

The Acceptance of Nuclear Energy

A Matter for Education

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Nature's "Instructions for Guests"
Energy for life
Fear and excitement
Natural science, imagination, technology
Placebo Effect, Nocebo Effect, and blind trials

Early mankind persuades and educates the frightened Green Party for a better life 600,000 years ago



The final confrontation with the Environmental Anti Fire Party

Lessons from food and its waste
Exhaust temperature
How to choose the ideal waste



Laws of natural science

1. Energy is conserved – it must have a source
2. Any concentration of energy leaks away, spreads out and disperses, eventually

Choosing fuel





ENERGY CRISIS FUEL WANTED

Sources **with a high concentration** of **primary energy**
that have **not already leaked** away and can be **controlled safely**

Energy density for hydro/wind/solar and their relative failure (simple Galileo physics)

Hydro: Energy density for any mass at height h of 100m

= $gh = \mathbf{981 \text{ J per kg}}$. Enough mass for one whole life = 10 million tonnes!

Wind: Energy density at speed $v = 10 \text{ ms}^{-1}$

= $\frac{1}{2}v^2 = \mathbf{50 \text{ J per kg}}$ of air (or water...). Power = 600 Wm^{-2} of turbine area

Solar: Similarly 600 W per sq m. average with no clouds.

Positive: Reassuring, “natural”, intuitive, transparent, popularly liked.

Negative: not “green”, only 20-30% availability, unpredictable, vulnerable, insecure, needs rare minerals, only 20 year life (wind/solar), needs a large grid – many MW-miles.

Cover picture from

National Infrastructure Assessment Report 10 July 2018



Solar

Intermittent.
Low energy flux,
worst in winter at
temperate latitudes.
So, needs a vast area,
e.g. a “meadow” near
Abingdon, Oxford.

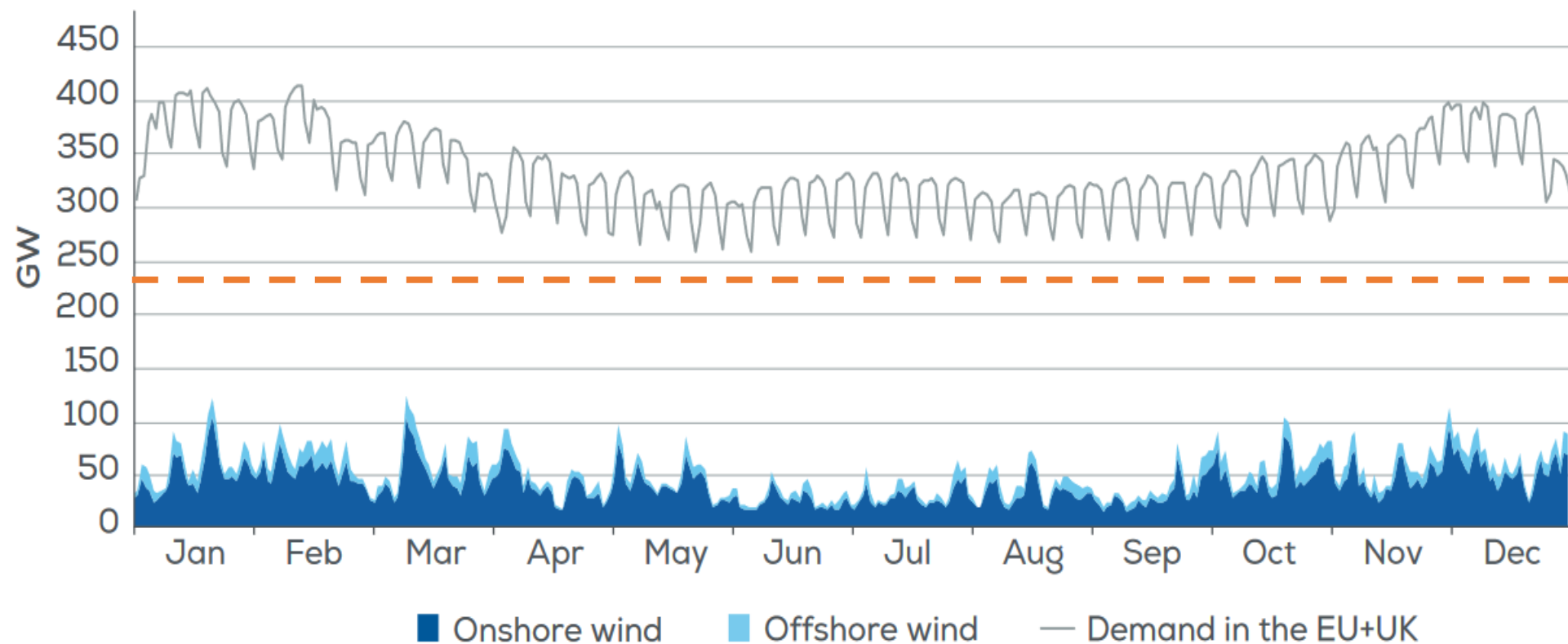
Not a “farm”, not “green”.
Hides nature.
Anti-environmental!

WindEurope 2021

Record daily production 103 GW on 11 March. Installed capacity 236 GW

FIGURE 8

Power demand and wind energy generation in the EU-27 and the UK in 2021 (GW)



Source: WindEurope

Where is the “clockwork” of food/chemistry/electronics?

Energy densities:

Hydro etc 0.001 MJ/kg

But the following energy densities are 10,000 times greater:

Biscuits 16.9 MJ/kg;

explosive (TNT) 4.6 MJ/kg;

LNG 55 MJ/kg

Lithium battery 0.6 MJ/kg;

Hydrogen 120 MJ/kg

Where is the hidden energy stored?

The Solvay Conference 1927 - “probably the most intelligent picture ever taken”



SOLVAY CONFERENCE 1927

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A. PICARD	E. HENRIOT	P. EHRENFEST	ED. HERSEN	Th. de DONDER	E. SCHRÖDINGER	E. VERSCHAFFELÉ	W. PAULI	W. HEISENBERG	R.H. FOWLER	L. BRILLOUIN
P. DIBRE	M. KNUDSEN	W.L. BRAGG	H.A. KRAMERS	P.A.M. DIRAC	A.H. COMPTON	L. de BROGLIE	M. BORN	N. BOHR		
L. LANGMUIR	M. PLANCK	Mme CURIE	H.A. LORENTZ	A. EINSTEIN	P. LANGEVIN	CHÉ. GUYÉ	C.T.R. WILSON	G.W. RICHARDSON		

Absent: Sir W.H. BRAGG, H. DESLANDRES et E. VAN AUDEL

Chemical energy and nuclear energy as quantum waves 1924

ALL matter described by waves with wavelength $= h/Mv$,
where $h = 6.6 \times 10^{-34}$ J s, M is mass in kg and speed v is in m/s.

An electron, as a wave **trapped in an atom like a sound wave in a musical instrument**, has kinetic energy $\frac{1}{2}Mv^2$
this is chemical/electronic energy.

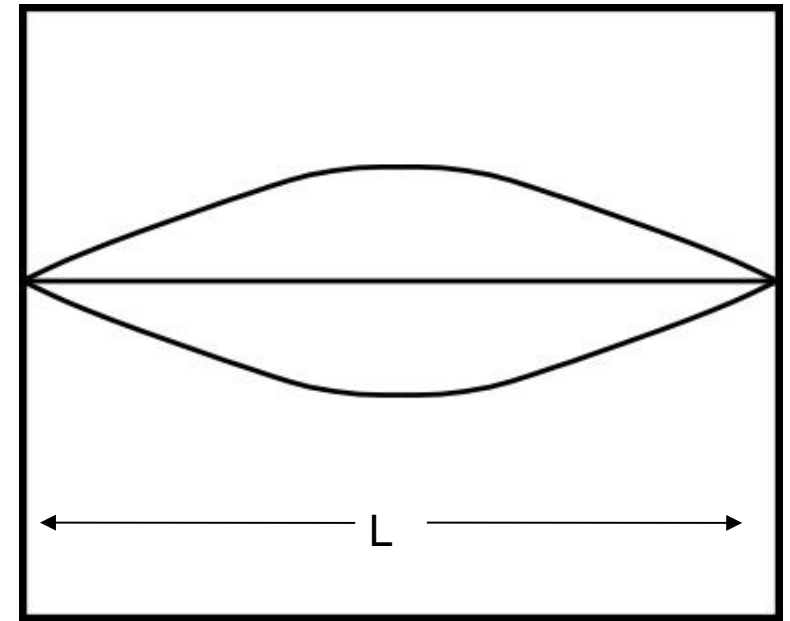
In exactly the same way, a proton or neutron as a wave **trapped in a nucleus**, has kinetic energy $\frac{1}{2}Mv^2$ **too**
this is nuclear energy.

Now let us actually work it out!

As in music,
a wave in a box size L has wavelength $2L$
(yes, there are harmonics and 3-D effects too)

So for a particle trapped in a box of
size L , the wavelength $= 2L = h/mv$.

Thence kinetic energy: $E = \frac{1}{2}mv^2 = h^2/(8mL^2)$.



1) Each **electron** wave must fit within its **atom**. All atoms similar size 10^{-10} m
the **chemical/battery/laser/food/electronic energy** scale is

Per atom $E = 7 \cdot 10^{-19}$ joules = 4 electron-volts. Per kg carbon = 35 MJ/kg.

2) Each **proton/neutron** wave must fit within its **nucleus**.

All nuclei similar size 10^{-15} m the **nuclear energy** scale is

$E = 3 \cdot 10^{-12}$ joules = 20 **million** electron-volts

Just by putting in the numbers for m and L for the two cases.

Mankind has still to recognise the true benefit of this huge number!

People should understand the difference between
1) nuclear energy, 2) radioactivity, 3) radiation

- **Nuclear energy** involves a nucleus and a neutron (fission), or two nuclei (fusion). Both are easily controlled
- **Radioactivity** involves a sole nucleus and is not controllable. It emits **Radiation just** once at random.
- **Radiation** damages atoms and molecules, **but not nuclei**
- **Radioactivity** and its **radiation** are not contagious
- **Radiation** does not make anybody or anything **radioactive**

The reaction of living tissue to radiation damage

- Live tissue reacts to radiation damage, dead tissue does not
- The cellular design of biology is optimised for protection
- The reaction repairs/replaces cells and adapts to improve the reaction
- This dynamic reaction is not suitable for description by maths

To defend against attack by radiation, oxygen, viruses, etc., life constantly changes and adapts its protection. But in this war-game radiation never changes the way it attacks. So in 3000 million years biology has learnt how to win!



Image from: <https://www.photobox.co.uk/shop/small-gifts/personalised-playing-cards>

What is a safe exposure to ionising radiation

Compare: normal metabolic heat production: $\sim 1 \text{ W/kg}$

Safe level for Ultrasound/MRI scan: 1 W/kg , same.

Dose to kill a tumour ionising radiation $2 \text{ J/kg/day} = 2 \text{ Gy/day} = 2 \cdot 10^{-5} \text{ W/kg}$

Safe level for Ionising Radiation (agreed 1934) $= 0.2 \text{ mGy/day} = 2 \cdot 10^{-8} \text{ W/kg}$

Why 50 million times more sensitive than MRI and ultrasound?

Effect of Quantum Mechanics. Photoelectric Effect, Einstein (1905)

A tiny fraction of atoms/molecules are smashed,

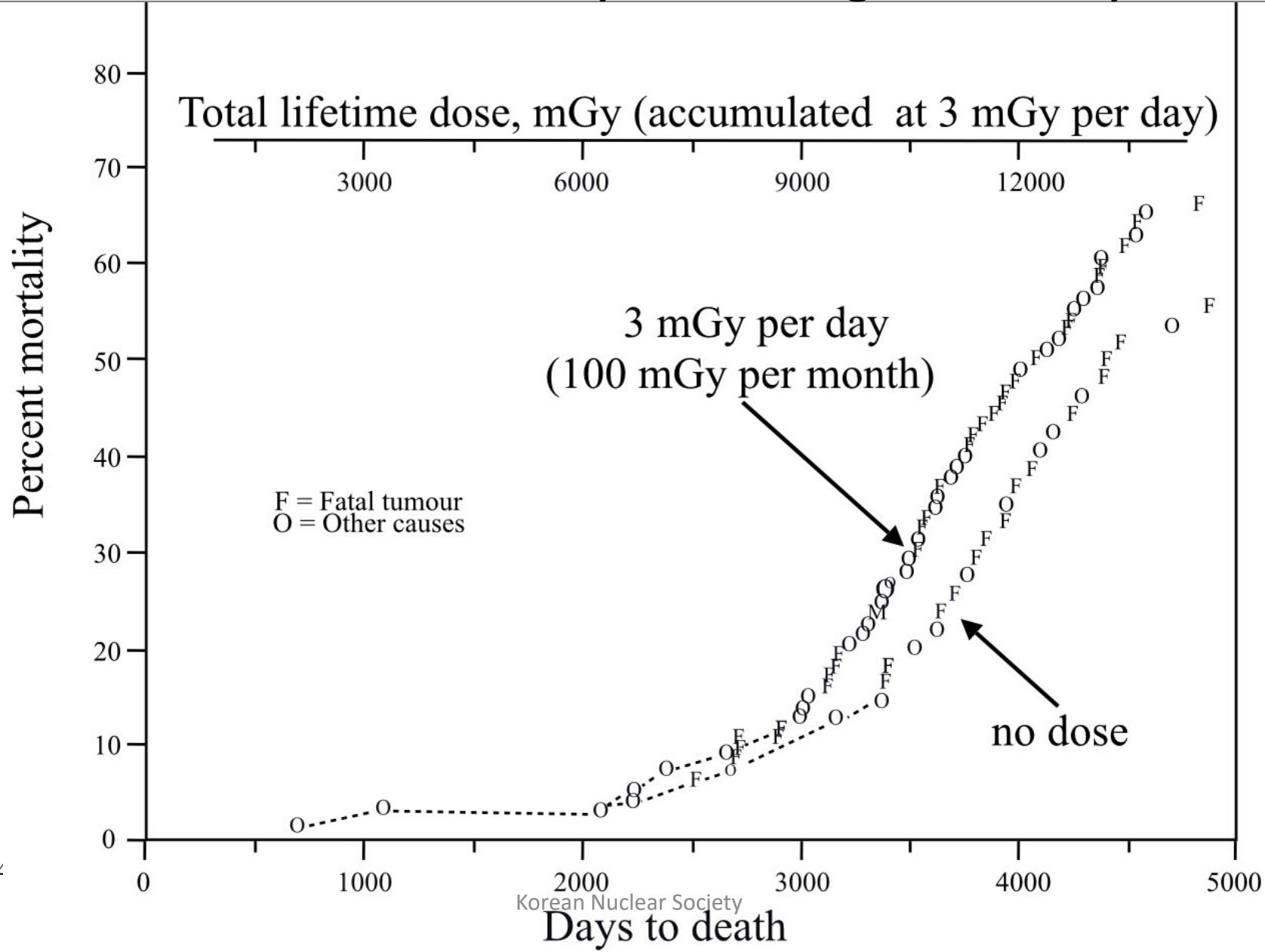
BUT others not touched at all.

This makes replacement/repair of DNA/cells clearer

Animals at Chernobyl are blissfully unaware, radioactive but thriving
[They have not been shown shock-horror documentaries on radiation]
So, is nuclear radiation harmless at low and moderate doses?
That is true!

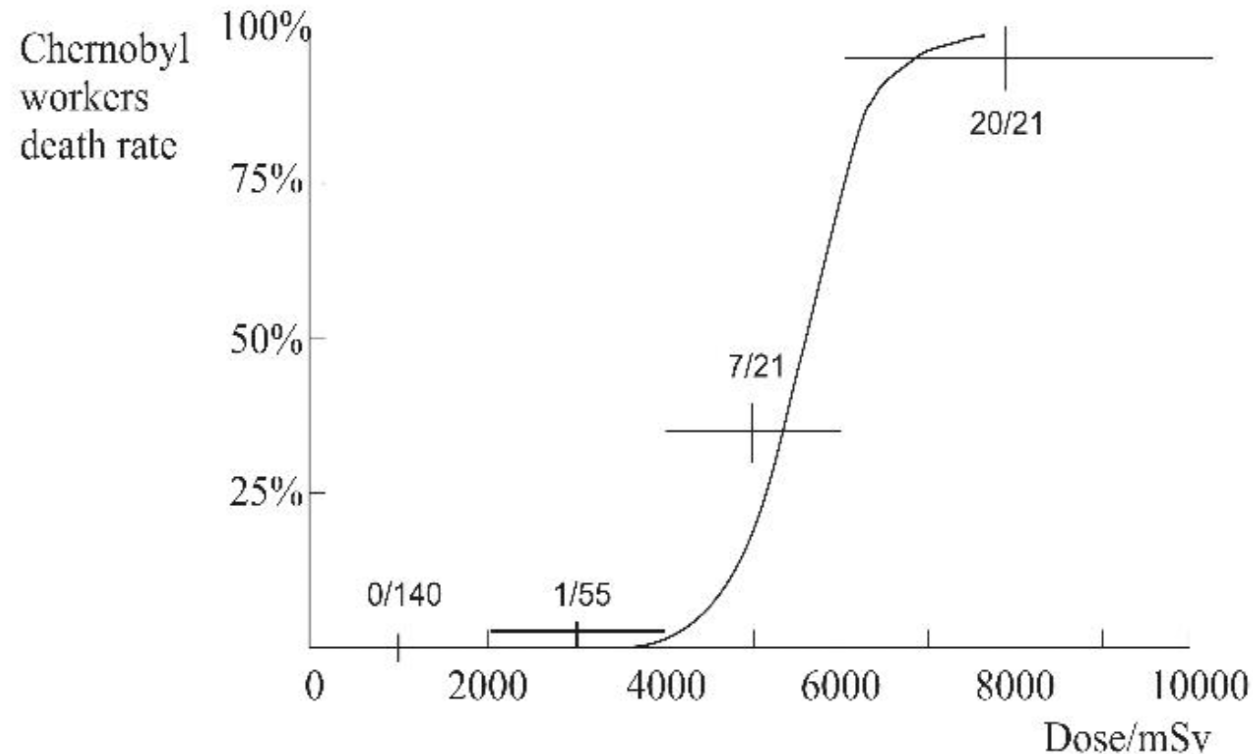


Mortality of beagle dogs given a whole-of-life chronic whole-body dose of gamma rays



Chernobyl early fire fighters

Of 237 early firefighters 28 died in a few weeks of Acute Radiation Syndrome. Crosses show their mortality (curve is for rats). The numbers show died/total in each dose range.



Suggests a threshold of 2000-4000 mSv for ARS in an acute dose. But what about cancer? And a chronic dose spread out over time?

A more significant accident.

70 internal doses of Caesium-137
Six early deaths.

All more than 1000 x the greatest
public dose measured at
Fukushima.

No cases of radiation-induced
cancer in 25 years.

But mental health, alcoholic
cases.



“On 13 September 1987, a shielded, strongly radioactive caesium-137 source (50.9 TBq, or 1375 Ci, at the time) was removed from its protective housing in a teletherapy machine in an abandoned clinic in Goiânia, Brazil, and subsequently ruptured.....” (IAEA)

The Radiological Accident in Goiânia



INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1988

The 3 stories of Fukushima March 2011

- The **unavoidable and deadly**. The earthquake and tsunami. Mitigated by brilliant education and personal responsibility. 18,000 deaths
- The **avoidable and commercially serious**. The destruction of 3 reactors. Made socially serious by total lack of education and competent authority. Zero deaths, even casualties, from nuclear.
- The **simply unnecessary but socially and environmentally deadly**. The evacuation and media-driven excitement. 2000 dead from evacuation Fossil fuel usage instead for a decade. Even worse in Germany etc.and then there was the water release!

Reassurance: radiation for personal health

Marie Curie 1867-1934

Nobel Prize in Physics, Nobel Prize in Chemistry,
her gift to the world in Medicine,
diagnosis and cancer therapy
with nuclear radiation.

*“Nothing in life is to be feared,
it is only to be understood.”*

1934 science-based international safety regulations.

1950s era of worldwide fear and distrust. Lead by Senator Joe McCarthy

1955-2022, the world (esp USA) demonised nuclear energy

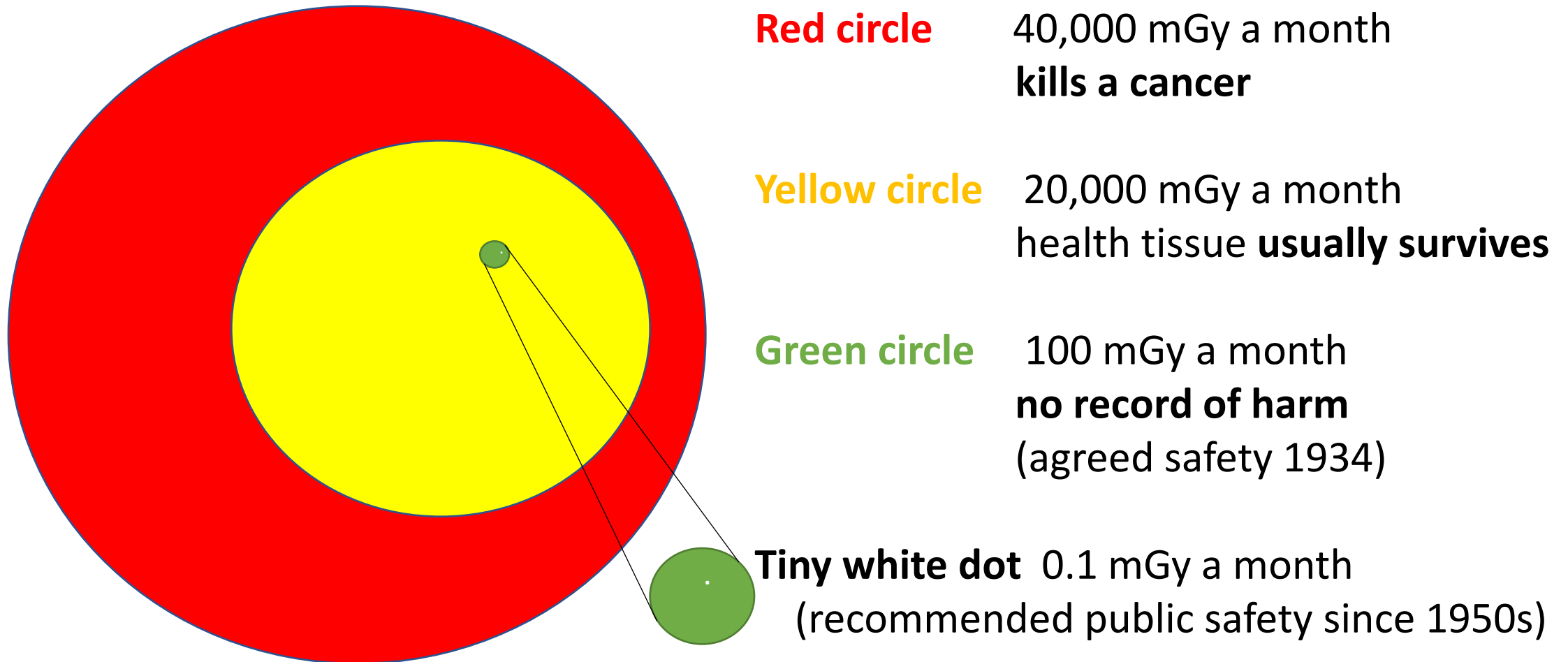
without scientific evidence and exaggerated caution a 1000 times!

Why have we allowed this to happen and to persist for 70 years?



High radiation doses welcomed for personal health.

Comparing monthly doses shown as areas --



Worldwide panic about nuclear radiation

1950s nuclear arms race with Soviet Union to build 000s of weapons

Nobody trusted the military and politicians to behave responsibly

Spies, foreign agents, secrets, nobody knew what was happening, fear.

Popular demonstrations in all western countries

Civil authorities and everybody frightened that radiation

1) damages DNA that is inherited by all later generations [certainly untrue] and

2) causes cancer [less than 1/2% addition to mortality of Japan bombs in 50 years]

Without evidence, radiation safety requirements tightened 1000 times “as a precaution”,

still maintained today secured with United Nations backing (US)

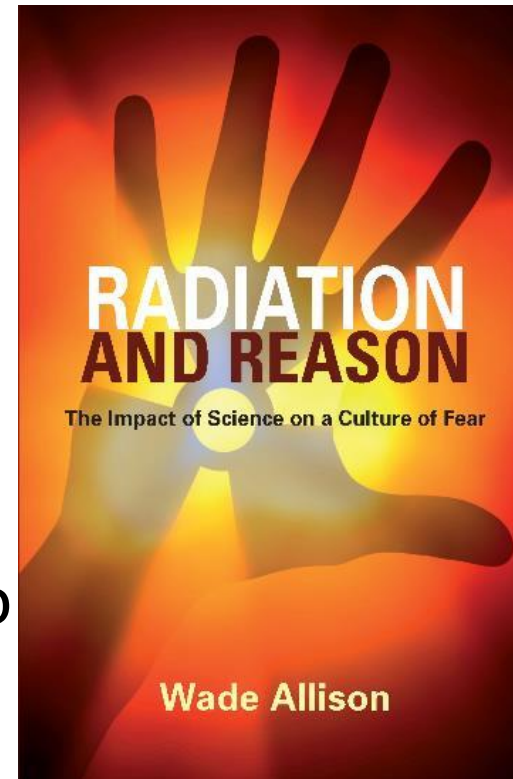
Serious consequences but no benefit

Social and environmental damage in accidents

Vast cost added to nuclear energy by over-design, over-regulation, enquiries and delay

Conclusion, nuclear energy is the only possible choice

- Are we sufficiently responsible to reverse the disastrous legacy of the 1950s, taking the matter up to the United Nations?
- Are we clever enough and organised sufficiently to accept responsibility for a new energy source, as when we accepted fire a million years ago?
- Are we ready to change regulations, and teach our children – not just experts – to welcome the benefits of the new nuclear age?



END

In biology, a little may be healthy,
even if a lot is poison.

as Rosie knows!

