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UNDERSTANDING THE PLACE OF NUCLEAR IN THE SCIENCE OF ENERGY

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- **Young people worry about Climate Change, and demand a reasonable solution. As responsible scientists we should answer them.**
- A science-wide knowledgeable independent comparison of **energy options** leads to simple accessible and unambiguous conclusions.
- The factors of ten in the **fundamental science** stand above the details and possible technological advances.

THE PHYSICS OF ENERGY

- **Energy is conserved**. So fuel has to come from somewhere - or be **primed.** [First Law of Thermodynamics]
- A concentration of **energy dissipates** over time. [Second Law of Thermodynamics]
- A viable fuel should be compact (**high energy density**), stable (safe), available 24/7, resilient, secure (socially and politically), primed, plentiful.
- Three types of energy: **1) Familiar classical motion** of things moving/falling. Example, most **"Renewables" primed by daily sunshine;**
  2) Chemical energy Quantum motion of electrons in atoms (chemistry/electronics). Energy 10^4X"Renewables". **Fossil fuel primed by ancient solar**
  3) Nuclear energy Quantum motion of protons/neutrons in nuclei. Energy 10^{10}X"Renewables". **U/Th primed by primordial gravitational collapse.**

THREE ERAS OF HUMAN ENERGY USE

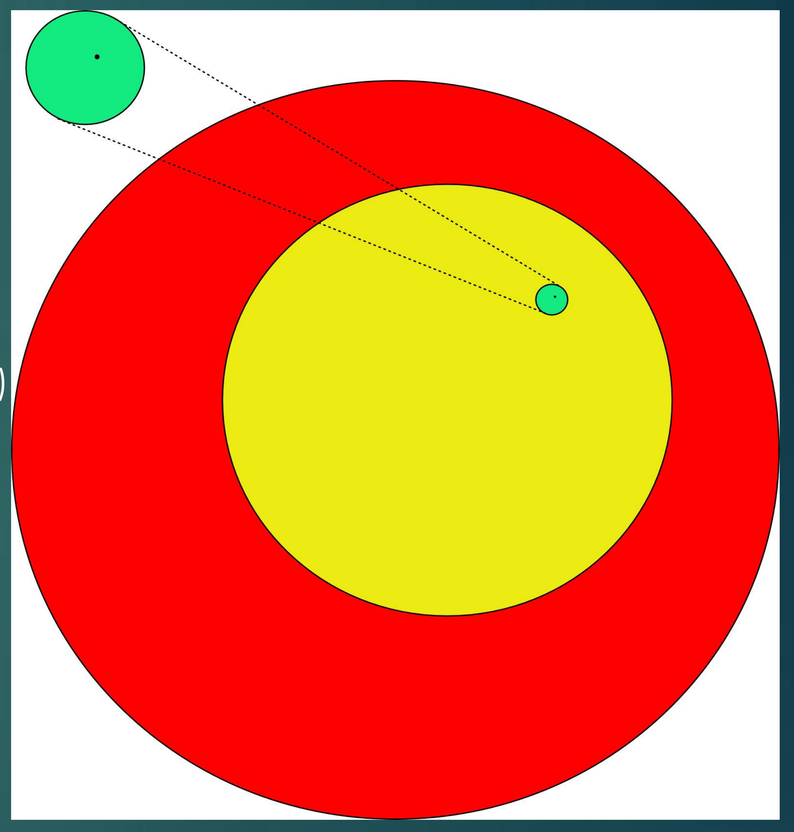
- **Pre-industrial:** the intelligence to use **external energy;**
  - other animals and wind/sun/water – "Renewables"
  - conquered the world but life short, unhealthy, miserable.
- **Industrial Revolution**: the intelligence to burn **fossil fuels;**
  - steam then power for chemical/electronic technology;
  - giant leap in standard of life, health and population.
- **Next Revolution**: the intelligence to **stop burning fossil fuels**;
  - **no role for "Renewables",** weak unreliable as before ;
  - build on the strength of **nuclear power**, cheap reliable safe;
    + small local plants with waste heat available;
    + security, resilience, less dependence on central grid;
    + **steady energy production** for electricity;
    + **desalination/hydrogen** production when less demand;
    + hydrogen for domestic heating, transport, industry;
    + vertical farming for food, season/location decoupled ;
    + recreation in an uninvaded rewilded environment.

The sole problem: the present culture of fear and apprehension of nuclear and radiation at all levels of society.

Human Era	Pre industrial	Industrial Revolution	Next Revolution
Fuel	Wind Sun Water, "Renewables"	Fossil fuels	Nuclear fission
Energy density kWh per kg	1/3000	1 to 7	20 million
Points in favour	Familiar, accepted	Available 24/7, living standard	24/7, safest, resilient, secure
Points against	Intermittent, weak, huge footprint	Emissions, unsafe	Fear. Ignorance,
Fuel per person per life	10 million tonnes	1000 tonnes	1 kg
Priming agent	Daily sunshine	Geological sunshine	Ancient stellar collapse

THE SAFETY OF NUCLEAR ENERGY ENSURED BY PHYSICS

- **Nuclei are permanently shielded** from reacting by the intense electric field that surrounds them;
- Only an uncharged **neutron** can unlock new nuclear energy, but they are unstable, decaying in 10 mins, and exist only inside a working reactor;
- **Nuclei do absolutely nothing** for billions of years – except rotate, as exploited in **MRI**;
- Exceptionally a single residual nucleus can **decay** having been primed either – because it was left over from stellar collapse before the Earth was formed (U235, U238, Th232, K40) – or exceptionally a residue of a recent nuclear event.
- The radiation emitted by **radioactive decay** was intense in the early Universe but less so today.
- Today **background radiation** from outer space, radioactive decay in rocks and our own bodies.

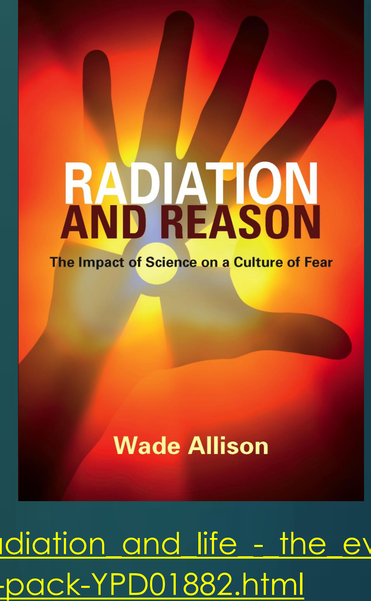


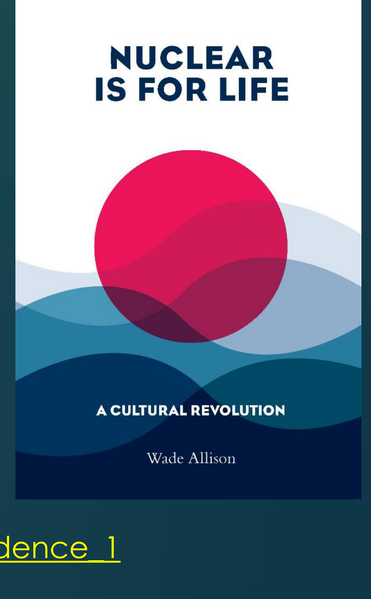
THE SAFETY OF IONISING RADIATION ENSURED BY BIOLOGY

- **Life evolved** in an environment of intense radiation.
- If biology had not secured a **complete set of overlapping protective mechanisms**, life would never have begun and we should not be here;
- Since the work of Marie Curie over a century ago moderate doses of radiation have been used to **diagnose disease** and intense doses used to **treat cancer** (monthly dose shown as the area of the **red circle**, 40 Gy per month; **yellow circle** dose to peripheral tissue, 20 Gy per month).
- The **green circle** (also magnified), ICRP safety limit agreed in 1934 remains scientifically adequately protective today, a limit of 70 mGy per month.
- A culture of fear was established during the **Cold War** and supported by unscientific ideas about radiobiology;
- The recommended limit of 1934 has since been tightened by a factor of several hundred (1 mGy per yr, area of the **black dot** in green circle). Safety not improved, but caused extra CO2 emissions, great suffering and unnecessary expenditure, for example after Chernobyl and Fukushima.
- Nuclear fuel gives a million times the energy of carbon, and leaves a **million times less waste**. This is not a significant problem.
- Nuclear power has the **safest record** of any energy source.

CONCLUSIONS

- N**uclear energy** is the only energy source that survives scientific scrutiny.
- The present **precautionary culture** obstructs and delays the rapid roll out of nuclear power needed to replace both fossil fuel and "renewable" plants worldwide.
- **Education challenge** is critical, to build the skill base and to get opinion formers on side – the media, teachers and politicians have never been told the truth.
- Climate Change brings likely **global dangers** that far outweigh any local nuclear risk.
- **Safety regulations** should be recast based on existing scientific evidence.
- Those concerned with **radiation safety** should review how they might best contribute towards a safe future in a new nuclear world.





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