Radiation, Safety and Life

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1. **Life needs energy - what are the options?**
2. **How nuclear energy can provide what is needed**
3. **Concern about the safety of ionising radiation**

Life needs energy

But without de-stabilising the environment for our children and fellow creatures.

Guidance from pure science, history and common sense:

1. Physical science – confidence where maths and axiomatic simplicity apply.
2. Biological science – confidence where design of life has been matched to its environment over aeons of time.
3. History – learning from understanding how we got here.
4. Common sense – keep it simple. Don't listen to the "sophistication" beloved by others!

We need to tell the children, urgently.

Messages from physical science

1. Expect no new energy sources – learn to use what we know
2. Energy is conserved – it cannot be made. All fuel comes from somewhere.
3. A concentration of energy may be used by letting it run down
4. Material can give energy if it is moving (kinetic) or uphill (potential). These are intuitively obvious and “classical”.
5. Any viable source of fuel must be plentiful, stable, available 24/7 and have been delivered by a superior agent.
6. Such agents work on distinct time scales:
   daily – sunshine and tidal forces;
   geological – fossil fuels laid down by ancient growth;
   primeval – products of supernovae older than Earth.

Most boulders have already rolled downhill.
Exceptionally. such energy is accessible.
Safety may conflict with ease of access.

Energy may be unstable and dangerous

Energy and stored energy are no different in principle

Energy density, J/kg or kWh/kg.
All classical energy - potential or kinetic

Potential energy density = *gh* J/kg at height *h.*

For example, at h = 100 m: 981 J/kg= 0.981/3600 = 0.0003 kWh/kg
not realistic to consider much higher.
Far lower dams have presented major accidents and safety threats.

Kinetic energy density = ½ V^2 J/kg at speed *V*

For example *V* = 30 mph (13 m per s) ½ 13^2 J/kg = 0.000027 kWh/kg

Compare ideal Wind Power at different speeds
mass per sq m per sec = V*density. Density = 1.3 kg/m^3
watts per sq m = ½V^3 *density = 330 watts per sq m at 30mph
2640 watts at 60mph; 41 watts at 15mph
Conclusion: cubic speed dependence of wind is a fundamental problem

Compare ideal Wind Power at 30 mph with Solar Constant
Wind 330 watts per sq m; solar constant 1300 watts per sq m
Conclusion: Wind and Solar power lie in the same range

The search for greater energy density

These energy density figures apply to any material.

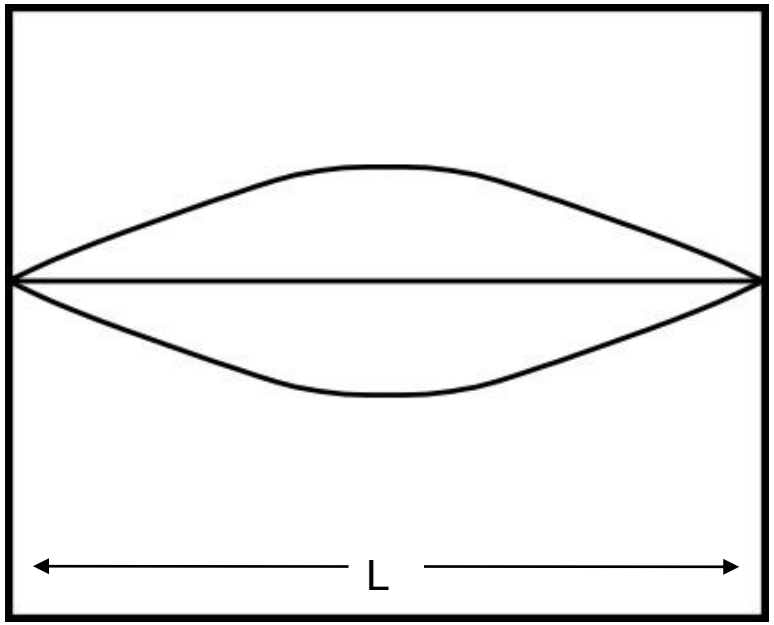
Heights over 100m and speeds over 60mph are not routinely available and bring safety concerns.

Hot gas molecules have higher speeds (speed of sound). For 200K temp rise, energy density of steam increases 400kJ/kg = 0.1 kWh/kg, but not a primary source.

Energy density of **food** printed on the package thus "2018 kJ per 100g serving". That is 5.6 kWh/kg, some 20,000 times the energy density of wind or hydro. Even 56 times super heated steam!

WHY? Where is the extra energy concealed?

Quantum kinetic energy



All matter is described by a wave with wavelength = *h/mv, where* *mv* = momentum and *h* = Planck's Constant

For a particle trapped in a box of size *L*, the wavelength = 2*L*.

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

1) Each electron wave must fit within its atom. 10^{-10} m

the chemical/battery/laser/food energy scale is

$E = 7\ 10^{-19}$ joules = *4* electron-volts = 7 kWh/kg for carbon

2) Each proton/neutron wave must fit within its nucleus. 10^{-15} m

the nuclear energy scale is

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

Just by putting in the numbers for each case

Available sources of energy and their relevance to the current environment

- **Classical:** Kinetic and Potential Energy according to Newton
  Moving and falling objects, motion of Sun and Moon, sunshine
  Wind, hydro, tides, waves, solar
- **QA – Quantum Atomic**: Energy from atomic structure of all matter
  Energy density many thousands times classical
  Chemistry, food, electronics, fuel combustion, batteries, etc.
- **QN – Quantum Nuclear**: Energy from nuclear structure of all matter
  Energy density some millions times QA
  Fission, fusion (the Sun), radioactive decay, volcanic activity, etc.
- **Gravitational collapse** (not now accessible on Earth)
  Even greater energy density in supernova explosions etc.
  Creation of all atomic nuclei heavier than iron, including the residual unstable forms: U238, U235, Th232, K40.

The development of life

Stages in the exploitation of these energy resources:

1. **Plant life.** No mobility, energy direct from sunshine.
2. **Animal life.** Mobility using food to fuel internal energy production by digestion. **Quantum Atomic**
3. **Early man.** Supremacy by using intelligence and external energy from other creatures and **Classical Sources**.
4. **Industrial Revolution**. Vast flowering of life with external energy production on demand, fossil fuels**. Quantum Atomic**
5. **Next Revolution.** Global Warming and turbulent weather. Need for new education and reformed use of intelligence.

Now at stake:
- the stability of the environment and the viability of life;
- the doubling of life expectancy and quality of life achieved as a result of the Industrial Revolution.

Note: Choosing nuclear is as natural as choosing nuts…

Animal life era: This enthusiastic follower of nature uses quantum energy internally and stores it for winter

	Animal era (only own body)	Pre-industrial era ("renewables")	Industrial Revolution (chemical/carbon)
Fuel	Foraged food	Other creatures, water, wind, solar, vegetation	Fossil fuels
Typical energy density (kWh per kg)	1 To 7	0.0003	1 to 7
Lifetime fuel per person	Life too short	Hydro: 10 million tonnes over 100 m dam (not available)	500 tonnes coal, 1800 tonnes CO2 emitted
Points in favour	No debate	Supremacy, familiar, accepted	24/7 availability, standard of living
Points against	Survival only	Intermittent, weak (huge plant damaging nature)	CO2 emissions, poor safety
Energy primed by	Daily sunshine	Daily sunshine	ancient sunshine

Solar, environmental?

Illustrated: a meadow, totally lost to nature, near Abingdon UK (and proudly exhibited by a totally misguided UK Government department)

1. Not "green" in any way. **Huge damaging footprint**, thanks to low energy flux.
2. **Unreliable and intermittent** with long breaks on continental scales for weeks at a time.
3. **No viable intermediate battery storage** solution available, or conceivable, on the scale required.
4. **Vulnerable** to major damage by extreme weather events as occur in increasingly turbulent atmosphere.
5. Quite short panel life, generating a major unsolved **waste** problem.

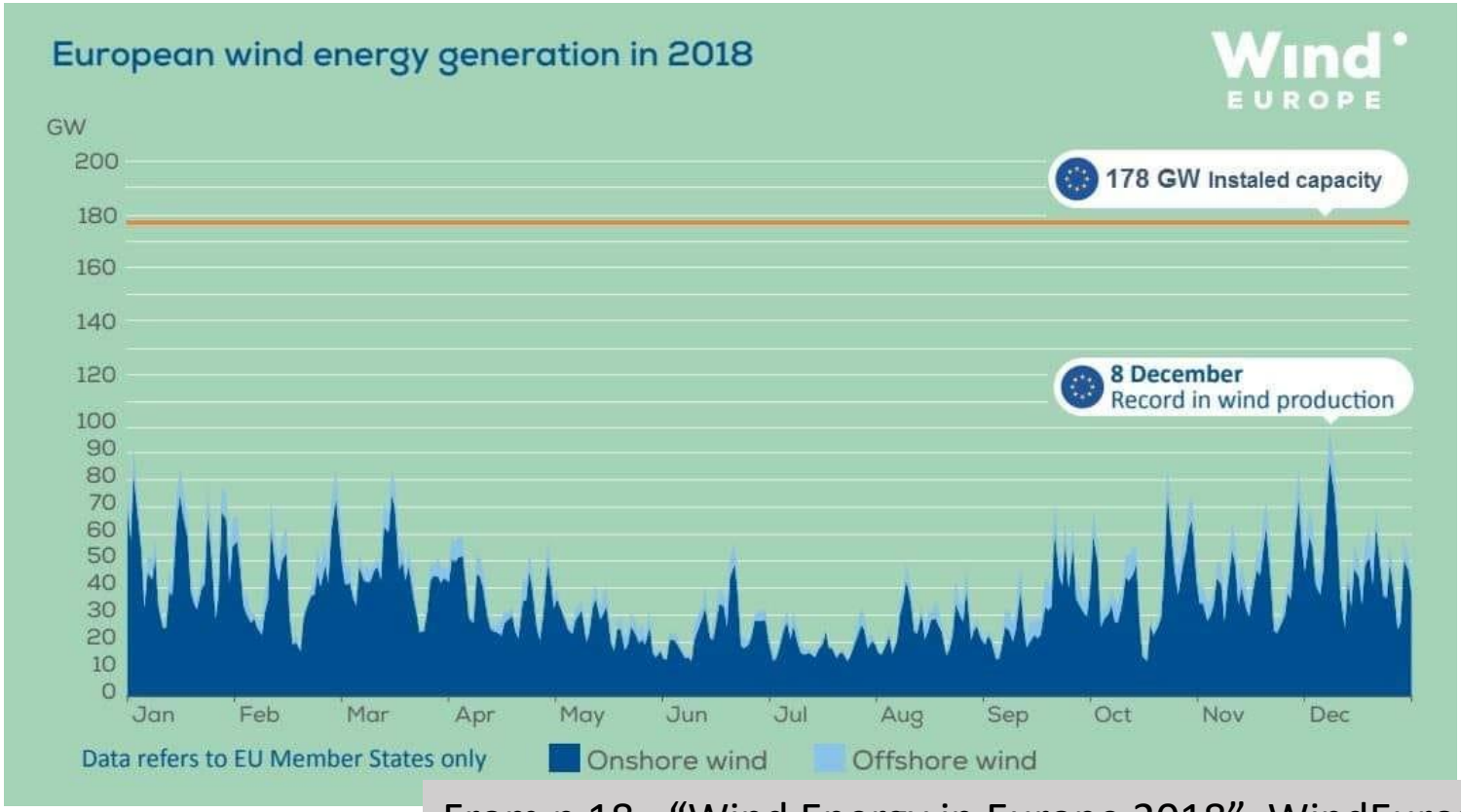
"No" to solar as a major primary energy source.

Resilience in a world with more turbulent weather eg hurricane in Puerto Rico…

Wind, reliable?

1. With Low energy density and low power flux, like solar, it requires **huge plant** at the expense of the environment. Not "green"
2. Unpredictable and variable output make production highly **unreliable**.
3. Cubic dependence of power on wind speed accentuates variability and makes for **grid "shock"** when tripped at high speed
4. **Capacity factor** 22%, even off shore only 37%

"No" to Wind, as major primary energy source.



From p 18, "Wind Energy in Europe 2018" WindEurope.org

Hydro, environmental/safe?

Many feared dead after Laos dam collapse

At least 100 people are missing and thousands have been left homeless by flash flooding.

1. Very low energy density and large environmental and social **footprint.**
   Examples: Yangtze, Me Kong, Snake River
2. Although apparently available 24/7, **vulnerable** to changes in rainfall including climate change.
   Example: Colorado River,
3. **Safety.** High loss of life recorded for dam failure.
   Example 230,000 (1975)
   https://en.wikipedia.org/wiki/Banqiao_Dam
   and threatened
   http://www.ibtimes.com/california-oroville-dam-evacuation-update-nearly-200000-people-evacuate
   also Whaley Bridge (Derbyshire2019)
4. Suitable locations are limited

"No" to a massive expansion of hydropower

- **Gas?** As now, but carbon emissions and poor security of foreign supplies (NordStream2, Middle East). **No to Gas**
- **Energy storage?** Scale needed:
  eg UK 36 Gw for days, a million MWh, about 3 10^{15} joules.
  Musk's Australian lithium battery offers 129 MWh
  Cost, replacement given battery life
  Battery technology limited by basic science
  – only small gains conceivable
  Safety of 3 10^{15} joules?
  One Hiroshima bomb 6.3 10^{13} joules
  Beware what you wish for. Battery accidents predicted.

2. How nuclear energy can provide what is needed

	Animal era (only own body)	Pre-industrial era ("renewables")	Industrial Revolution (chemical/carbon)	Next Revolution nuclear. fission, later fusion
Fuel	Foraged food	Other creatures, water, wind, solar, vegetation	Fossil fuels	Uranium and thorium (later hydrogen)
Typical energy density (kWh per kg)	1 To 7	0.0003	1 to 7	20 million
Lifetime fuel per person	Life too short	Hydro: 10 million tonnes over 100 m dam (not available)	500 tonnes coal, 1800 tonnes CO2 emitted	1 kg = 1/1000 tonne
Points in favour	No debate	Supremacy, familiar, accepted	24/7 availability, standard of living	24/7 availability, compact, resilient, no harm to life or nature
Points against	Survival only	Intermittent, weak (huge plant damaging nature)	CO2 emissions, poor safety	**Popularly feared, unfamiliar, education lacking**
Energy primed by	Daily sunshine	Daily sunshine	ancient sunshine	ancient gravitational collapse

To stop carbon emissions

- Stop reliance on **carbon fuels**, Polish coal or Russian gas
- Stop pretending that going back to pre-industrial sources, the so-called **"renewables",** could support life today
- Build a massive switch to **nuclear energy**, with changes to transport, agriculture, buildings, heating.
- Prepare for the social stresses that will come with such a rapid **cultural change** and its effect on governance, law, education, media.
- Build **trust and confidence** locally without simply relying on international authority with its failings.
- Engage with people's **motivation and understanding** at every level and by every means.
- Rely on **education for safety**, not just on regulations.

Nuclear energy is powerful but safe

and that is ideal – 1 kg for a lifetime. No waste!

It is much safer than fire, but why?

first because of physics (the basic nuclear energy)

second because of biology (the impact of radiation)

It is avoided by many people

they have never been told the true story

politics and the media tell a more exciting story

But all should come to accept it

they already welcome it for personal health

they need to see the firm evidence

Children in school, students on courses

nuclear is their future

they should start studying to ensure their survival

Physics ensures nuclear energy itself safe

- Nuclei are kept apart by +ve charge and they **never meet** except in lab experiments and
  - once in 10 billion years in the Sun;
  - frequently in supernova, neutron stars, etc
- Only neutrons can penetrate into nuclei and cause a reaction. But there are no neutrons in the wild, because they decay with 10 min lifetime.
- So nuclear reactions almost **don't happen**.
  Hence nuclear activity not discovered until 1896
- Nuclei do almost **nothing** (except some rotate, hence MRI)

Biology ensures nuclear radiation safe

- Radiation ionises/breaks molecules easily,
  but so does oxygen – oxidation
- Life on Earth evolved in a radioactive environment, even greater in the past
- So multi-level cellular protection:
  quenching,
  repair,
  replacement,
  surveillance by immune system.
  Effective against both oxygen and radiation
- If life had not found ways to be safe, we would not be here. Nor would any other forms, from single cellular organisms upwards.

3. Concern about the safety of ionising radiation

Understand, rather than follow the crowd

As the story of King Canute relates the tide ignored the King's command
Science and the laws of nature are deaf to the authority of governments, to the UN, to any legal decisions, majority votes and the influence of money

Understanding life

- Through evolution life exploits the statistical method of survival at two separate levels:
  - multiple semi-autonomous **individuals within society**;
  - multiple semi-autonomous **cells in the individual**.
- These manifestations rely on the occurrence of **outliers to initiate change**. This creates constructive tensions between a populist majority and a minority seeking change.
- Evolution has ensured that attention to ionising **radiation**, both for detection and repair, has been devolved to the **cellular level**.
- **Reasons:** the cellular system works well, signals very small, false alarm rates for the whole body would be very high, most life has no nervous system/brain to react.

The magnitude of radiation dose rates – is tiny

- A **radiation dose rate** is measured in Gray (or Sievert) per year.
  1 Gray (or Sievert) is 1 Joule of absorbed energy per kg.
- Background radiation rate is about 2.3 mSv per year
  Recommended additional ionising radiation limit is
  1 mSv per year = 1/1000 * 1/secs per year = 30 10^{-12} W/kg.
  The recommended Ultrasound and MRI safety = 1 W/kg. **Why?!!**
- **Quantum effect**: Ionising radiation is absorbed in a tiny number of big collisions instead of being spread uniformly as heat, **Einstein 1905**
- This means that biology has to cope with a **small number** of severely damaged atoms/molecules, the rest being untouched.
- In 3 billion years life has learnt how to **isolate/repair/replace** the damage. If it had not so learnt, we should not be here.
- Unfortunately, modern humans now have **instruments** to detect radiation at this level. Life would be safer and happier if they did not!

Animals at Chernobyl are blissfully unaware

Do they know something that we don't? To which Dr Watson might say

"But they know nothing!"

and to which Sherlock Holmes might reply

"Quite so. But may be something that we think we know is not so."

Nuclear radiation is apparently harmless at low and moderate doses.

Evolve and Adapt

To defend living cells against the effects of radiation and oxygen biology has been playing a game since life began – like a game of cards, if you like.
It has been trying to play a similar game against bacteria and viruses.

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

Why biology wins this game against the odds

The quantum energy of nuclear radiation is many thousands to millions times stronger than the bonds that hold the **feeble** molecules of life together. You might expect that nuclear would win against biology!

BUT

The physical science of radiation and the way in which it deposits its energy is local and fixed – its **game plan never changes**.

The strategy of biology **can change** and evolve.

So in the battle with the twin physical oxidising agents, **oxygen and radiation**, that always play the same game, biology has learnt over billions of years to win.

(Unlike in the contest with cancer or infectious disease where both **parties can adapt** and the outcome is uncertain.)

Indeed, this is the reason for the **structure of life** with its disposable self replicating cells and also disposable self replicating individuals

Conclusion confirmed by all available evidence

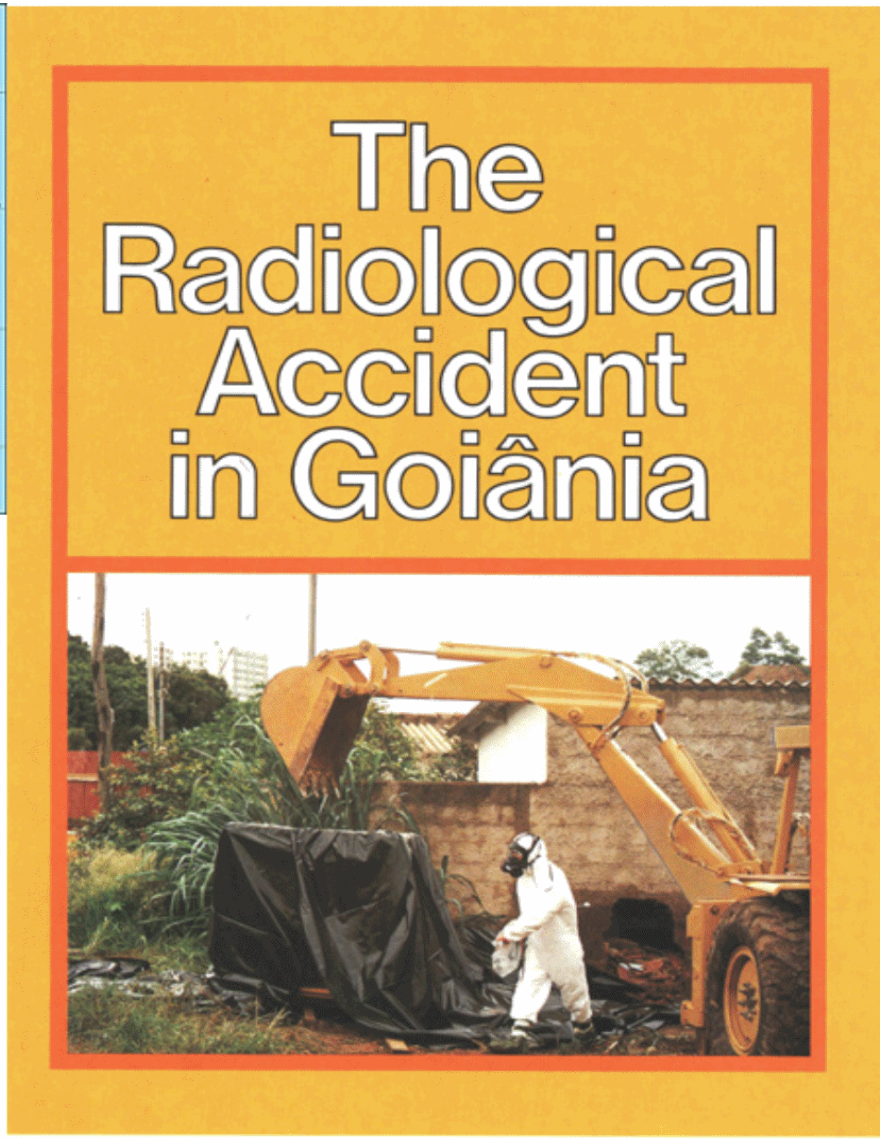
especially where people are unaware of the radiation:

- Cancer in regions with high background
- Fukushima www.bbc.co.uk/news/world-12860842
- Chernobyl
- Goiania, a very significant case
- Hiroshima and Nagasaki
- Animal experiments and in vitro studies
- A century of use in clinical medicine
- An understanding of evolutionary biology

But this has not stopped courts and authorities making vast payments to compensate for the self-fulfilling effects of fear.

Education and enlightened pubic information are the only cure, but it will take time.

"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 Goiania, Brazil, and subsequently ruptured....." (IAEA)



Goiania, Brazil (1987)

Therapy source taken home by scrap merchant and split open.

The radiation gave a pretty blue glow in the air!

Children played with it in the kitchen, it got on their skin and in their food.

They invited the neighbours in to see what they had found – then sold it to another family.

249 people significantly contaminated, over 50 internally.

4 died in a few weeks. 28 had operations for burns. 0 cases of cancer due to radiation in following 25 years.

Many cases of mental health, alcoholism, depression from the label “irradiated”

Significant cases of internal contamination more than 10,000 times the highest measured for any member of the public at Fukushima.

Two successful births to women contaminated.

Details later.

4. More on Goiania Whole-body internal Cs-137 activity compared to Fukushima and K-40

No	Whole body activity	Persons	Deaths	Relative activity
Goiania Cs137	Above 1000 MBq	1	1 ARS death	>100,000
Goiania Cs137	100 to 1000 MBq	7	3 ARS death	>10,000
Goiania Cs137	10 to 100 MBq	20	No deaths or cancers in 25 years	>1,000
Goiania Cs137	1 to 10 MBq	23		>100
Goiania Cs137	1/10 to 1 MBq	15		>10
Goiania Cs137	1/100 to 1/10 MBq	11		>1
Fukushima adults Cs137	At or below 1/100 MBq	32811	Not expected	Less than 1
Everybody natural K40	4/1000 MBq	all	--	
Fukushima children Cs137	All below 2/1000 MBq	1491	Not expected	

Reassurance: radiation for personal health

Maria Skłodowska-Curie 1867-1934

Nobel Prizes Physics AND Chemistry
establishing basic evidence
in nuclear physics

But best known and loved for her
work on radiation in Medicine,
Diagnosis and Cancer Therapy
as used for over a century

Radiation doses cover a huge range:

LOW 0.2 mSv per month body, rocks, space
MEDIUM 10 mSv at once in a CT scan,
may be repeated perhaps weekly
HIGH 20,000 mSv per month, or more, in radiotherapy treatment. 1000mSv per day

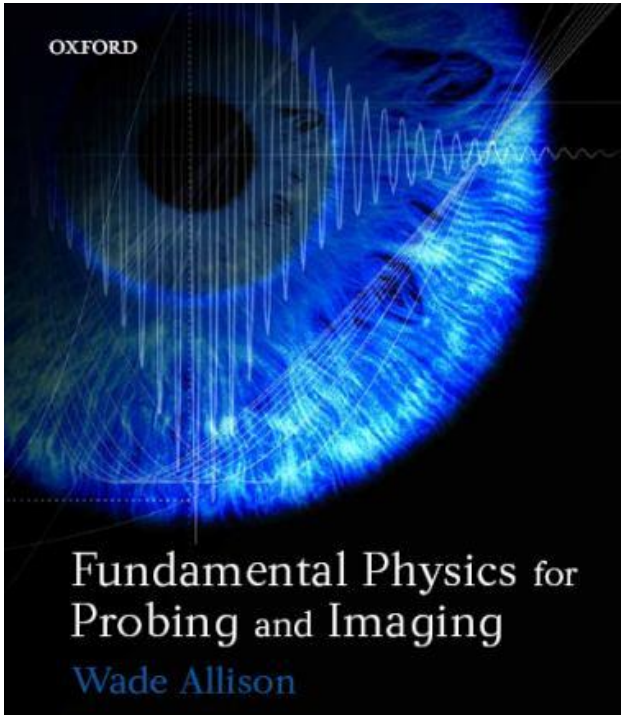
Read ***"Marie Curie and Nuclear Power"***
www.researchgate.net/publication/321020610_Marie_Curie_and_Nuclear_Power

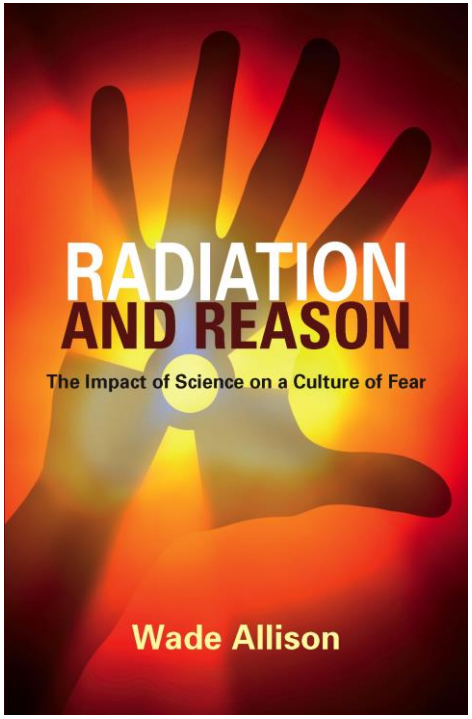
Protection and safety by Darwinian evolution or the deliberations of a UN committee

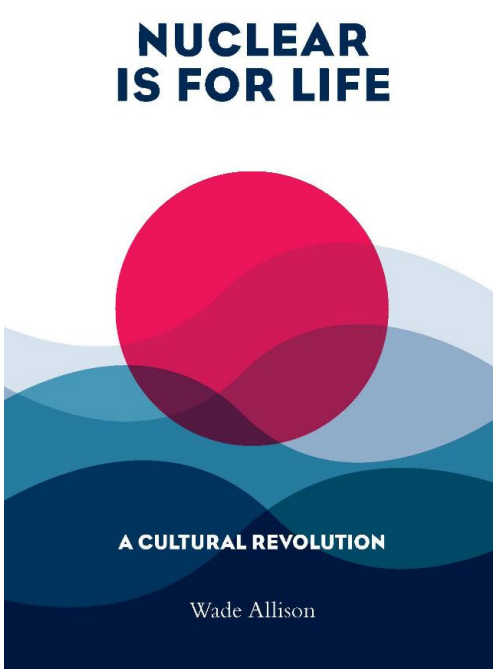
As Aesop's Fable of the Tortoise and the Hare illustrates

The natural protection of life, eg from ionising radiation, provided by slow evolution wins easily against regulation determined by committee

Books with references







First book is an advanced student book published by Oxford (2006). Last two are written in accessible language (2009 and 2015) and are available from distributors https://www.ypdbooks.com/science-and-technology/1690-wade-allison-special-book-pack-YPD01882.html and Amazon etc.
Also many articles, videos, lectures, tutorials, etc. free to download from www.radiationandreason.com www.nuclear4life.com and researchgate.

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