it thus:

> *Audi has completed the research phase of the e-gas project and will take the second step in mid-2011: investing several tens of millions of euros in the construction of an industrial facility. Audi will kick off this large-scale energy project together with its project partners: SolarFuel GmbH from Stuttgart; the Centre for Solar Energy and Hydrogen Research (ZSW), also based in Stuttgart; the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Kassel, Germany; and EWE Energie AG.*
>
> *Wind turbines are the first significant component of the Audi e-gas project. During the project's first phase, four large power plants at an offshore wind park in the North Sea are being financed by Audi and a regional power-supply company. Rated at 3.6 MW each, these four turbines are to supply some 53 GWh of electricity annually.*

> *The project's second large component is the e-gas plant, which will produce hydrogen and methane on an industrial scale. Ground is scheduled to be broken in Werlte, Germany in July 2011. The e-gas plant is connected to a waste-biogas plant, which supplies the concentrated CO2 necessary for methanation and which would otherwise pollute the atmosphere. The plant will annually produce some 1,000 metric tons of e-gas while consuming 2,800 metric tons of CO2.* [70]

Both the gas-fired power plants and the RPM/e-gas plants co-generate heat which could be used for District Heating, so cutting the gas consumption for heating. Moreover in this energy solution, both gaseous and liquid fuels could be made using CO2 absorbed from the air. This could be scaled up and the CO2 sequestered to 'roll back' the atmospheric concentration.

To deliver such a solution, the power companies should become Energy Service Companies selling energy saving and energy efficiency measures as well as energy. This could be done by Ofgem granting franchises for access to the UK energy markets, conditional on contractually binding roadmaps for declining Greenhouse Gas emissions by dates. These would have to be agreed, but most of the power generating companies - including E.ON, RWE (npower), and EdF (British Energy) - have experience of running District Heating from large-scale Combined Heat and Power plants on the Continent. Thus they would be well aware of the potential savings. Additional evidence for such a solution is given in other documents linked to my home page. [71]

3.1.10 The Fraunhofer Institute for Wind Energy and Energy Storage (IWES) has recently shown that the potential for inland wind energy in Germany is electricity of 390 TWh/y. [72] This would be 65% of the present demand and almost three times that produced by nuclear power plants. The global wind potential, accessible to today's wind turbines, onshore and offshore, is about 840 PWh/y (840,000 TWh/y). [73] This is about ten times the world demand for all energy.

3.1.11 Here is some empirical evidence from Paul Gipe:

> *German wind energy generation, on the other hand, has been far more stable from one year to the next than Fukushima 1. Throughout the last two decades more and more wind generation has been added to the German electrical system. Today, German wind turbines generate as much electricity as the entire Fukushima 1 complex at its peak.* [74]

4. ELECTRICITY COSTS

4.1.1 The US Price Anderson Act limits the liability of all the nuclear plant operators together to a maximum - as of 2011 - of about $ 12 bn. [75] However, the Sandia CRAC-2 report gives values for property damage for a single nuclear power plant ranging from $ 122 to 314 bn (in 1980 $). [76] The latter is more than $ 560 billion in 2000 dollars. [77] The rest falls on the public purse - i.e. the taxpayers. It must have a value, otherwise the nuclear operators would not demand it. So it must be a subsidy. The value of the US government insurance subsidy has been put at $ 2.3 million per reactor-year [78] or $ 600,000 per reactor per year. [79]

The Paris and Vienna Conventions were prompted by the Price-Anderson Act of 1957 in the USA and followed by the Nuclear Installations Act of 1965 (plus later amendments) in the UK, saying that the risk would be carried by the State. Such 'Statutory Indemnities' are described by the UK Government as 'unquantifiable'. [80] This means 'unlimited', so must be taken as 'infinite'.

4.1.2 'Four Nuclear Myths', by Amory Lovins, 2009. [81] This opens with the following:

> *Public discussions of nuclear power, and a surprising number of articles in peer-reviewed journals, are increasingly based on four notions unfounded in fact or logic: that*
>
> 1. *variable renewable sources of electricity (windpower and photovoltaics) can provide little or no reliable electricity because they are not "baseload" -- able to run all the time;*
> 2. *those renewable sources require such enormous amounts of land, hundreds of times more than nuclear power does, that they're environmentally unacceptable;*
> 3. *all options, including nuclear power, are needed to combat climate change; and*
> 4. *nuclear power's economics matter little because governments must use it anyway to protect the climate.*

This work is very closely argued and has 108 references as evidence.

4.1.3 Greenpeace has published a table of state subventions for nuclear power in Germany. [82] They have amounted to about 165 billion euros for 1950 to 2008 and will amount to about 92 billion euros from 2009 onwards.

4.1.4 'Nuclear Power in a Post-Fukushima World', by Mycle Schneider et al, for Worldwatch Institute, 2011. [83] This shows that nuclear capacity is slowing and renewable capacity is rising fast – due to their comparative costs and speed of deployment.

4.1.5 'EdF's Financial Meltdown', by John Busby, February 2011. [84] This includes:

> *UK NEW BUILD*
>
> *An Infrastructure Planning Commission (IPC) and its successor is expected to approve the new nuclear build in principle, leaving only local issues to public inquiries. The coalition government has resolutely rejected any state subsidy for nuclear, but this is under challenge by the nuclear lobby. EdF has made the curious statement that it needs no subsidy, but would be content with a "guaranteed", "robust" or "floor" price for carbon.*
>
> *The working of a "floor" price in auctions of carbon allowances under the EU Emissions Trading System is obscure. Trading consists of matching buyers and sellers between members of one of Europe's climate exchanges. Presumably if the "floor" price failed to find a buyer, there would be "no sale" and the allowances would have to be offered at another exchange.*
>
> *However, the introduction of a "floor" price for carbon will simply add to the new build costs, before any enhanced revenue from raised market prices can be earned. Its advocacy is nonsensical. Every component in a new build will be more expensive as it will be made with the benefit of fossil fuels, making a capital intensive pursuit more intensive. RWE has already stated that a high carbon price will not suffice in order to fund its new build.*
>
> *DECC has announced a "market reform" consisting of a further three "incentives" for the UK new build. There are to be "feed-in-tariffs" (FiTs) for nuclear generation and "capacity" grants for the provision of low carbon generation at peak times. Emission standards will be applied to nuclear's fossil fuel competitors. It is admitted that the costs of the FiTs and capacity grants will accrue to the consumer, while the exaction of emission standards will close coal-fired stations.*
>
> *The four "incentives" (or "subsidies") will only benefit a nuclear developer once the station has been commissioned and in revenue. So a potential investor will be unimpressed by them, especially as extended construction times delay the payback.*

4.1.6 'Ministers are Breaking Their Promises on Subsidies for Nuclear Power', Joss Garman, 2011. [85] This mentions that the government has set a fixed price for the 'disposal' - actually storage for ever - of nuclear waste, so absorbing the risk, that the public supported the nuclear power industry with more than £ 10 billion in the last decade and that a 'floor' price for carbon could give it a further £ 3.43 billion between 2013 and 2026.

4.1.7 A report 'Nuclear Subsidies' was published by Energy Fair in May 2011. This identifies many of the nuclear subsidies that apply in the UK. The real cost of nuclear power is put at 25.39 US cents per kWh (about 15.5 p/kWh), excluding 'the cost of underwriting the commercial risks, the cost of protection against terrorist attacks, the short-, medium- and long-term costs of disposing of nuclear waste, the cost of decommissioning nuclear plants, institutional support for the nuclear industry and a range of other subsidies'. [86]

4.1.8 The German Renewable Energy Association published on 2011-05-11 a study commissioned from 'Versicherungsforen Leipzig GmbH' on the calculation of an adequate insurance premium for the operators of nuclear power plants. [87] This found that the mean insured sum payable for a nuclear disaster could be 6090 billion euros. If passed on to consumers and spread over 50 years, the additional cost of electricity in euros per kWh would be 8.71 for each individual nuclear plant or 0.51 for all 17 plants in Germany and if spread over ten years, 67.3 or 3.96. (At 1 euro = £ 0.88, these are 766, 45, 5922 and 348 p/kWh). The study concluded that 'in practical terms, nuclear disasters are not insurable'. It has been reported briefly in English. [88]

4.1.9 We have recently learned the term 'moral hazard' in the context of bank risk and 'too big to fail'. Now we know that the bill has to be picked up by the state – i.e. the tax-payers. Nuclear power also brings a 'moral hazard' in the form of nuclear risk that is too big to insure beyond a token amount – so the bill is again picked up by the state – i.e. the tax-payers. This has happened in Japan, for Fukushima. Risk equals Probability times Consequences. The Probability is both unknown and unknowable, so must be taken as 1, and the Consequences are 'unquantifiable' – i.e. unlimited, potentially infinite - so this amounts to an infinite subsidy.

4.1.10 Then there is the long-term storage of the nuclear waste. This too is a 'moral hazard', since once it exists we have no option but to pay for it to be stored – effectively for ever. (The half-life of U238 is 4.5 billion years). This is a second infinite subsidy. Moreover, as Greenpeace noted:

> *ten new reactors alone would quadruple the amount of high level radioactive waste and spent fuel the UK would have to be deal with. It would increase the amount of radioactivity in the wastes, above that in all the wastes that currently exist, by 150%'.* [89]

5. CONCLUSIONS

For a given radioactive release from a nuclear power plant, the Sandia CRAC-2 report of 1982 predicted Peak Early Fatalities of 42,000 to 100,000 deaths and other consequences. The Chernobyl catastrophe occurred in 1986 yet only in 2005 did the IAEA state that up to 4,000 people could eventually die of radiation exposure. However Chernobyl contaminated not only huge areas of the Ukraine, Belarus and Russia but also 40% of Europe. Fairley and Sumner estimated worldwide excess cancer deaths of 30,000 to 60,000 and Busby of 370,000 to 1.2 million, while Gofman, Bertell and Yablokov et al estimated total deaths of 0.5 to 1.8 million. Moreover, the IPPNW/GfS report of 2011 found that a comparable radioactive release in (more crowded) Germany could cause millions of cancer deaths. Even greater consequences are possible while so much spent fuel remains in the reactor storage pools. Due to the high population density, Fukushima has been predicted to cause up to 210,000 excess cancer deaths. Radioactive releases from worldwide nuclear facilities are clearly inevitable and could contaminate not only vast areas of the home country but also many others including those like Denmark, which does not use nuclear power.

Another moral question is why we should dump the cost of looking after the radioactive waste on all future generations. We have already contaminated extensive regions of the world with radioactive fallout, making some parts uninhabitable. The countries and companies which produced the nuclear waste must be made 'to immobilize the radioactive waste physically and to isolate it from the biosphere in deep geologic repositories, lasting at least a million of years'.

In all countries using nuclear power, the taxpayers are underwriting the unlimited costs of insurance and waste storage – thus affording it two infinite subsidies. If insurance alone was fully paid, the cost of nuclear power would increase by e.g. 45 to 348 p/kWh. In addition, the UK government is apparently expecting electricity consumers to pay for a 'floor' price for carbon and a 'market reform' with three further 'incentives' favouring nuclear. Yet many countries from Denmark to Germany are showing that there are safe, sustainable and infinitely cheaper solutions for supplying electrical and other services, so there is no need to add to our already huge nuclear risks and debts. Moreover, the consequences of a major radioactive release are completely unacceptable, so all existing nuclear plants should be phased out before they kill and injure any more of us.

Gordon Taylor, B.Sc., M.Sc., M.I.Mech.E.

G T Systems,

19 The Vale, Stock, Ingatestone, Essex, CM4 9PW, U.K.

Tel: +44(0)1277-840569

Email: gordon@energypolicy.co.uk

Web: http://www.energypolicy.co.uk

REFERENCES

1 (http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr75-014/appendix-vi/).

2 The Swedish Reactor Safety Study: Barseback Risk Assessment', Industridepartmentet, Energikommissionen, Ds I 1978:1, p 1-11.

3 (http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr75-014/appendix-vi/, Page 13-34 (logical 202), Table VI 13-6).

4 The Swedish Reactor Safety Study: Barseback Risk Assessment', Industridepartmentet, Energikommissionen, Ds I 1978:1, Table 1-1 and Table 2-3.

5 The Swedish Reactor Safety Study: Barseback Risk Assessment', Industridepartmentet, Energikommissionen, Ds I 1978:1, Table 2-4.

6 (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/11/538/11538820.pdf, p 9, 11).

7 (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/15/047/15047481.pdf, Page 11, 26).

8 (http://www.nirs.org/reactorwatch/accidents/crac2.pdf).

9 (http://www.greenpeace.org/usa/Global/usa/report/2008/3/risky-business-the-probabilit-2.pdf)

10 (http://www.greenpeace.org/usa/Global/usa/report/2008/3/risky-business-the-probabilit-3.pdf).

11 Gofman, J. (1994). Chernobyl Accident: Radioactive Consequences for the Existing and Future Generations ("Vysheihsaya Shcola," Minsk): 576 pp. (in Russian). Quoted in 'Bertell, R. (2006). The death toll of the Chernobyl accident. In: Busby, C. C. & Yablokov, A. V. (Eds.), ECRR Chernobyl 20 Years On: Health Effects of the Chernobyl Accident. ECRR Doc. 1 (Green Audit Books, Aberystwyth): pp. 245–248. (http://www.euradcom.org/publications/chernobylebook.pdf).

12 (http://www.ratical.org/radiation/Chernobyl/Chernobyl%4010p1.html)

13 (http://www.ratical.org/radiation/Chernobyl/Chernobyl%4010p2.html)

14 (http://www.greenpeace.org/raw/content/international/press/reports/nuclearreactorhazards.pdf).

15 (http://dels-old.nas.edu/dels/rpt_briefs/beir_vii_final.pdf).

16 (http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf).

17 (http://www.greenpeace.org/raw/content/international/press/reports/chernobylhealthreport.pdf).

18 (http://www.chernobylreport.org/torch.pdf).

19 Bertell, R. (2006). The death toll of the Chernobyl accident. In: Busby, C. C. & Yablokov, A. V. (Eds.), ECRR Chernobyl 20 Years On: Health Effects of the Chernobyl Accident. ECRR Doc. 1 (Green Audit Books, Aberystwyth): pp. 245-248. (http://www.euradcom.org/publications/chernobylebook.pdf).

20 (http://www.strahlentelex.de/Yablokov%20Chernobyl%20book.pdf, Page 210).

21 (http://www.greenpeace.org/raw/content/international/press/reports/the-john-large-report.pdf).

22 (http://www.beyondnuclear.org/storage/documents/nuclearhealthrisks-final.pdf).

23 (http://www.worldwatch.org/system/files/WorldNuclearIndustryStatusReport2011_%20FINAL.pdf, Pages 4, 5).

24 (http://www.smithschool.ox.ac.uk/nuclearreport2011/nuclear_study.pdf).

25 (http://www.fissilematerials.org/ipfm/site_down/rr05.pdf, Page 8 to 12).

26 (http://www.carnegieendowment.org/files/reprocess.pdf, Page 5).

27 (http://www.chernobylcongress.org/fileadmin/user_upload/pdfs/chernob_report_2011_en_web.pdf)

28 (http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf).

29 (http://www.euradcom.org/2011/chernhealthrept3.pdf).

30 (http://www.euradcom.org/2011/ecrr2010.pdf).

31 (http://www.llrc.org/fukushima/subtopic/fukushimariskcalc.pdf).

32 Professor Chris Busby. Personal communication, 2011-05-20.

33 (http://www.fissilematerials.org/ipfm/site_down/rr02.pdf, Table 2.2).

34 (http://www.carnegieendowment.org/files/reprocess.pdf, Page 4).

35 (http://www.mellatinsurance.com/magazine/Article-site/novin/Nuclear%20risks%20in%20property%20insurance%20.pdf).

36 (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/15/047/15047481.pdf, Page 18).

37 'Swedish Reactor Safety Study: Barseback Risk Assessment', Industridepartmentet, Energikommissionen, Ds I 1978:1, p 1-11.

38 (http://nuclear.tamu.edu/~burchill/609/Class%2024/Keller%2C%20Modarres%20PRA%20History%20Article.pdf, Page 278).

39 (http://www.osti.gov/bridge/servlets/purl/6489792-nii8Km/6489792.pdf, Page ix (11 logical)).

40 (http://nuclear.tamu.edu/~burchill/609/Class%2024/Keller%2C%20Modarres%20PRA%20History%20Article.pdf, Page 279)

41 (http://www.osti.gov/bridge/servlets/purl/6489792-nii8Km/6489792.pdf, Page x (12 logical)).

42 (http://www.stat.auckland.ac.nz/~wild/ChanceEnc/Ch04.pdf, Page 54).

43 (http://www.radstats.org.uk/no029/speed.pdf).

44 The Swedish Reactor Safety Study: Barseback Risk Assessment', Industridepartmentet, Energikommissionen, Ds I 1978:1, p 1-2.

45 (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/11/538/11538820.pdf).

46 (http://www.greenpeace.org/raw/content/international/press/reports/the-greenpeace-book-of-the-nuc.pdf).

47 (http://www.prop1.org/2000/accident/facts1.htm)

48 (http://old.disinfo.com/archive/pages/article/id2165/pg1/index.html)

49 (http://en.wikipedia.org/wiki/List_of_civilian_nuclear_accidents).

50 (http://www.theoildrum.com/node/7724, SRSrocco2 on March 27, 2011 - 2:58 pm).

51 (http://www.marklynas.org/2011/03/176/).

52 (http://www.ecoequity.org/wp-content/uploads/2009/07/meinshausen_nature.pdf).

53 (http://us.greenpeace.org/site/DocServer/Nuclear_power_climate_change.pdf).

54 (http://old.rmi.org/images/PDFs/Energy/E88-28_GreenhouseWmg.pdf).

55 (http://www.energyblueprint.info/fileadmin/media/documents/energy_revolution.pdf)

56 (http://www.mng.org.uk/gh/scenarios/energy_revolution2009.pdf)

57 (http://www.greenpeace.org/international/Global/international/publications/climate/2010/fullreport.pdf)

58 (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2010_web.pdf, p 34).

59 (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/backgrounder_energy-savings-forecast.pdf).

60 (http://www.greenpeace-stuttgart.de/themen/energie/Der_Plan.pdf).

61 (http://www.greenpeace.de/fileadmin/gpd/user_upload/themen/atomkraft/Hintergrundpapier_Atomausstieg_2011_02.pdf).

62 (http://www.greenpeace.de/fileadmin/gpd/user_upload/themen/atomkraft/Datengeruest_Atomausstieg_2015_02.pdf)

63 (http://www.eutech-energie.de/typo/fileadmin/user_upload/Klimaschutz_PlanB_2050_Kurzfassung.pdf).

64 (http://www.berr.gov.uk/files/file35607.pdf, p 5).

65 (http://www.stormsmith.nl).

66 (http://www.physorg.com/news/2011-05-nuclear-power-world-energy.html).

67 (http://www.energypolicy.co.uk/wind.htm).

68 (http://www.upress.uni-kassel.de/publi/abstract.php?978-3-89958-798-2).

69 (http://www.volkswagenag.com/vwag/vwcorp/info_center/en/themes/2011/05/Audi_balanced_mobility___The_route_to_CO2-neutral_mobility.html).

70 (http://www.greencarcongress.com/2011/05/egas-20110513.html).

71 (http://www.energypolicy.co.uk).

72 (http://www.wind-energie.de/fileadmin/dokumente/Themen_A-Z/Potenzial%20der%20EE/IWES_Potenzial_onshore_2011.pdf)

73 (http://www.pnas.org/content/early/2009/06/19/0904101106.full.pdf)

74 (http://www.wind-works.org/FeedLaws/Japan/FukushimaNuclearYeartoYearReliabilityandGermanWind.html).

75 (http://en.wikipedia.org/wiki/Price-Anderson_Nuclear_Industries_Indemnity_Act).

76 (http://www.greenpeace.org/usa/Global/usa/report/2008/3/risky-business-the-probabilit-2.pdf, Page 6).

77 (http://www.citizen.org/documents/Price%20Anderson%20Factsheet.pdf, Page 2).

78 (http://www.stanford.edu/group/siepr/cgi-bin/siepr/?q=system/files/shared/pubs/papers/briefs/policybrief_jan02.pdf)

79 (http://www.cbo.gov/ftpdocs/91xx/doc9133/05-02-Nuclear.pdf, Page 29).

80 (http://www.bis.gov.uk/assets/biscore/corporate/docs/b/10-p102-bis-resource-accounts-2009-10.pdf, Page 171).

81 (http://miriam-english.org/files/nuclear-myths/2009-09_FourNuclearMyths.html).

82 (http://www.greenpeace.de/fileadmin/gpd/user_upload/themen/atomkraft/Tabelle_Subventionen.pdf)

83 (http://www.worldwatch.org/system/files/WorldNuclearIndustryStatusReport2011_FINAL.pdf).

84 (http://www.after-oil.co.uk/edf_financial.htm).

85 (http://www.leftfootforward.org/2011/02/coalition-broken-promise-nuclear-power-subsidies/).

86 (http://www.mng.org.uk/gh/private/nuclear_subsidies1.pdf).

87 (http://www.bee-ev.de/3:720/Meldungen/2011/AKW-nicht-versicherbar-BEE-verlangt-ehrliche-Kostendebatte.html)

88 (http://www.pv-magazine.com/news/details/beitrag/true-cost-of-nuclear-examined-in-new-study_100002882/).

89 (http://www.uk.greenpeace.org.uk/MultimediaFiles/Live/FullReport/7619.pdf, Page 2).