The Next Industrial Revolution

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Plans and flowers get energy from sunshine

**Animal life: This enthusiastic follower of nature uses food energy internally and stores it for winter.
What should we do?**

The development of life

1. **Plant life.** No mobility, energy direct from **sunshine**.
2. **Animal life.** Mobility using **food**
   fuel producing energy **inside the body** by digestion
3. **Early man.** Supremacy by using intelligence and sources of energy **outside the body**: other creatures, wind, water, sun
4. **Industrial Revolution**. Engines burning **fossil fuels,** external energy on demand, 24/7.
5. **Next Revolution.** Green house gases and Global Warming
   Invaded environment and turbulent weather.
   A turning point
   What should we do now?   Stop using fossil fuels?
   Open study of options: pure science, medicine, sociology.
   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.

Messages from physical science

1. Energy cannot be made. All fuel comes from somewhere. Similarly energy cannot be destroyed. It must go somewhere. [First Law]
2. When fuel is used it runs downhill – dissipates. It doesn't run up again by itself! [Second Law]
3. **Wanted:** useful sources of fuel must be a) plentiful, b) stable, c) available 24/7, d) have been "put there" by some superior source.
4. Available agents work on three distinct time scales:
   daily/seasonal – 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.

Photo of Notre Dame on fire

(removed for reasons of copyright)

Energy may be unstable and dangerous

Energy and stored energy are really no different

Where is energy to be found?

Moving and falling "stuff". Intuitive and transparent.
In Mechanics: $E = ½mv^2$ and $E = mgh$
So energy density at 30 mph = 0.000027 kWh per kg
Also 100m high **hydro dam** density = 0.0003 kWh per kg.
Wind at 30 mph has 330 W per sq metre
Sunshine (no clouds) average 300 W per sq m.

Food?
"2018 kJ per 100g serving" printed on the packet.
Energy density = 5.6 kWh/kg, but no machinery seen.
Ten thousand times hydro! How is energy hidden?

Electrical energy.
Electrons travel through solid copper wire?
No clockwork. Something non-intuitive going on!

Greater energy density – Quantum kinetic energy

Heights over 100m? speeds over 60mph?
Not often available or safe.

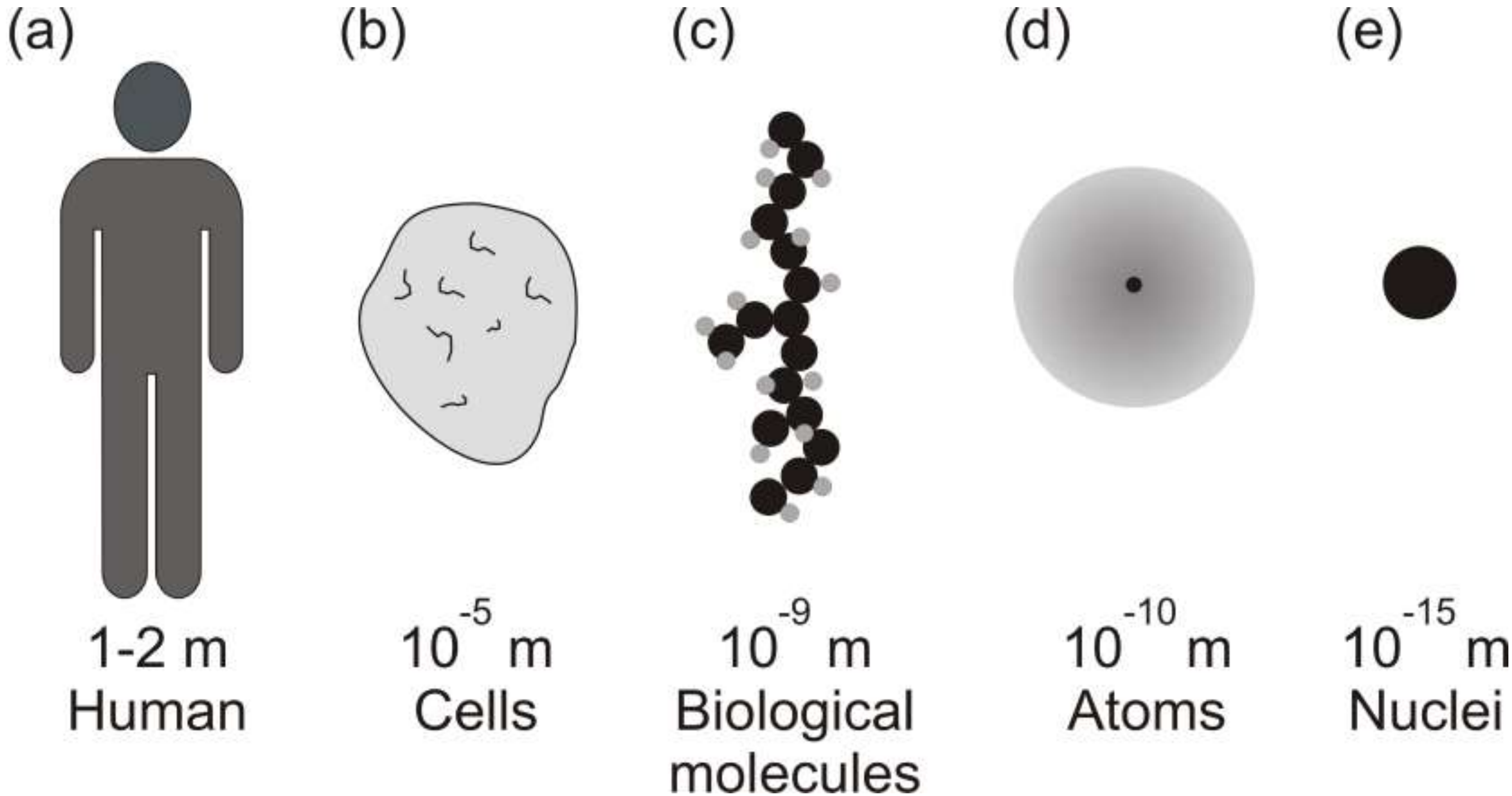
Hot gas molecules - higher speeds (speed of sound).
For 200K temp rise, energy density of steam increases 400kJ/kg = 0.1 kWh/kg.
Not a primary source and still 56 times less than food.

Extra energy? Modern basic Quantum Mechanics (1920s)

All matter is described by waves.

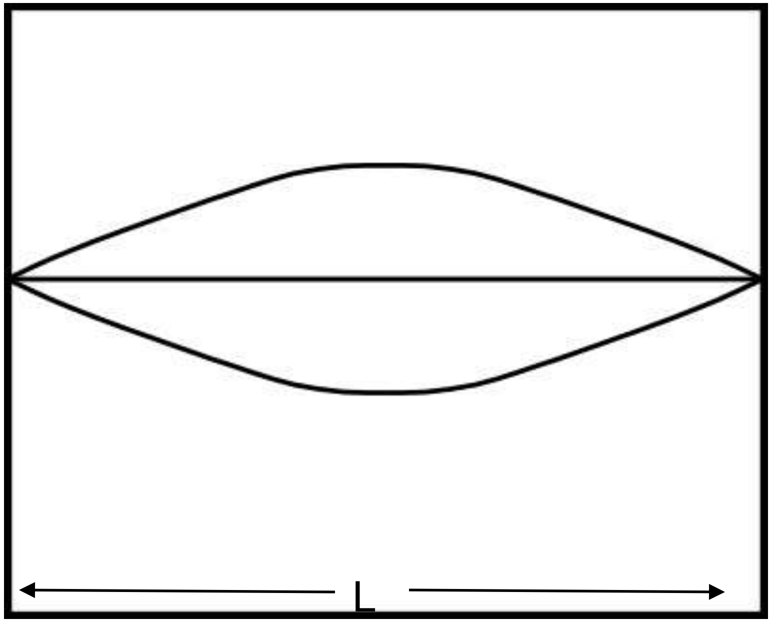
Electrons pass through solid copper as waves.

An electron trapped in an atom has kinetic energy $\frac{1}{2}mv^2$, similarly a proton or neutron trapped in a nucleus – ah!!



Stepping down by factors of 100,000!

Quantum kinetic energy



All matter is described by waves 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* = *h/mv*.

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

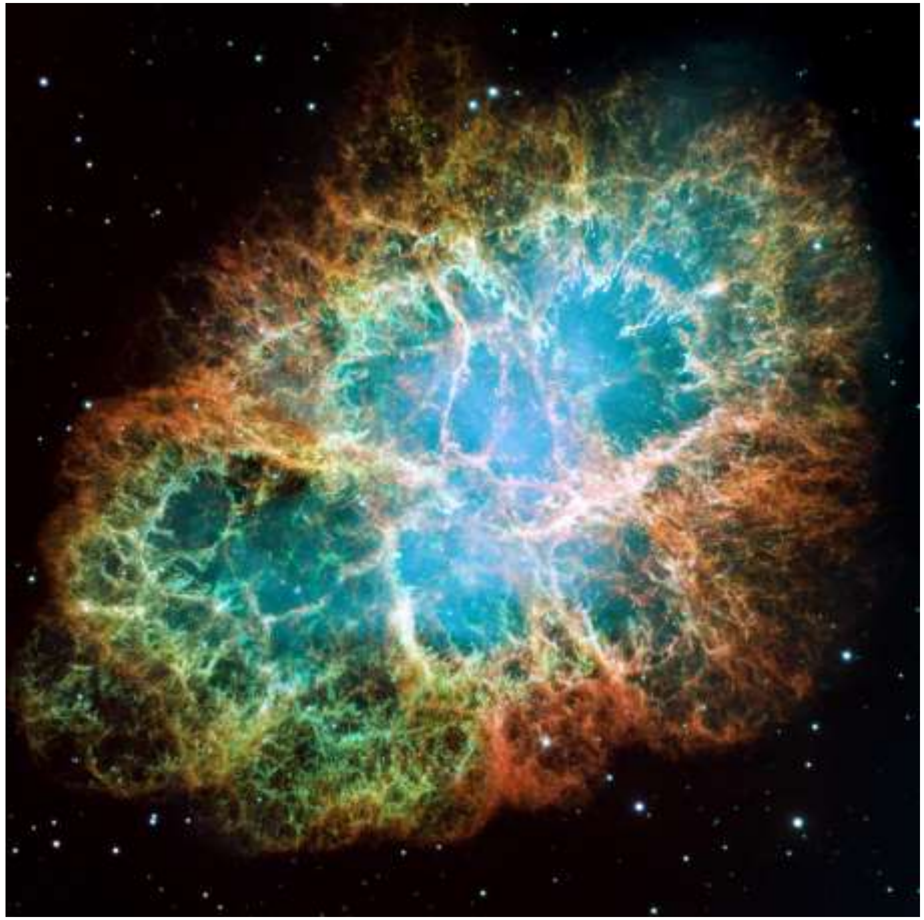
the nuclear energy scale is

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

Just by putting in the numbers for each case.

Three kinds of energy and their relevance to the current environment

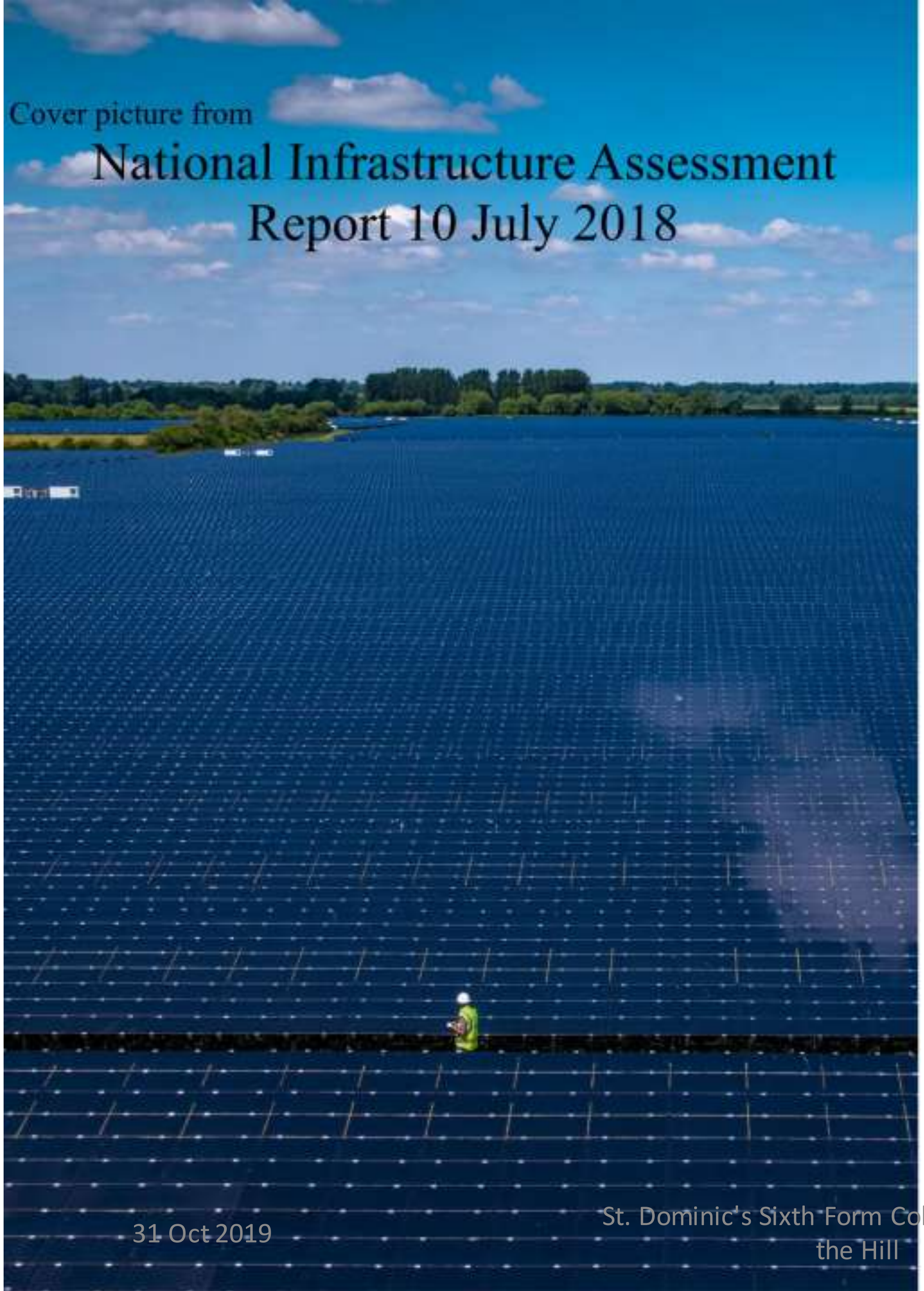
- **Classical:** Kinetic and Potential Energy according to Newton. Moving and falling objects, motion of Sun and Moon, sunshine, wind, hydro, tides, waves, solar. Clockwork!
- **Quantum Atomic, aka Chemical**: Atomic structure of all matter. Energy density many thousands X classical: Chemistry, food,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



“Modern” example: the “Crab” Supernova, 6300 light years away. Seen for 23 days in daylight by Korean astronomers in July 1054 and pictured today by the Hubble Space Telescope

2. How did we get energy in the past and how should we get it in future?

	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 CO_2 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)	CO_2 emissions, poor safety	**Popularly feared, unfamiliar, education lacking**
Energy primed by	Daily sunshine	Daily sunshine	ancient sunshine	ancient gravitational collapse



Solar, environmental?

A meadow near Abingdon lost to nature!

1. Not “green”. **Huge footprint**, thanks to low energy flux.
2. **Unreliable and intermittent** long breaks for weeks at a time.
3. **No viable intermediate battery storage** likely on the scale required.
4. **Vulnerable** to extreme weather.
5. Short panel life.

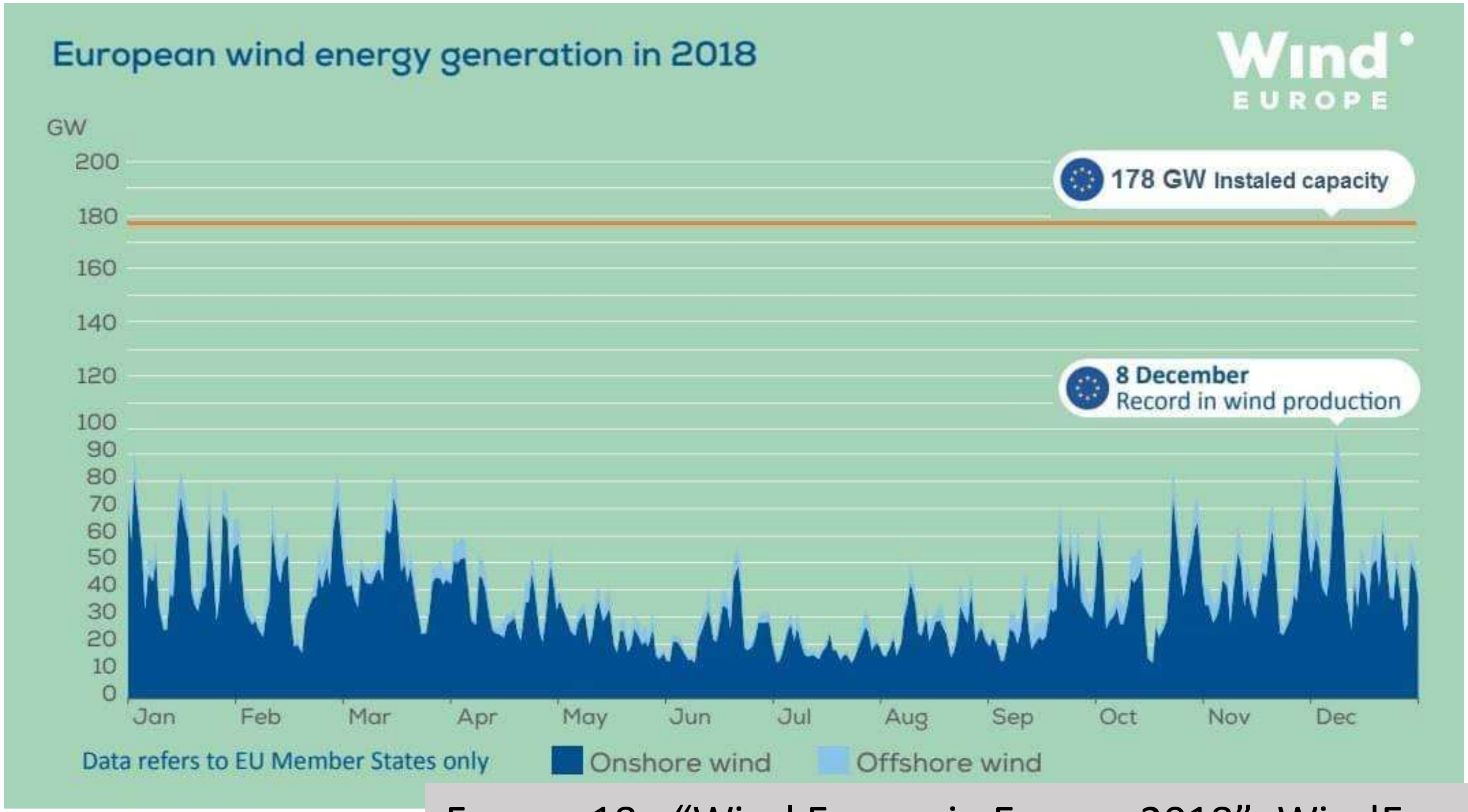
Not a suitable primary energy source.

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

Wind, reliable?

1. Low energy density, low flux, huge plant. Not “green”
2. Unpredictable, variable, unreliable.
3. Power as wind speed cubed. hence “shock” if tripped at high speed
4. Capacity factor 22%, off shore 37%.

“No” to Wind as primary source.



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

Many feared dead after Laos dam collapse

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

Hydro, environmental/safe?

1. Low density, invasive footprint.
2. Available 24/7, but vulnerable to climate change.
3. Safety. High mortality 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. Few new suitable locations.

No major expansion of hydropower

3. Should we worry about the safety of radiation?

Placebo Effect and Nocebo Effect

Placebo: A diseased patient is given dummy medication.
He believes he is being treated.
His chances of recovery improve significantly. True!

Nocebo: A healthy person is told falsely that he is diseased.
His physical and mental health will often genuinely deteriorate in many ways.
(The effect of voo-doo or a curse by a witch doctor is an example.)

When people are told they have been irradiated,
as at Chernobyl and Fukushima, they become deeply affected.

To find true effect of radiation without Nocebo,
first study subjects who are unaware or unworried:
1) humans living in high radiation background regions;
2) clinical evidence taken in conditions of trust;
3) animal data;
4) considerations of evolutionary biology and "test tube" evidence.

Only then consider data influenced by fear or compensation.

Animals at Chernobyl are blissfully unaware

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

"But they know nothing!"

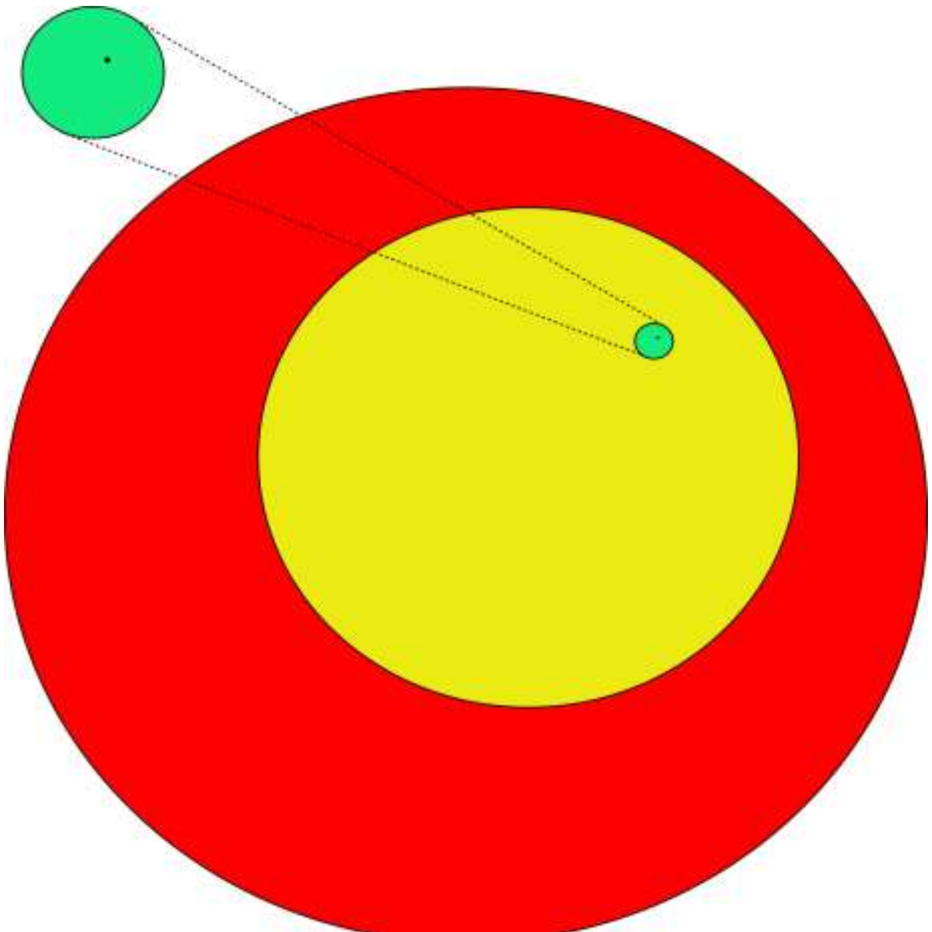
and Sherlock Holmes might reply

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

Conclusion: Nuclear radiation is harmless at low and moderate doses.

Nuclear energy is safer than fire

except at extreme levels. The recommended safety regulations are too cautious by a factor about 1000, as experienced by the public if receiving monthly radiotherapy to cure cancer.



Red circle, 40,000 mGy per month, less than a radiotherapy dose rate that kills a tumour

Yellow circle 20,000 mGy a month, a survivable therapy dose rate to healthy tissue near a treated tumour

Green circle 100 mGy per month, a conservatively safe dose rate, As High As Relatively Safe (AHARS)

Small black dot 0.08 mGy per month, [1 mSv per year] an unreasonably cautious rate, As Low As Reasonably Achievable (ALARA) recommended by UN.

Why is it so safe? (1) Physics isolates nuclear energy

- Nuclei are kept apart by +ve charge and **never meet** except in laboratory 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.
- Matter is 99.98% nuclear, but nuclei do **nothing at all** for billions of years
  (exception – some rotate, hence MRI).

Why is it so safe? (2) Life is vaccinated for radiation

- Life on Earth evolved in a radioactive environment, even more so in the past.
- The reason for a) mortal individuals, b) mortal cells.
- Multi-level cellular protection by:
  - quenching "hot" molecules;
  - repairing;
  - replacement;
  - surveillance by immune system.
- Necessary for us to be here now.
- For any other life form too, from single cellular organism up.

Also, radiation does not "catch" and spread, like fire or infectious disease.

Evolve and Adapt

To defend life against the effect of radiation, biology has changed and adapted.
But radiation has never changed.
So in 3000 million years life has learnt how to win!

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

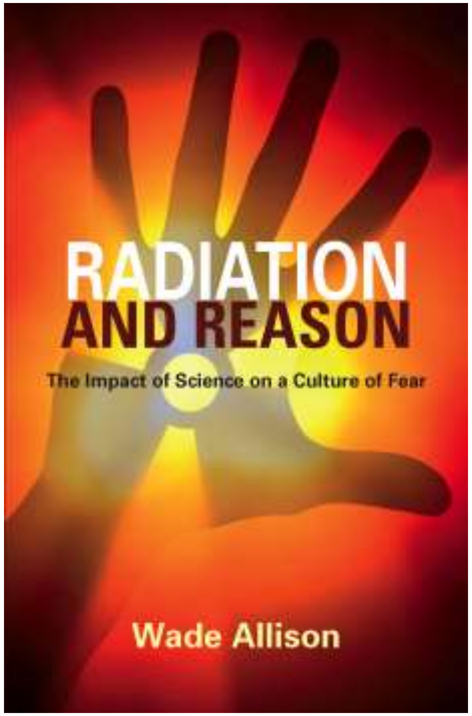
Protection and safety by Darwinian evolution or the deliberations of a UN committee

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

4. Our message for Greta Thunberg

1. **Renewables: weak, inadequate, harmful to nature.**
   Fossil fuels: pollute.
   Nuclear energy: the ideal solution.
   <u>All</u> should learn about nuclear in school - not hard.
2. **Record shows nuclear is safer than fire.**
3. **Radiation is natural and good for personal health.**
   Life is well protected by evolution.
4. **Rather we should be concerned about global risks that affect everybody and the natural world:**
   - **Infectious diseases with no protection;**
   - **effects of climate change;**
   - **ignorance that leads to panic/unrest.**



Books can be downloaded free from

https://www.researchgate.net/publication/234037551_Radiation_and_Reason_The_Impact_of_Science_on_a_Culture_of_Fear#fullTextFileContent

and

https://www.researchgate.net/publication/285420212_Nuclear_is_for_Life_A_Cultural_Revolution#fullTextFileContent