Fukushima: What Happened and the Real Lessons for Energy Policy

Gordon Taylor

G T Systems

www.energypolicy.co.uk

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Summary

1 – Decay Heat after Shut-down and It's Implications

2 – Health Effects of Radioactive Releases

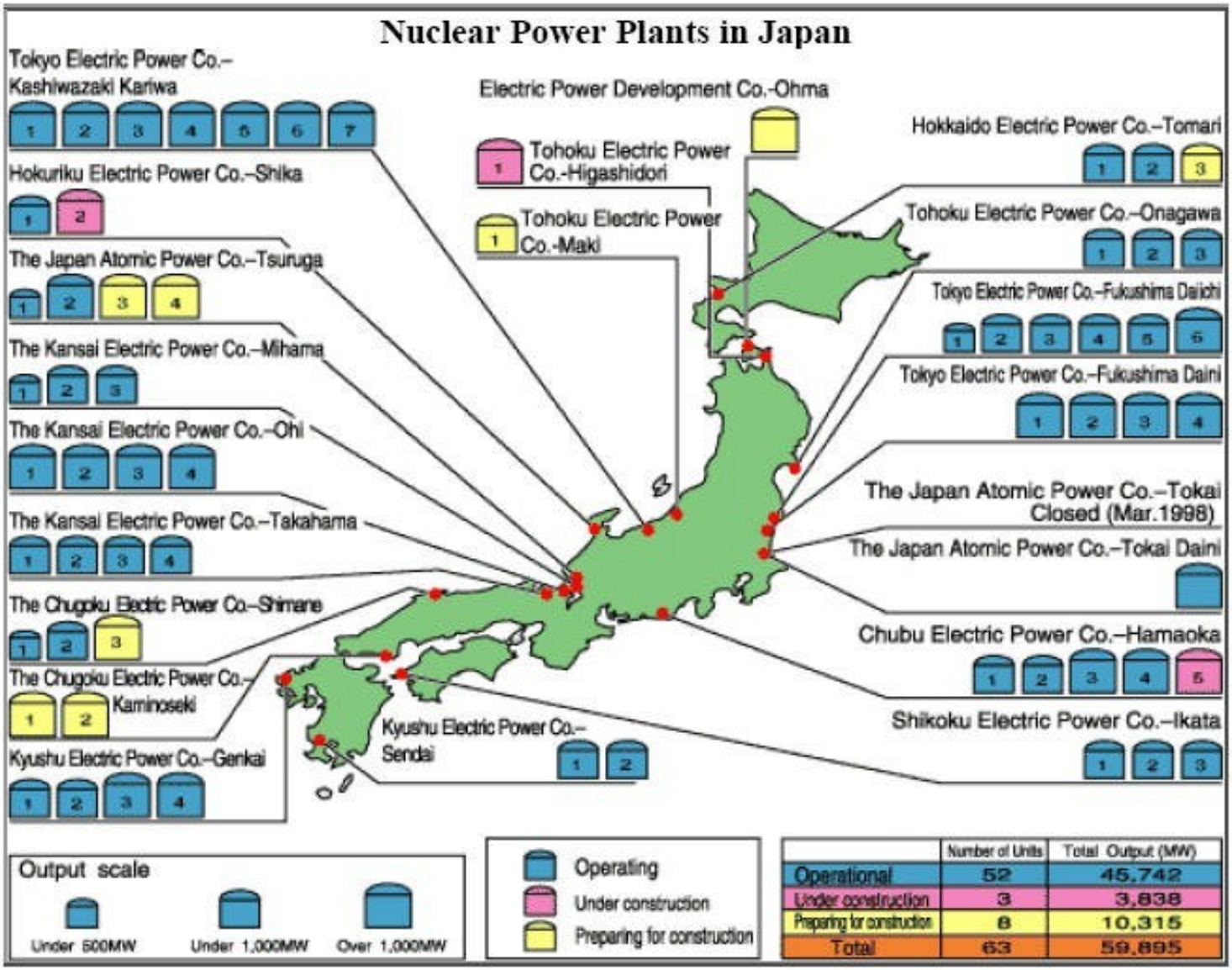
3 – Readiness for Nuclear Disasters

4 – Worst Cases and Probabilities

5 – Insurance and Ethics

6 – Real Lessons of Fukushima and Siting Criteria

7 – Rational, Robust and Sustainable Energy Policy



nucleartourist.com

1 - Decay Heat after Shut-down

Occurs always with all nuclear power plants.

In the event of a Station Black-Out (SBO),

Gives rise to a Loss of Cooling Accident (LOCA)

And within hours, Meltdown of nuclear fuel rods,

And the production of Hydrogen, which can explode,

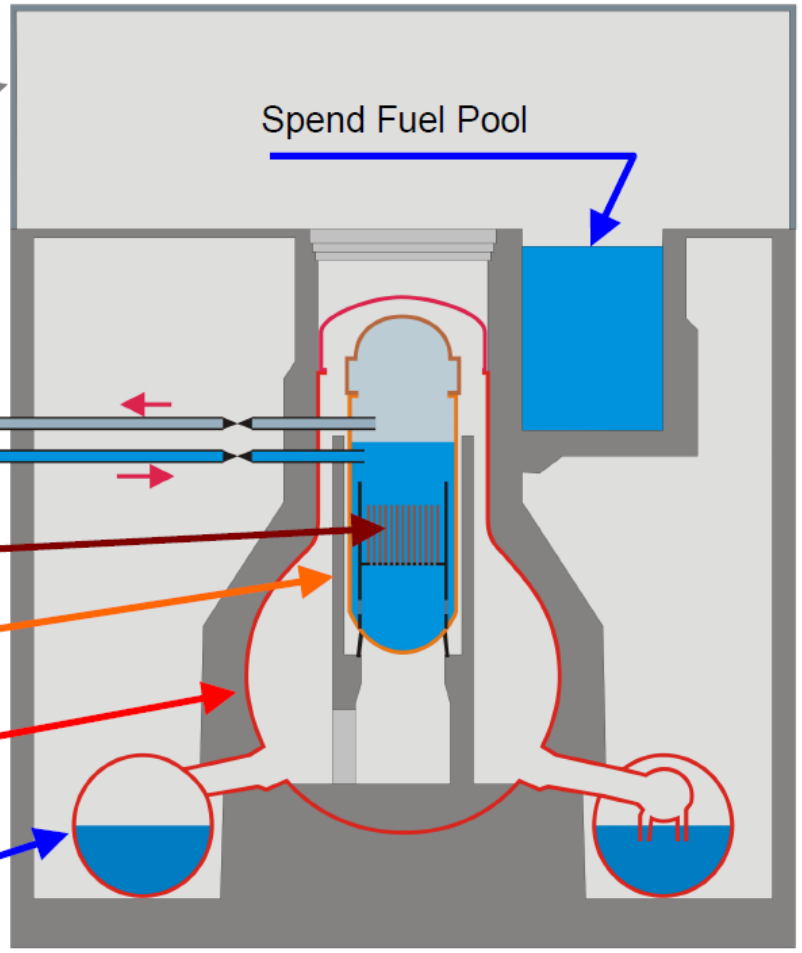
Breaching the final containment,

Releasing Radioactive Fission Products and Fallout

The Fukushima Daiichi Incident

1. Plant Design

- Reactor Service Floor (Steel Construction)
- Concrete Reactor Building (secondary Containment)
- Reactor Core
- Reactor Pressure Vessel
- Containment (Dry well)
- Containment (Wet Well) / Condensation Chamber

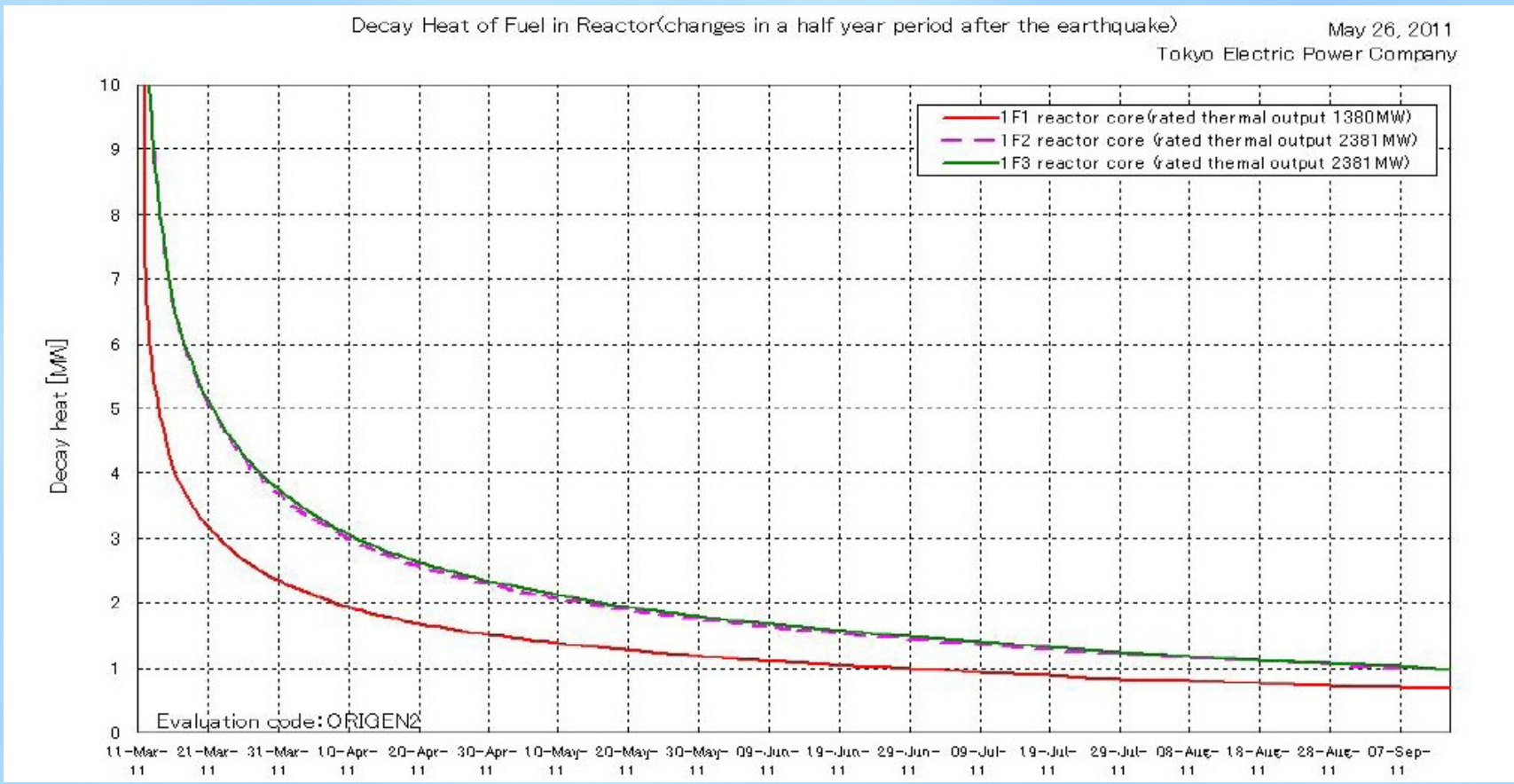


AREVA

Implications of Nuclear Power

- After shut-down, all nuclear fuel produces 'Decay Heat', which can lead to radioactive releases
- From Reactor Safety Studies, the worst releases result from 'Loss of Cooling Accidents'
- These happened at Windscale, Three Mile Island, Chernobyl and now Fukushima
- The Consequences of radioactive releases include personal injury/death, business, land loss and costs

Decay Heat Curves - Fukushima



Loss of Cooling - 1

- Decay Heat – in the Reactors and Spent Fuel Pools - requires pumped cooling for years
- Losing both the grid connection and standby generators is known as 'Station Blackout'
- Thereafter the cooling pumps depend upon batteries, lasting only 4 or 8 hours
- Unless grid or standby power is restored, the Reactors and Spent Fuel Pools will overheat

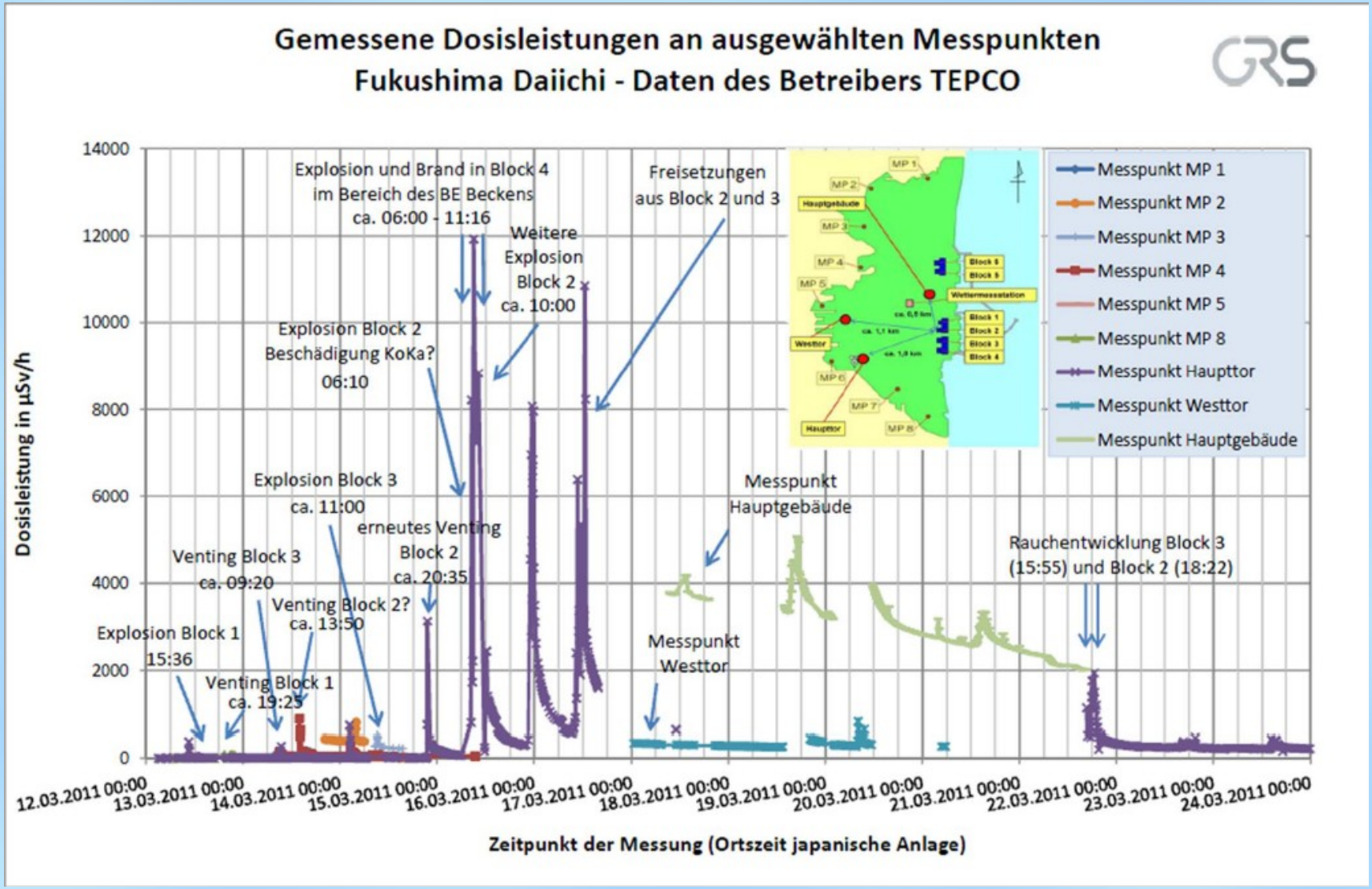
Loss of Cooling - 2

- Reactor fuel can reach 'Melt-down' in a few hours releasing highly radioactive Fission Products
- At the same time, the overheated fuel cladding produces hydrogen, which will probably explode
- The explosions will breach the final containment so releasing Fission Products to the environment
- These are carried by the winds until they fall out and by any water pumped in for cooling

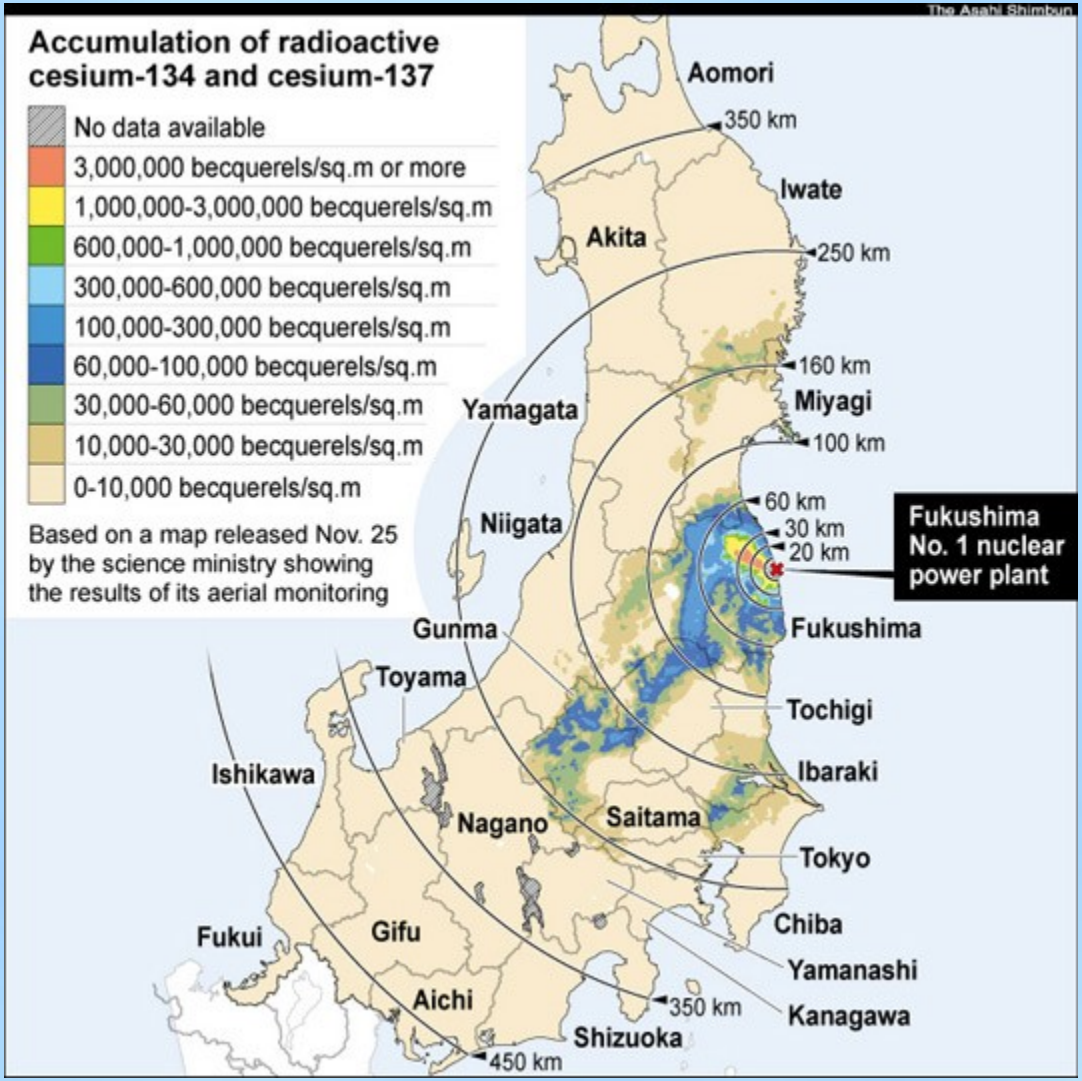
Fission Products (examples)

Isotope	Boiling Point - C	Half Life	Radiological Equiv. I131
I131	184	8 days	1
Cs134	678	2.1 y	3
Cs137	678	30.2 y	40
Sr90	1384	28.82 y	20
(U235)	3818	704 million y	500 - 1000
Pu239	3232	24,360 y	10,000

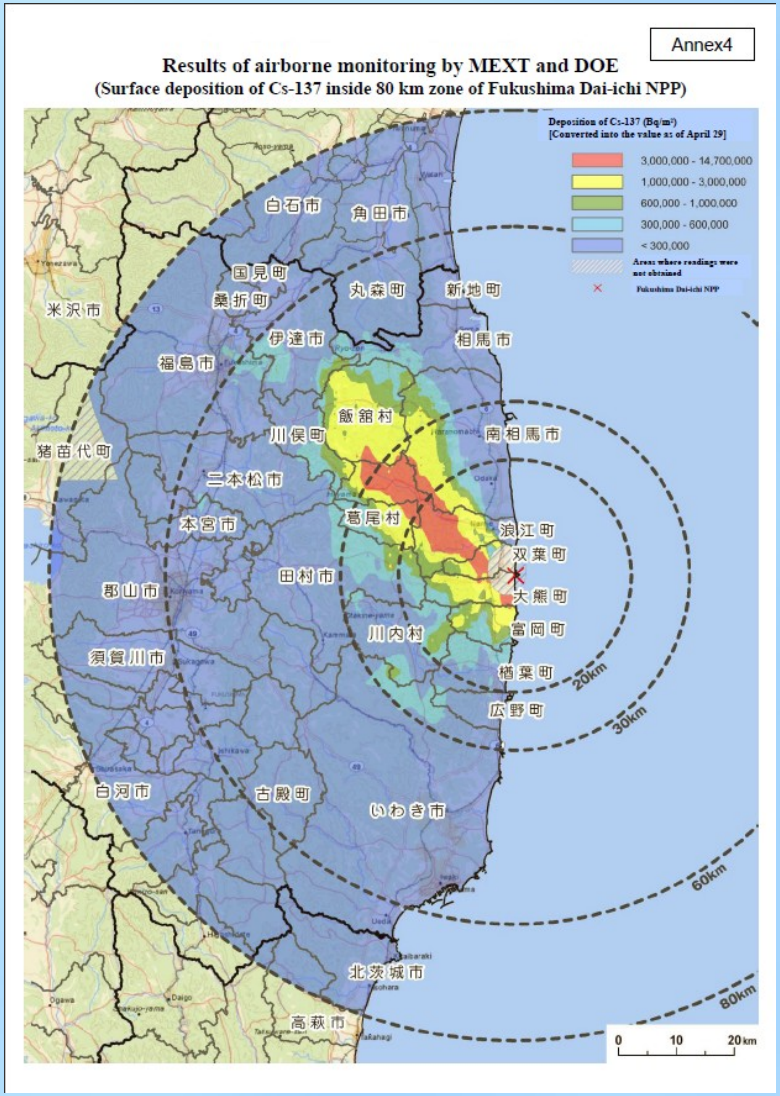
Fukushima Daiichi – Dose Rates v Time



Fukushima Daiichi – Fallout - 1



Fukushima Daiichi – Fallout - 2



2 – Health Effects of Releases

Institutions – IAEA a promoter, while WHO is muzzled

Magnitudes of Prompt and Latent Cancers and Deaths

Evidence from Atom Bombs, Testing and Chernobyl

Effects of this last were minimised by IAEA-WHO

Yet evidence from Chernobyl is in over 30,000 reports

Best summary in English is Yablokov et al, 2009

Latent Deaths 1986 to 2004 is put at 985,000

Now we have Fukushima

Health Effects - Institutions

- The International Atomic Energy Authority (IAEA) promotes nuclear power
- Even the World Health Organization (WHO) has deferred to the IAEA
- The US Nuclear Regulatory Commission (NRC) and the UK Office for Nuclear Regulation (ONR) are both too close to the nuclear industry
- The Biological Effects of Ionizing Radiation (BEIR) was set up by the US National Academy of Sciences
- The International Committee on Radiation Protection (ICRP) evolved from the US Committee on Radiation Protection
- Only the European Committee on Radiation Risk (ECRR) is independent of nuclear interests

Health Effects - Magnitudes

- Correct interpretation of the evidence is vital, since the human consequences could be huge
- The best evidence available is that from Chernobyl, now 25 years ago, most of which was originally published in Russian
- The best summary available in English is that of Yablokov et al, 2009, based on about 1000 of over 30,000 original reports
- As well as prompt injuries and deaths, the latent incidences, only manifest after decades, are far more numerous
- Radiation also damages DNA, leading to still-births and genetic deformities, including in all future generations
- So when assessing the evidence, it is vital to follow the Precautionary Principle, as endorsed by the European Union

Health Effects - Evidence

Interpretation of the evidence on health effects of ionizing (nuclear) radiation after Chernobyl, 1986, differs markedly

Date	Author	Model	Excess Deaths
2005	IAEA, WHO	ICRP	4000, 9000 for FSU to 2006
2011	IPPNW-GfS	ICRP	10,000 – 25,000
2006	Fairlie & Sumner	ICRP	30,000 – 60,000 worldwide
1994	Gofman	Gofman	475,000 worldwide
2009	Yablokov et al	Y. et al	985,000 to 2004
2011	Busby	ECRR	740,000–1,480,000 cancers, 50y
2006	Bertell	Bertell	899,600 – 1,787,000 eventual
2011	Busby	Tondell	2,450,000 cancers in 50 y

Fukushima Latent Health Effect Estimates

Author	Dose-Effect Model	Period - y	Excess Deaths
Cochran et al.	BEIR VII		350
Von Hippel, F.	ICRP	life	1000
Turkenburg, W.			~ 2000
Busby, C.	ICRP	50	3079
Busby, C.	Tondel	10	112,111
Busby, C.	ECRR	50	210,000
Vitazkova & Cazzoli	1 death/person-Sv	80	10,000 – 300,000+

3 – Readiness for Nuclear Disasters

Off-Site Centre some distance away, with air filtration

Thermal Model to predict progression of LOCA

Requires monitoring of Temperatures & Radioactivity on & near site

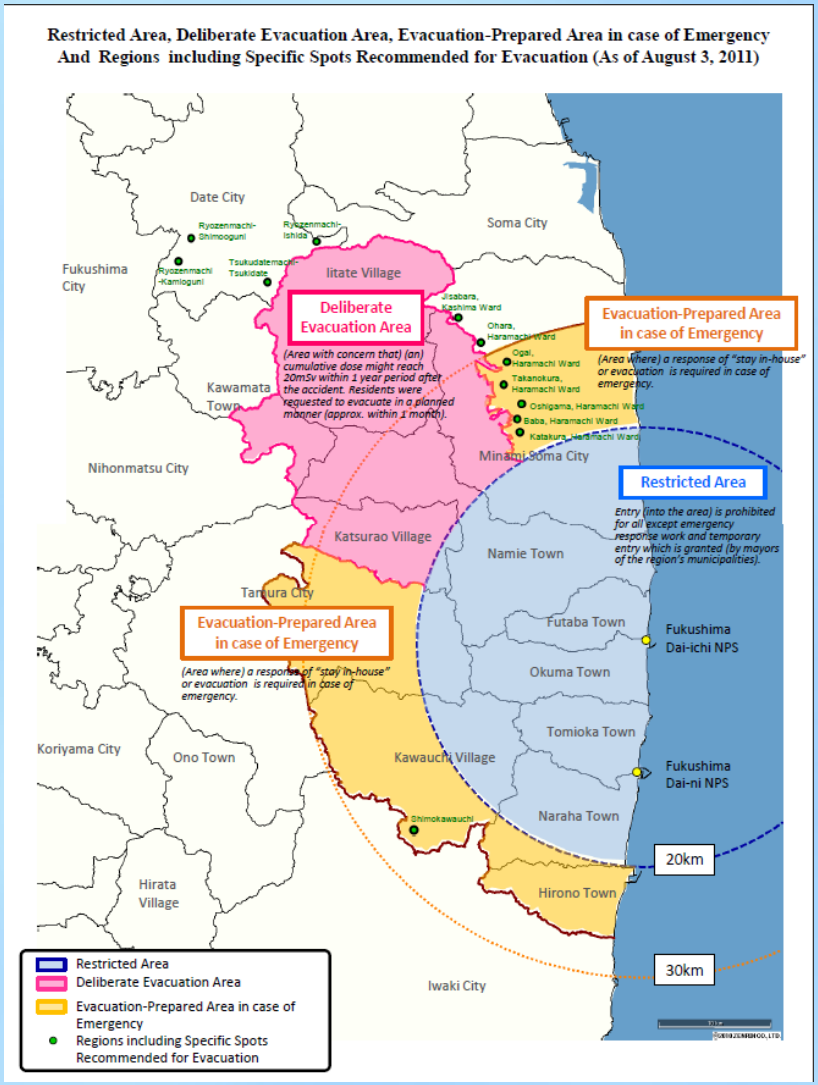
Plume Model to estimate path of Radioactive Release

Requires Real-Time Weather Data – wind speed, direction & rain

Communicate the Plume Model Output to Local Authorities

To inform the Populace about Evacuation Areas and Routes

Fukushima Daiichi – Evacuation Areas



4 – Worst Cases and Probabilities

Nuclear Releases to date are far short of worst case

Effect of larger Reactors

Effect of Multiple Reactors

Effect of Spent Fuel Pools

Effect of larger Release Fractions

Effect of release passing over larger populations

Fallout depends on wind speed, direction and rainfall

The Kondo Report - 1

Following the explosions and radioactive releases at Fukushima on and after 2011-03-12, the then Prime Minister of Japan, Naoto Kan, required Shunsuke Kondo, Chairman of the Japan Atomic Energy Commission, to report on the 'worst case' scenario.

This was delivered in late March 2011. It was not made public, but was reported in the Asahi Shimbun on 2012-01-07. The whole text was included in the 2012-02-28 report of the private panel on the Fukushima disaster chaired by Koichi Kitazawa.

The Kondo Report - 2

The Kondo Report - 3

The Kondo Report - 4

The 'worst case' scenario would require:

- Mandatory evacuation of all within 170 km

- 'Voluntary' evacuation of all within 250 km

These include Fukushima City, with 290,000,
Sendai, with 1 million
and Tokyo, with 35 million

Nuclear Releases – Actual and Worst Cases

INES	I131 equivalent - TBq	Event
(9)	5,000,000 – 50,000,000	Kondo 2011, Nuclear Installations Inspectorate 2011
(8)	500,000 – 5,000,000	
7	50,000 – 500,000	Chernobyl 1986, Fukushima 2011
6	5000 – 50,000	
5	500 - 5000	Windscale 1957, Three Mile Island 1979

Probabilities

Originally Risk was taken as Consequence

Later Risk was taken as Consequence x Probability

But Probabilistic Safety Analysis requires:

- Identification of accident sequences (billions)
- Probabilities for each unit in sequence (most are unknown)

In practice, far fewer sequences are considered

So the overall Probability must be an under-estimate

And is not just unknown, but unknowable

Hence Probability must be taken as 1 – i.e. inevitable

And Risk must be taken as Consequence

5 - Insurance and Ethics

- From the beginning of civil nuclear power in 1954, the worldwide insurance industry refused to provide complete cover
- The operators' interests were secured by limiting their liability with the Paris Convention of 1960 and the Vienna Convention of 1963
- These were prompted by US Price-Anderson Act of 1957 and followed by the UK Nuclear Installations Act of 1965 whereby, apart from a nominal amount, the risk is carried by the State
- Such 'Statutory Indemnities' are 'unquantifiable' – i.e. infinite
- The Versicherungsforen Leipzig found in 2011 that the mean sum payable for a nuclear disaster could be 6090 billion euros
- The German Ethics Commission found in 2011 that withdrawal from nuclear energy is necessary, recommended and possible because there are less risky alternatives

6 – Real Lessons and Siting

The IAEA and ONR reports lack detail and data

Deaths may be 350-3000 or 10,000-200,000

Contaminated land may be 13,000-30,000 km2

The plume passed over Tokyo, but it did not rain

UK siting criterion is 30 km, but Kondo is 250 km

The Real Lessons of Fukushima - 1

- Many quantitative studies have been found, but no proper studies from the IAEA or the UK ONR.
- Plume models of radioactive releases are essential to inform evacuations. The Japanese have such a plume model, but it was ignored until later.
- Also they had no instrument for airborne radioactivity measurements and had to rely initially on aerial surveys carried out by the US military.
- Yet these deficiencies were omitted or downplayed in the reports of the IAEA Fact Finding Mission.

The Real Lessons of Fukushima - 2

- Nearly 15,000 workers have received doses of up to 250 mSv.
- Excess cancers and resulting deaths may take up to 50 years to appear. Depending on the dose-effect model assumed, these may be 350 to 3000 or 10,000 to 200,000.
- About 80,000 persons have been forced to evacuate parts of Fukushima prefecture.
- Radioactivity above Japanese government limits has been found in many foods. This 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 Real Lessons of Fukushima - 3

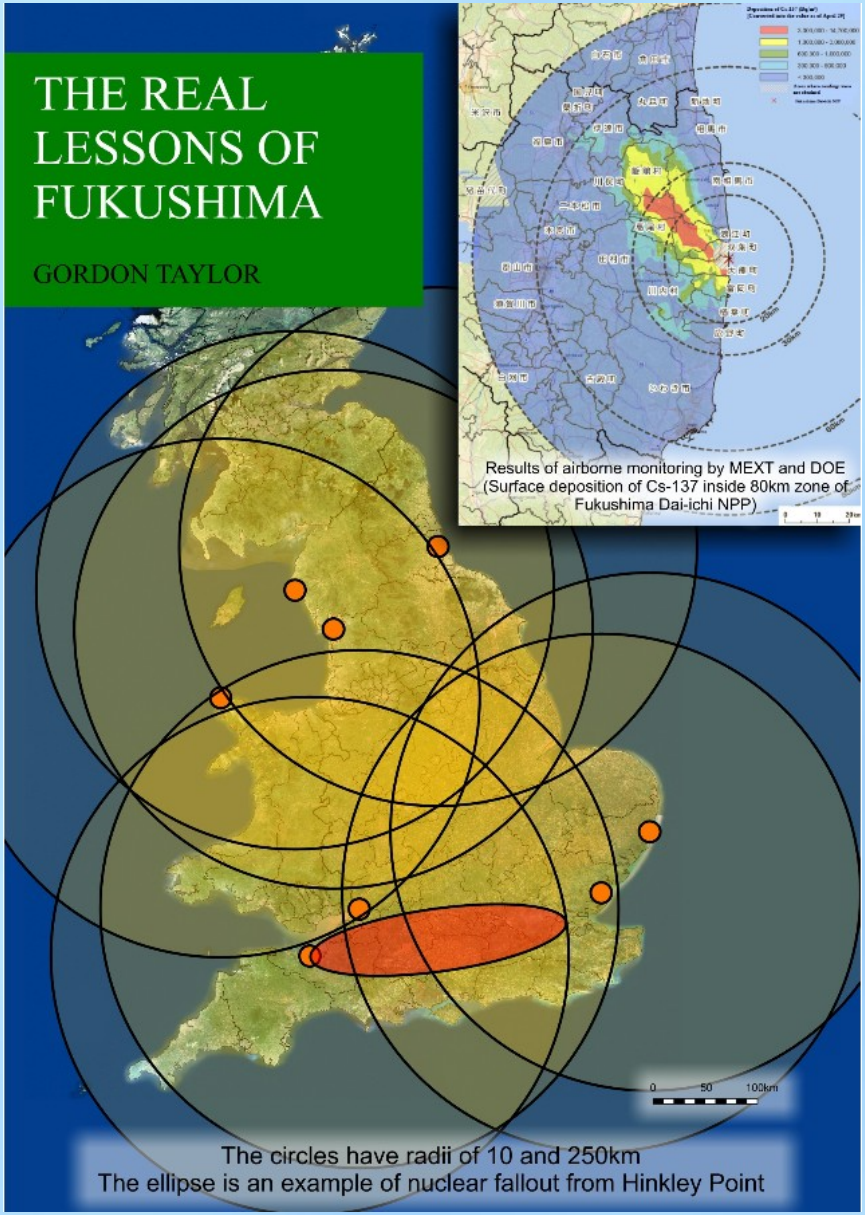
- The area of land contaminated with radioactive cesium to more than 10,000 Bq/m2 is about 30,000 km2, some 8% of the land area of Japan. Part of this will be uninhabitable for 10 to 20 years or more.
- According to the decontamination plan, the land area for which the dose to humans would be over 1 mSv/y is about 13,000 km2.
- 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. Since TEPCO is virtually bankrupt, almost all the cost must be met by the taxpayers.
- Such subsidies mean that nuclear power can never be competitive.

The Real Lessons of Fukushima - 4

- 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 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, as in the Kondo Report, have consequences that are even more horrific.
- Japan has shut down all the nuclear power plants. Whether the citizens will allow any number to be re-started remains to be seen.
- Germany, Switzerland and Italy have decided to join many other countries and phase out nuclear power.

The Real Lessons of Fukushima - 5

- 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 Nuclear Installations Inspectorate 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 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'.


THE REAL LESSONS OF FUKUSHIMA
GORDON TAYLOR
Results of airborne monitoring by MEXT and DOE
(Surface deposition of Cs-137 inside 80km zone of Fukushima Dai-ichi NPP)
0 50 100km
The circles have radii of 10 and 250km
The ellipse is an example of nuclear fallout from Hinkley Point

7 - Rational Energy Policy - Questions

- Oil is used for transport, gas and coal for heat and power, but what is electricity used for ?
- How much less energy could be used for all these services ?
- In the UK, electricity is 20% of energy

  and nuclear is 20% of electricity = 4% of energy, so what will replace the (depletable) uranium ?
- What will replace the 96% that is oil, gas & coal ?

7 - Rational Energy Policy - Answers

- After a major nuclear release, all nuclear plants may be shut down – as happened after Fukushima
- As the consequences are completely unacceptable, all nuclear power plants should be phased out
- Others are moving to supplying all energy services with increased energy efficiency and renewables
- These are safe, robust (not subject to disastrous events with huge consequences) and sustainable

Gordon Taylor

G T Systems

email: gordon@energypolicy.co.uk

Reports with References are at:

www.energypolicy.co.uk/TheCaseAgainstNuclearPower.pdf

and

www.energypolicy.co.uk/FukushimaRealLessons.pdf

More presentations and papers on energy are at: