THE REAL LESSONS OF FUKUSHIMA

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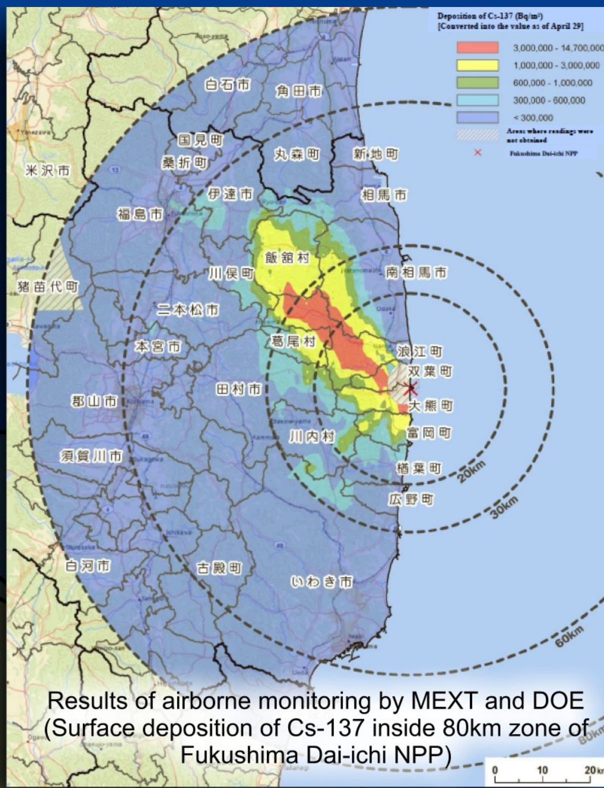

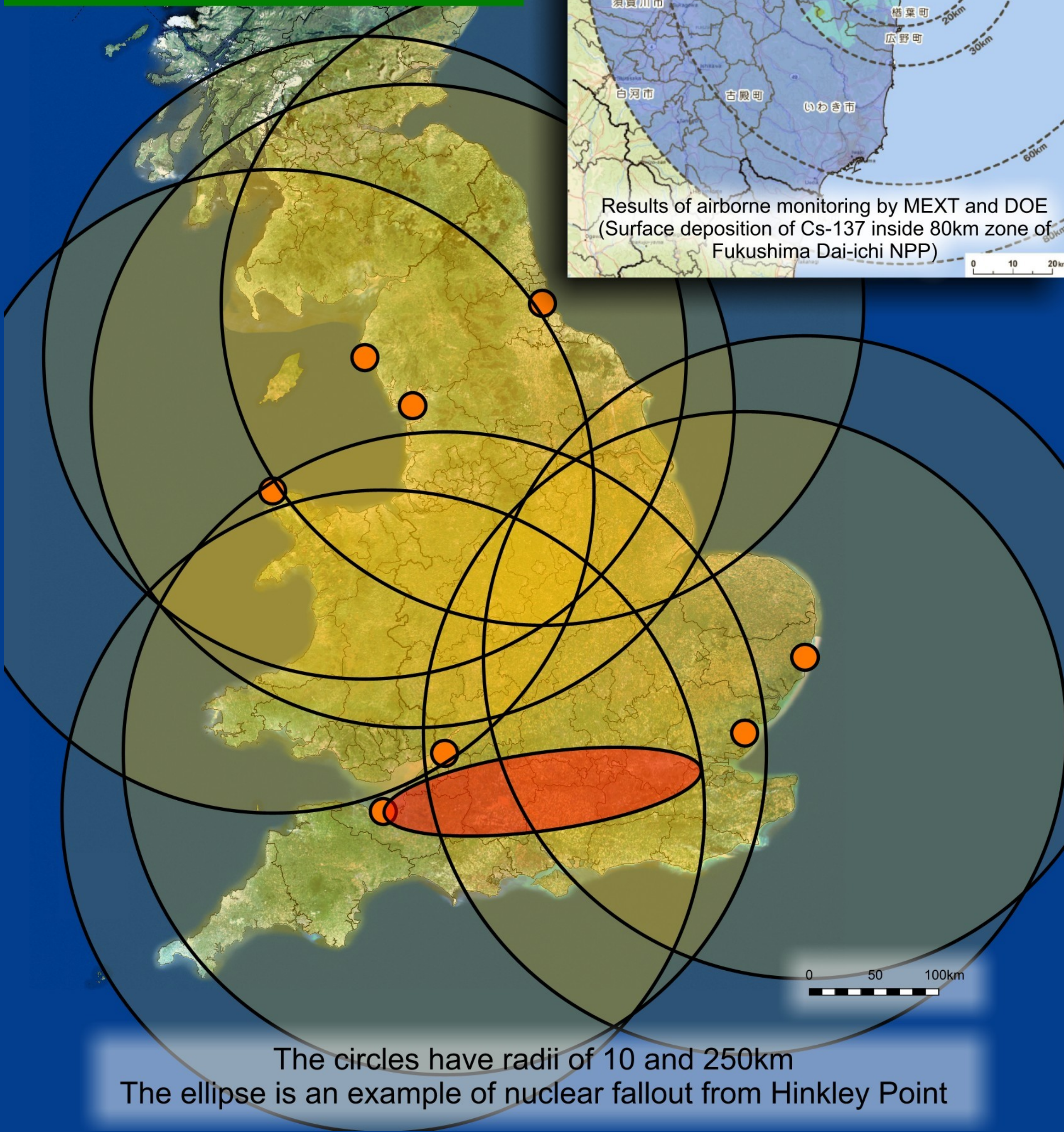

THE REAL LESSONS OF FUKUSHIMA SUMMARY

This study is based on evidence on the Fukushima disaster and it's consequences, almost all from the internet. Many quantitative studies have been found, but no proper studies from the IAEA or the UK ONR. The fast-moving and highly dangerous events of such a disaster require decision support. Thermal models of the reactors and spent fuel pools are essential to predict their behaviour under Station Blackout and to evaluate possible counter-measures. Also plume (dispersion) models of possible radioactive releases are essential to inform decisions on the magnitude and direction of evacuations. The Japanese have such a plume model, but it was ignored until later. Also they had no instrument for airborne radioactivity measurements at hand and had to rely initially on aerial surveys carried out by the Japan-based US Emergency Response Centers. These deficiencies were omitted or downplayed in the reports of the IAEA Fact Finding Mission, but most were included in the report of the Hatamura Panel.

Following the disaster, nearly 15,000 workers have received radiation doses of up to 250 mSv. Including the general public and using widely accepted dose-effect models, the estimated excess cancer deaths are 350 to 3000, while with other dose-effect models they are 100,000 to 200,000, though all these should be reduced by evacuation. About 80,000 persons have been forced to evacuate parts of Fukushima prefecture and live elsewhere. For the public, the dose criterion for evacuation was set at 20 mSv/y. However, for the decontamination plan the target dose limit was set equal to the ICRP dose limit of 1 mSv/y. This also requires more evacuation.

The area of land contaminated with radioactive cesium to more than 10,000 Bq/m2 is about 30,000 km2, some 8% of Japan. Even with considerable decontamination, a significant area of Japan will remain uninhabitable for 10 to 20 years or more. Moreover, land is required for storing the huge volumes of radioactive waste.

The household and business compensation cost may be Y 3.6 trillion and the decontamination cost up to Y 10 trillion or more, for a total of Y 14 trillion ($ 180 billion) or more. With insurance cover of only $ 1.6 billion, the shortfall may be up to $ 178 billion or more, which will have to be met by the taxpayers. This and other subsidies means that nuclear power can never be competitive. In any case, such consequences make it an ethical issue.

The Fukushima release source term is far less than the maximum possible and if it had fallen on a major city such as Tokyo, the consequences would have been even more horrific. The record shows that in severe accidents of INES 5 to 7, the contribution of human errors is 100%. Hence the worst case, with core meltdowns and the maximum physically possible release of radioactivity, must be considered. Germany, Switzerland and Italy have decided to join most other countries and phase out nuclear power. All the nuclear power plants in Japan will be shut down by the spring and the citizens may not allow any to be re-started. Economy minister Yukio Edano said he does not expect any nuclear power plant to be operating this summer, but thermal power and conservation efforts should be enough for the nation to get by.

The UK criteria for siting nuclear power plants consider only a small radioactive release and fallout reaching 30 km. Yet the Fukushima release was about 4000 times as much and the NII Fukushima 'reasonable worst-case scenario' release about 270,000 times as much. According to the Kondo Report worst case, the fallout would require evacuation to 170 or 250 km or more, e.g. from Hinkley Point to Birmingham or London. Also the compensation for the land and property losses and the decontamination costs would be far larger than for Fukushima, at roughly £ 1 trillion. So the UK siting criteria are wholly inadequate and almost all the citizens of Britain are threatened by the existing and proposed nuclear power plants. In the words of Dr John Gofman, this is 'licensing random premeditated murder'. Thus the former must be phased out forthwith and the latter abandoned.

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The Full Study, with Tables, Figures and References, may be downloaded from:
http://www.energypolicy.co.uk/FukushimaRealLessons.pdf

THE REAL LESSONS OF FUKUSHIMA
THE LESSONS

1. INTRODUCTION

An earlier paper 'The Case Against Nuclear Power' is based mainly on evidence prior to Fukushima. The sections are 'The Consequences of Radioactive Releases', 'The Probability of Radioactive Releases', 'Electricity and Greenhouse Gas Implications' and 'Electricity Costs'. The third section includes the demands for electricity, transport fuels and heat, all met by energy savings and wind energy.

The main reason for the present work is that the 'official' reports on Fukushima are complacent and inadequate, with the notable exception of that of the Hatamura Panel. This is due to the fundamental conflict of interests within the International Atomic Energy Agency (IAEA), which sees it's primary purpose as the promotion of nuclear power. Moreover, all the national nuclear regulatory agencies and the World Health Organization (WHO) defer to the IAEA, and thus lack the independence essential to their proper function.

2. EVENT PROGRESSION, RESPONSES AND DECISION SUPPORT

2.1 NUCLEAR POWER AND DECAY HEAT

The event progression under Station Blackout (SBO) and a Loss Of Cooling Accident (LOCA) can be estimated with thermal models of the reactors and spent fuel pools. With the known parameters of the plants, and the characteristics and inventory of the nuclear fuel, thermal models can simulate the event progression, including fuel melting and the production of hydrogen. However, they cannot predict whether any hydrogen will explode or the magnitude of any radioactive releases to the environment, known as 'source terms'. Provided that the assets are available, they require only known parameters plus operating data for the plants, so can be real-time. This is crucial since, as Fukushima has shown, nuclear fuel meltdown, hydrogen explosions and radioactive releases to the environment can occur within hours to days.

2.2 RESPONSES AND DECISION SUPPORT

Both the Nuclear Industrial Safety Agency of Japan (NISA) and Tokyo Electric Power Company (TEPCO) failed to consider the possibility of a SBO and a LOCA. Also, the off-site centre, thermal model, plume model and measurement capabilities – fixed and aerial – needed for decision support, were all wanting. The off-site centre only 5 km from the site had to be abandoned and in the hasty and unplanned evacuation of a hospital only 4 km from the site, at least 68 patients died. Despite this gross negligence, the IAEA Final Mission Report of 2011-06-22 described the Japanese emergency preparedness and response system as 'well organized'. However, the government Hatamura Panel Report of 2011-12-26 set out these failings in detail. Moreover, the private Kitazawa Panel report of 2012-02-28 quotes a U.S. official as saying that Japan's NISA declined to take measures, recommended by the U.S. Nuclear Regulatory Commission, to ensure the ability to cool down reactors in the case of terrorist attacks and other situations. (This means in the event of a SBO and a LOCA). That constituted a grave "failure to act," the report says. It seems unlikely that the UK response would be any better.

2.3 SEVERE ACCIDENT PROBABILITIES AND RISKS

In the US reports WASH-740 of 1957 and CRAC-2 of 1982, nuclear risk was expressed as the consequences of a 'maximum credible accident'. However in 1967, Farmer suggested that, for a given level of Risk in a 'balanced' design, the logarithm of the Consequence should be inversely related to the logarithm of the Probability. This became known as the 'Farmer curve' and interpreted as 'Risk = Consequence x Probability'. Yet regardless of the level of Risk, the Probability can never be zero, and while the Consequence can never be infinite, it can still be unacceptable. Even so, the Farmer curve has been used for risk assessment in all Reactor Safety Studies from WASH-1400 of 1975. This has had the effect – whether intended or not – of giving a false sense of security against unacceptable consequences.

The record shows that if an event reaches International Nuclear Event Scale INES 5, then it will almost certainly progress quickly to INES 7. Moreover, in severe accidents of INES 5 to 7, the contribution of human error is 100%. Above about INES 3.5, the actual probability of core melt increasingly exceeds that predicted by the safety analyses.

With three at Fukushima, the core melt frequency is now 1 in 8 years. Thus several would occur in the design life of a nuclear power plant, any one of which could be much worse than any so far. (See Section 11 below). Moreover, the danger depends very little on the safety of any new nuclear power plants, but very largely on that of the worldwide fleet of about 440 plants. As in the case of the Fukushima Daiichi Reactors 1 to 4, their ages are up to 40 years and more.

The case against nuclear power depends ultimately on logic. As all engineers know, whatever can happen will happen - and invariably at the worst possible time. The probability of earthquakes or tsunamis is irrelevant. Even the anticipated accident sequences can number billions, so with the unanticipated, the probability of any radioactive release up to the maximum physically possible is unknowable. Hence this must be taken as 1 – i.e. inevitable. So Probabilistic Safety Analyses are misleading and inadequate due to human errors, deterioration and logic. Thus the worst case - involving core meltdown(s) and the maximum physically possible release of radioactivity - and its consequences must be considered. (See Section 11 below). By suggesting otherwise, the governments, national nuclear agencies, IAEA, and the nuclear power plant suppliers and operators are all guilty of deliberate deception.

Masashi Goto and Hiromitsu Ino, advisers to Japan's nuclear safety agency, say that the stress tests on the idle nuclear reactors do not guarantee their safety and call into question the impartiality of the IAEA, which approved Japan's handling of the tests on 2012-01-31, Haruki Madarame, chairman of the Nuclear Safety Commission of Japan, established under the Cabinet Office, agrees and says that the results of the much-stricter second-stage tests - designed to ensure that Japan's nuclear facilities will be safe even in an accident that far exceeds expectations - should also be considered.

Ino also noted: "It is highly unlikely that the IAEA can undertake a fair assessment. The agency promotes the nuclear industry and it is only investigating the stress tests for a short time," he said. "The last IAEA report was very flimsy, and I fear it'll be the same this time."

Economy minister Yukio Edano said he does not expect any nuclear power plant to be operating this summer, but thermal power and conservation efforts should be enough for the nation to get by. Such a phase-out would eliminate all the dangers of continued generation with nuclear power, including those from routine discharges.

3. RADIOACTIVE RELEASES

3.3 BIOLOGICAL EFFECTS OF RADIOACTIVITY

Freeman quoted Gofman: ‘Licensing a nuclear power plant is in my view, licensing random premeditated murder'. 'And I realized that the entire nuclear power program was based on a fraud--namely, that there was a *safe* amount of radiation, a permissible dose that wouldn't hurt anybody'. 'The new NRC was only supposed to involve itself in safety--no promotion. Which turned out to be one of the greatest lies in history. . . .’.

The energies of biologically significant levels of radiation are typically one million times those of chemical changes. These highly energetic emissions carry enough energy to tear electrons from neutral atoms and molecules. This can cause cancers and, by damaging DNA (deoxyribonucleic acid), also affect subsequent generations.

Strontium and actinides such as U-238 contribute to internal exposures, very strongly with the European Committee on Radiation Risk (ECRR) dose-effect model. So while the nuclides I-131, Cs-134, and Cs-137 are of great concern, others such as Sr-89 and Sr-90 and actinides, such as Pu-238, Pu-239, Pu-240 and Pu-241 and Np-239, are highly dangerous, especially if ingested or inhaled. Strontium can substitute for calcium and be retained in the bones and some actinides emit alpha particles. Both can cause cancer.

4. MEASUREMENTS OF RADIOACTIVITY FROM FUKUSHIMA

Of the radioactive attributes - alpha, beta, gamma, X-rays and neutrons - most simple instruments can measure only gamma radiation. By assuming the Quality Factor as 1, they measure the absorbed dose rate – in Greys/time – but display it as the (human) dose equivalent rate – in Sieverts/time. However, this is true only for gamma radiation. Therefore most reports give only dose values for the gamma emitters Iodine (131) and Cesium (134 and 137) and fail to mention that these are only indicative of the complete release. Moreover, the accuracy may be only +/- 50%. To identify and quantify all the nuclides that may be present requires further measurement and analysis. Measurements of radioactivity inside the human body require more elaborate equipment, such as whole body counters.

4.2 AERIAL SURVEYS

Although Japan has installed and operated nuclear power plants capable of major radioactive releases for over 40 years, the Japanese authorities had no instrument at hand for airborne radioactivity measurements. This was gross negligence. Instead they had to rely initially on aerial surveys carried out by the Japan-based US Emergency Response Centers.

4.3 SOIL SAMPLING FOR IODINE AND CESIUM

Kinoshita et al reported: 'Radioactive iodine, strontium, and cesium, which have large fission yields and low boiling points, present a large risk for internal radiation exposure via ingestion of contaminated agricultural crops'.

5. ESTIMATING SOURCE TERMS OF THE RELEASES FROM FUKUSHIMA

5.1 AIR-BORNE SOURCE TERMS FOR GASES AND VOLATILES

It is noteworthy that Wotawa was the first to publish an estimate of the source terms. He leads a group of full-time professionals who are conversant with plume modelling and have access to data from the Comprehensive Test Ban Treaty Organization (CTBTO) worldwide network. This is what it takes to get rapid results, which are vital when so many lives and livelihoods are at stake.

The source term values obtained by reverse estimation are notably consistent, with Chino et al's values for I-131 of 1.5E17 Bq and Cs-137 of 1.3E16 Bq, and the others within factors of about 3.

Michel estimated the total radioactive inventory for units 1 to 4, of which the IRSN values of the releases were - I-131: 1.8%, Cs-134: 0.5% and Cs-137: 0.5%. This shows that they could be very much higher. (See Section 11 below).

5.2 AIR-BORNE SOURCE TERMS FOR STRONTIUM AND ACTINIDES

According to the MEXT report, the accumulated effective dose for 50 years at points where the largest deposition amounts of strontium 90 was detected would be only about 0.12 mSv. (See Section 4.4). The Dose Conversion Factor for internal exposure of Sr-90 according to the ECRR model is about 60 times that according to the ICRP model. However, this would still be only about 7 mSv, compared with the largest amounts detected of Cs-134 at 71 mSv and Cs-137 at 2000 mSv. Also almost all the Np-239 and Pu-239 have been carried over the ocean.

5.3 SOURCE TERMS FOR THE SEA

TEPCO reported that the radioactive I-131, Cs-134 and Cs-137 source terms released to the sea via water discharges, deliberate and not, was 6.7E15 Bq. Other studies found that the Cs-137 released via airborne fallout was 2.8E16 Bq and the total, via both waterborne and airborne pathways, was 2.7E16 Bq, about 4 times as much.

6. CONSEQUENCES OF THE RADIOACTIVE RELEASES FROM FUKUSHIMA

6.2 LAND AREA AND PEOPLE AFFECTED

In the various studies, both the land areas and the people affected vary widely, depending on the values of the criteria. The land areas vary inversely with the deposition criteria in Bq/m2. In most cases, the number of people affected vary inversely with the dose criterion in mSv/y, but some estimates are based on simple deposition models, or on other studies. Also those favouring low dose-effect models may choose high dose criteria values and vice-versa. In these studies of Fukushima, the highest estimates of the land area – at 30,000 km2 (8% of Japan) – and of the people affected – at about 1 million – are both very large.

6.3 PEOPLE EVACUATED

Although there was some voluntary evacuation, the number of people to be evacuated depends mainly on the value of the exposure criterion applied. The dose limit was a political judgement, set initially at 20 mSv/y. So the number of people evacuated – at about 80,000 – was far smaller than the largest estimate of those affected – at about 1 million. However, the dose limit for the decontamination plan was later set equal to the ICRP recommendation for the general public, at 1 mSv/y. So to reduce the health effects, the evacuation zones should be far larger and more people should evacuate.

6.4 ANIMALS LEFT BEHIND

‘Naoto Matsumura, Tomioka City, Fukushima Prefecture, Japan–the last man standing in Fukushima’s Forbidden Zone. He will not leave; he risks an early death because his defiance of Tokyo Electric Power Company (TEPCO) and the government is his life now. He is not crazy and he is not going. He remains there to remind people of the human costs of nuclear accidents. He is the King of The Forbidden Zone; its protector. He is the caretaker or empty houses, a point of contact for those citizen who can’t return. He takes care of the animals, “the sentient beings”, that remain behind because no one else will’.

‘Matsumura notes that “TEPCO and the Japanese government have never stopped lying, out of their good will, in order to avoid panic among the population. Such good intentions, of course.”.’

6.5 DURATION OF LAND LOST AND PEOPLE EXCLUDED

The nuclear fallout from Fukushima includes Cs-137, which has a half-life of about 30 years. So unless the contamination and dose to humans can be reduced by removal, it will take many decades to die away. Therefore, even with decontamination, a significant area of Japan will remain uninhabitable for 10 to 20 years or more.

7. HUMAN HEALTH EFFECTS FROM FUKUSHIMA

7.1 PROMPT HEALTH EFFECTS

Following nuclear disasters, the people most exposed – both in dose and time - are the workers at the plant. Many are temporary and are 'burned out' by working in radioactive areas until they have received a certain dose and then replaced. Hence they are most likely to suffer prompt health effects – cancers and deaths.

Officials claimed that no workers showed health problems as a result of their exposure. However latent cancers can take 10 or even 50 years to appear, and about half would be lethal. (See Section 7.2 below). So TEPCO, the nuclear agencies and the government were all misleading the workers and the general public.

The authorities took advantage of the loyalty of firemen and sent them into high-risk areas with inadequate protection. Since many such rescuers have been involved, this death is likely to be followed by others.

Even though they are hired to be exposed to higher radiation, the temporary workers are treated far worse than TEPCO employees. Yet TEPCO should be fully aware of human rights and the capabilities of robots, so this is inexcusable.

7.2 LATENT HEALTH EFFECTS

Many nuclear reports and news items imply that the only health consequences are the 'prompt deaths and injuries' and fail to mention the (latent) excess cancers and resulting deaths that may appear only after 10, 50 or even 70 years. Even if workers escape prompt health effects, they are still liable to suffer latent health effects. Many studies estimate depositions and doses but stop short of estimating health effects. (See Section 6.2 above). Only the study by Vitazkova and Cazzoli used a plume model to estimate the deposition and dose, together with the population distribution before evacuation, a criterion to determine the number of people affected and evacuation assumptions, to estimate the human health effects. The other studies estimated the health effects with simple models or by comparison with other data, such as that from Chernobyl.

The human health effects vary widely, depending on the dose-effect model used. Thus the BEIR (Biological Effects of Ionizing Radiation) VII model implies 100s, the ICRP model implies 1000s, while the Tondel, ECRR and '1 death/person-Sv' models imply 100,000s of excess cancers and deaths. The BEIR and ICRP have adopted the lowest dose-effects in the literature, and ignored much low-dose data. Moreover, release source terms can include up to 100 different nuclides, but only a few are normally considered, so any estimates of the human health effects must be low. In this case, the source terms of Sr and Pu seem to be very small. (See Section 5.2 above). Even so, these human health effects omit those of ingesting contaminated food and water. (See Section 8 below). Furthermore, radioactivity – especially inhaled alpha-particles – causes genetic damage, which will be manifest as still-births, deformities, cancers and premature deaths in future generations. This contravenes the 'precautionary principle', which would be met by using the ECRR model.

The evacuations should reduce these latent health effects, but if the Fukushima evacuees were to return before decontamination and/or decay of the radioactivity over decades, they would increase again. So the evacuees must be informed accordingly before any return is permitted, much less encouraged. (See Section 4.5 below).

Many quantitative studies of the Fukushima disaster and consequences – such as release source terms, ground deposition, human dose, land area, people affected and health effects - have been published (mostly in English) by individuals and organizations in many different countries. These include Austria, France, Germany, Japan, Netherlands, Switzerland and the USA. However, no proper studies have been found from the IAEA or the UK Office of Nuclear Regulation (ONR), which casts doubt on their readiness and ability to carry out such studies.

7.3 HEALTH CHECKS

The Fukushima prefectural government plans to test some 360,000 people who were under 18 on March 11 throughout their lives and all of the approximately 2 million residents for at least 30 years.

8. FOOD AND WATER CONTAMINATION FROM FUKUSHIMA

The health effects are increased if radioactivity is ingested with food and drink - and especially if inhaled – causing additional, internal exposure. (See Section 3.1 above). Japan has had nuclear power plants for more than 40 years, yet had no guidance levels or restrictions for nuclear substances on food at the time of the Fukushima nuclear disaster. The reason for this is unknown, but is at least incompetence. That said, Europe did not develop such standards until the fallout from Chernobyl arrived in 1986. In both cases, the nuclear interests knew of the dangers, but failed to alert the politicians to the need for such standards, even though the criteria values would be political judgements. To comply with the current German radioactivity limits for food, the EU limits should be reduced by around 40-fold. However the World Health Organization (WHO) has relinquished jurisdiction to the IAEA, which like the ICRP and European Atomic Energy Community (EURATOM), is dominated by the nuclear industry and their commercial interests.

8.1 LAND FOOD CONTAMINATION

The requirements for testing land foods for radioactivity are very considerable. They include staff, instruments and compensation for any that is rejected as over the limit. Moreover, this must continue for 10 to 20 years or more.

8.2 SEA FOOD CONTAMINATION

Since the radioactive half-life of Cs-137 is 30 years, and the radioactivity in sea foods is very hard to estimate, it is necessary to have comprehensive testing. The activity values of radioactive cesium (Cs-134 + Cs-137) in sea foods from the coastal areas now only rarely exceeds the limit of 500 Bq/kg while that in other species from fishing grounds some 100 km away measures less than 10 Bq/kg. Even so, the coastal fishing industry has been greatly damaged.

9. DECONTAMINATION AND RADIOACTIVE WASTE STORAGE AFTER FUKUSHIMA

9.1 DECONTAMINATION OF WATER AND LIQUID RADIOACTIVE WASTE STORAGE

Radioactive waste water will continue to accumulate until the reactor and fuel pool decay heat falls, reducing the cooling load, and the radioactive water cleanup plant throughput catches up with the water demand for cooling. Until then, fresh water must be supplied for 'once-through' cooling, and the resulting radioactive waste water would require ever more 'temporary' storage tanks and/or discharges to the sea.

9.2 DECONTAMINATION OF LAND AND SOLID RADIOACTIVE WASTE STORAGE

Minimising the loss of developed land will require vast efforts at decontamination, but this will be impractical for undeveloped land and forests. Also some land will be required for storing the huge volumes of radioactive waste.

10. COSTS OF HUMAN, LAND AND WATER CONSEQUENCES AND DECONTAMINATION AFTER FUKUSHIMA

For Fukushima, the household and business compensation may be Y 3.6 trillion and the decontamination cost up to Y 10 trillion or more for a total of up to Y 14 trillion ($ 180 billion) or more.

These costs may or may not include the equipment for and testing of human health and any treatment required for this and future generations, the necessary research on soil-to-food transfer factors and of testing foods for radioactivity for 10 to 20 years and more and the food discarded. However, all these should be paid by TEPCO. Yet no recompense is possible for the human misery, injury and loss of life-span, including of future generations, or likely for the loss of homes and communities and the economic outputs of farming, fishing, and industry in the contaminated areas.

10.1 INSURANCE, SUBSIDIES AND ETHICS

With insurance cover of only $ 1.6 billion the shortfall may be up to $ 178 billion or more, which will have to be met by the taxpayers. In the UK, the nuclear accident risk is carried by the State, under the Nuclear Installations Act of 1965. Such 'Statutory Indemnities' are described as 'unquantifiable', which means 'unlimited' or 'infinite'.

The Versicherungsforen Leipzig found that the hypothetical mean insured sum payable for a nuclear disaster in Germany could be 6090 billion (6 trillion) euros. (See Section 12 below). At 1 euro = £ 0.88, if shared by the 54 nuclear power plants in Japan and spread over 50 or 10 years, the value would be about 14 or 110 p/kWh. Then at £ 1 = 130 yen, it would be 18 or 143 yen/kWh. This and other subsidies means that nuclear power can never be competitive.

The German Government set up an Ethics Commission for a Safe Energy Supply. This found that: 'The withdrawal from nuclear energy is necessary and recommended to rule out future risks from nuclear in Germany. It is possible because there are less risky alternatives'. 'The Ethics Commission has come to the conclusion that a safe energy supply can be achieved which provides more jobs in business and manual trade without compromising environmental protection, whilst also avoiding a power shortage and having to import nuclear energy'.

11. FUKUSHIMA COULD HAVE BEEN FAR WORSE

11.1 LARGER INVENTORY AND RELEASE FRACTION

The Fukushima release source term is far less than the maximum possible from Reactors 1 to 4. Compared with the Chino et al Fukushima I-131 release estimate of 1.5E17 Bq, the I-131 source term for the NII 'reasonable worst case scenario' is about 1E19 Bq, which is about 66 times higher. This is consistent with the estimates of the radioactive inventories of I-131. It is roughly 100 times higher than INES 7 – the highest value defined by the IAEA – but it would be INES 9. The total for all nuclides would be larger. (See Sections 5.1 and 5.2 above). Therefore the total release source terms could be far larger than anything that has occurred to date. Also, multiple reactors and spent fuel pools per site and nearby sites would further increase the potential total release.

11.2 MORE OF THE RELEASE FALLING ON LAND AND MAJOR CITIES

If the release had fallen on land and especially a major city such as Tokyo (population about 35 million), complete evacuation would be impossible and the health and economic consequences would have been much worse.

11.3 COMBINATION OF FAR LARGER RELEASE AND FALLING ON MAJOR CITIES

If a worst case release fell on a major city, complete evacuation would be impossible and the health effects would affect millions. The compensation and decontamination cost for a worst case release could be between $ 936 billion and $ 4.8 trillion – i.e. roughly £ 1 trillion. This is of the same order as the hypothetical mean insured sum payable for a German nuclear disaster of 6 trillion euros estimated by the Versicherungsforen Leipzig. So the consequences of a major radioactive release are comparable to those of nuclear weapons, but are self-inflicted. Moreover, the NII estimate of the 'reasonable worst case scenario' and the Kondo report on the worst case consequences are from within the UK and Japanese nuclear communities. So such horrific consequences are undeniable.

When the next major release occurs, the citizens will demand immediate shut-down of all nuclear power, as has happened in Japan. Yet they would still suffer huge health effects, a damaged country and vast amounts of radioactive waste. Germany, Switzerland and Italy have already decided to join many other countries and phase out nuclear power. Meanwhile Japan has shut down most of the nuclear power plants, and will shut down the rest this spring. Whether the citizens will allow any to be re-started remains to be seen.

In the light of the Kondo report on Fukushima, studies of the consequences for a worst case release must be carried out for each country where nuclear power plants are installed or proposed. Since fallout crosses national boundaries, the consequences should include those for neighbouring countries. Plume models can be used to estimate the ground and marine depositions for various combinations of wind and rain. Following the 'precautionary principle', the ECRR model must be used to estimate the human health effects. Moreover, these studies must be carried out independently of all nuclear power interests, including the IAEA and the national nuclear regulatory agencies.

12. CONSEQUENCES OF A MAJOR RADIOACTIVE RELEASE IN THE UK

Dr Clifford Beck of the US Atomic Energy Commission (AEC) said in 1959: 'If worst conceivable accidents are considered no site except one removed from populated areas by hundreds of miles would offer sufficient protection'.

Following the nuclear accident at Three Mile Island in 1979, Sandia produced the 'CRAC-2' study on the siting criteria for nuclear power plants in 1982. Most were located near to major cities and for a major release, the 'Peak Early Fatalities' were estimated at up to 100,000.

> The UK Government has proposed ten sites for new nuclear power plants, of which three are very close together. Also, it is proposed to install more than one unit per site, each far larger than Fukushima in output and hence nuclear fuel inventory. Just who and how many would suffer death, injury, exclusion and economic loss would depend on which site produced the release, its magnitude, the direction of the wind, and whether it was raining or snowing as the plume passed. The ground level concentration pattern of radioactive fallout - for a constant wind over a level surface - is approximately elliptical. For the Kondo Report worst case release, with evacuation compulsory to 170 km and voluntary to 250 km or more, this could be from Hinkley Point to Birmingham or London. By extrapolation, at the ICRP dose criterion of 1 mSv/y, the radius would be about 800 km. (See Section 11.3). Moreover, fallout could fall on other nuclear power plants - particularly for the Sellafield cluster - and compound the consequences. Also the land and property losses and decontamination costs would be far larger than for Fukushima, at roughly £ 1 trillion. (See Section 11.3). This is of the same order as the hypothetical mean insured sum payable for a German nuclear disaster of 6 trillion euros estimated by the Versicherungsforen Leipzig.
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> Fig. 4 is a map of Great Britain, showing the areas threatened by the ten proposed nuclear power plants and an example of fallout from Hinkley Point extending 250km to London. After Fukushima, such consequences would be inexcusable, especially as the UK suffered from Windscale and Chernobyl. So the UK siting criteria are wholly inadequate and almost all the citizens of Britain are threatened by the existing and proposed nuclear power plants. In the words of Dr John Gofman, this is 'licensing random premeditated murder'. Thus the existing nuclear power plants must be phased out forthwith and the proposed ones abandoned.

13. CONCLUSIONS

This study is based on evidence on the Fukushima disaster and it's consequences, almost all from the internet. Many quantitative studies have been found, but no proper studies from the IAEA or the UK ONR. The fast-moving and highly dangerous events of such a disaster require decision support. Thermal models of the reactors and spent fuel pools are essential to predict their behaviour under Station Blackout and evaluate possible counter-measures. Also plume (dispersion) models of possible radioactive releases are essential to inform decisions on the magnitude and direction of evacuations. The Japanese have such a plume model, but it was ignored until later. Also they had no instrument for airborne radioactivity measurements at hand and had to rely initially on aerial surveys carried out by the Japan-based US Emergency Response Centers. These deficiencies were omitted or downplayed in the reports of the IAEA Fact Finding Mission, but most were included in the report of the Hatamura Panel.

Following the disaster, nearly 15,000 workers have received doses of up to 250 mSv. Several have received more and at least one has died due to internal radiation. Excess cancers and resulting deaths may take up to 50 years to appear. Using widely accepted dose-effect models, the excess cancer deaths are estimated as 350 to 3000, while with other dose-effect models they may be 100,000 to 200,000, though all these should be reduced by evacuation.

About 80,000 persons have been forced to evacuate parts of Fukushima prefecture and live elsewhere. Radioactivity above Japanese government limits has been found in many foods, including rice, beef and fish. This would cause internal exposure if eaten, and has destroyed the businesses of farmers and fisherfolk over wide areas. The compensation for persons and businesses has been estimated at 3.6 trillion yen ($ 47 billion).

The area of land contaminated with radioactive cesium to more than 10,000 Bq/m2 is about 30,000 km2, some 8% of the land area of Japan. Part of this will be uninhabitable for 10 to 20 years or more. According to the decontamination plan, the land area for which the dose to humans would be over 1 mSv/y is about 13,000 km2. It would require removing about 29 million cubic meters of topsoil and fallen leaves, and such radioactive waste needs land for storage. The cost of the decontamination measures have been estimated at from 1.2 to more than 10 trillion yen ($130 billion).

Hence the personal and business compensation and the decontamination cost may be up to 14 trillion yen ($ 180 billion). Yet the insurance fund available is only about 120 billion yen ($ 1.6 billion) per nuclear plant. In principle, the electric power companies should pay the rest, but TEPCO is virtually bankrupt. So almost all the cost must be met by the taxpayers. This and other subsidies means that nuclear power can never be competitive.

Of the radioactive fallout from Fukushima, only 19% fell on Japan, 2% on other land, and 79% on the sea.

So the fallout over land could have been higher by up to 5 times. The radioactive plume passed over Tokyo, but by chance it was not raining. If it had been, the human health and other consequences would have been hugely higher. Scenarios with larger releases, all over land and over crowded cities, have consequences that are even more horrific.

Germany, Switzerland and Italy have decided to join many other countries and phase out nuclear power. Also Japan has shut down almost all the nuclear power plants, and will shut down the rest this spring. Whether the citizens will allow any to be re-started remains to be seen. Economy minister Yukio Edano said he does not expect any nuclear power plant to be operating this summer, but thermal power and conservation efforts should be enough for the nation to get by.

The UK criteria for siting nuclear power plants consider only a small radioactive release and fallout reaching 30 km. Yet the Fukushima release was about 4000 times as much and the NII Fukushima 'reasonable worst-case scenario' release is about 270,000 times as much. According to the Kondo Report, the worst case release would require evacuation for 170 or 250 km or more, e.g. from Hinkley Point to Birmingham or London. Also the compensation for the land and property losses and the decontamination costs would be far larger than for Fukushima, at roughly £ 1 trillion. So the UK siting criteria are wholly inadequate and almost all the citizens of Britain are threatened by the existing and proposed nuclear power plants. In the words of Dr John Gofman, this is 'licensing random premeditated murder'. Thus the former must be phased out forthwith and the latter abandoned.

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The Full Study, with Tables, Figures and References, may be downloaded from:
http://www.energypolicy.co.uk/FukushimaRealLessons.pdf

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