Our Burning Economy, Siren Song, and Fission Promise

Fission, Technologies, Safety

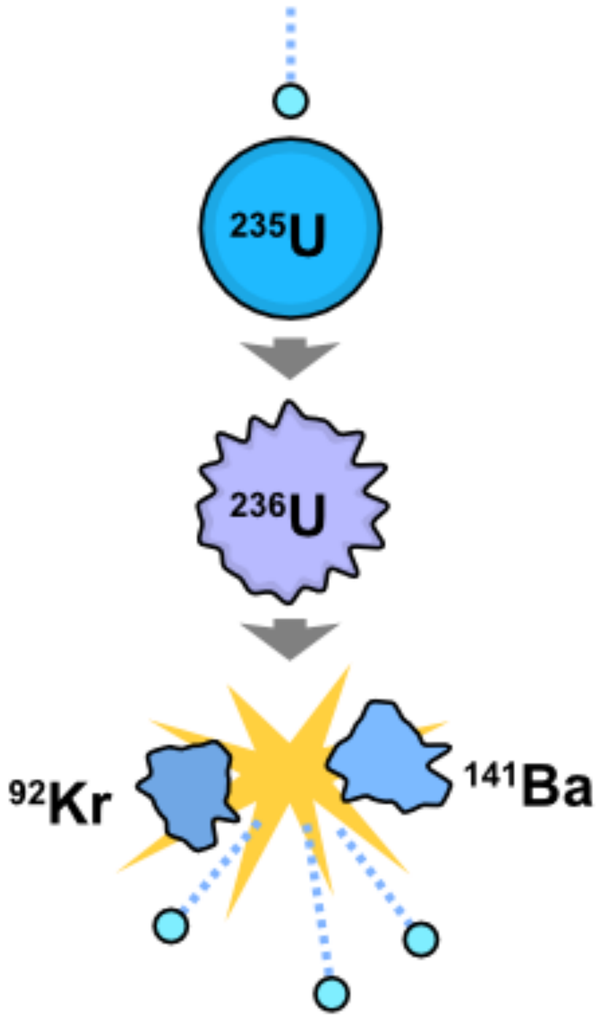
Osher @ Dartmouth

Robert Hargraves

Jan 18, 2023


Uranium
created in a supernova
at the center of the galaxy

Uranium-235 fissions to krypton and barium releasing energy.



http://en.wikipedia.org/wiki/Nuclear_fission

The total mass of the resulting

barium-141
krypton-92
neutrons (3)

is a bit less than the mass of the U-235 + neutron,

and by $e = mc^2$
immediately releases 166 MeV of energy, totaling 200 MeV after Kr and Ba decay.

1 tonne-U235 fissioned -> 79,000 TJ
= 2.6 GW-years(t)

2 billion years ago
Oklo, Gabon

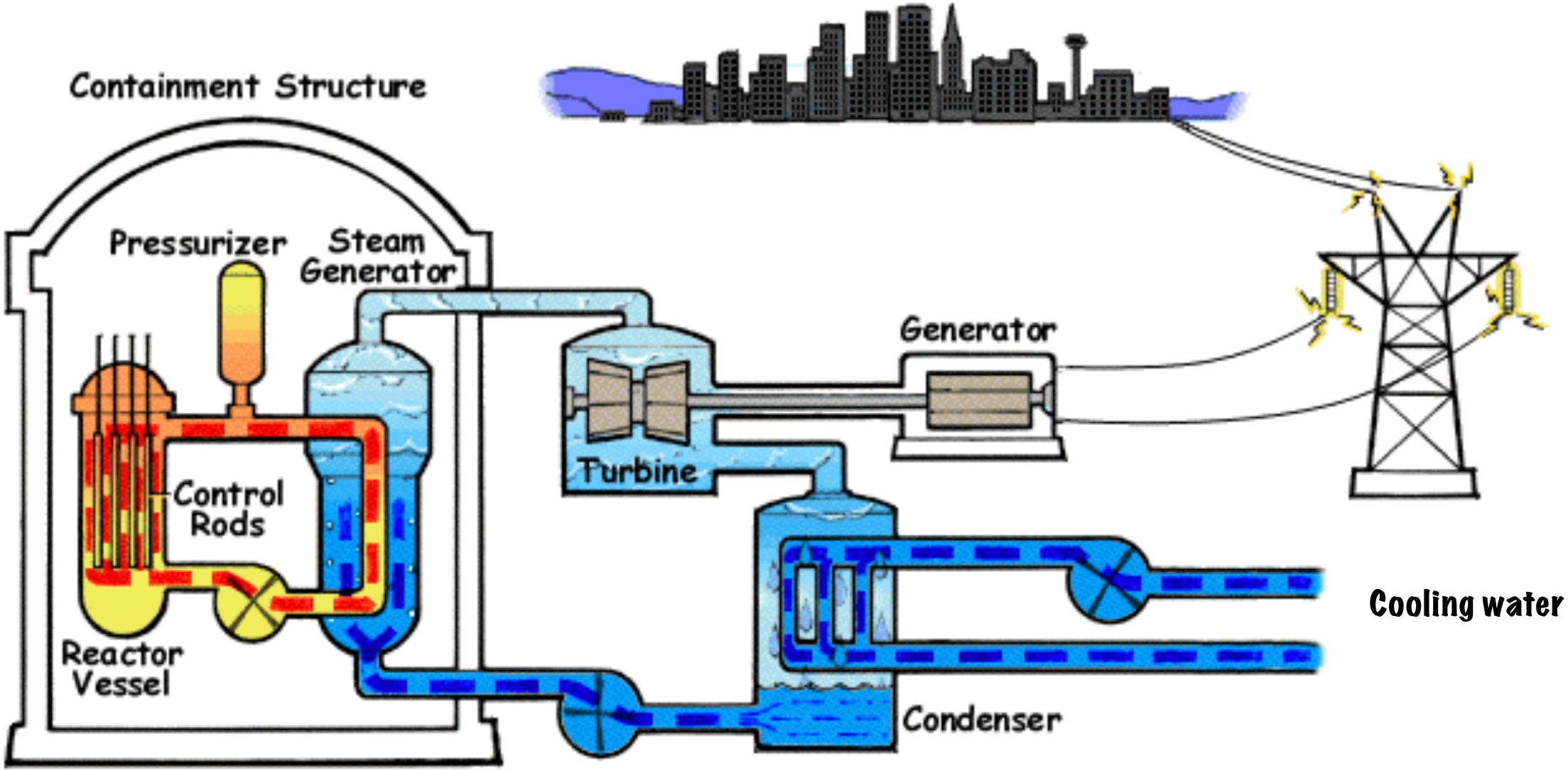
Fissile U-235 was
~ 3% of uranium.

Groundwater **H**2O
slowed neutrons to
fissioning speeds.

Fission heat
evaporated water.

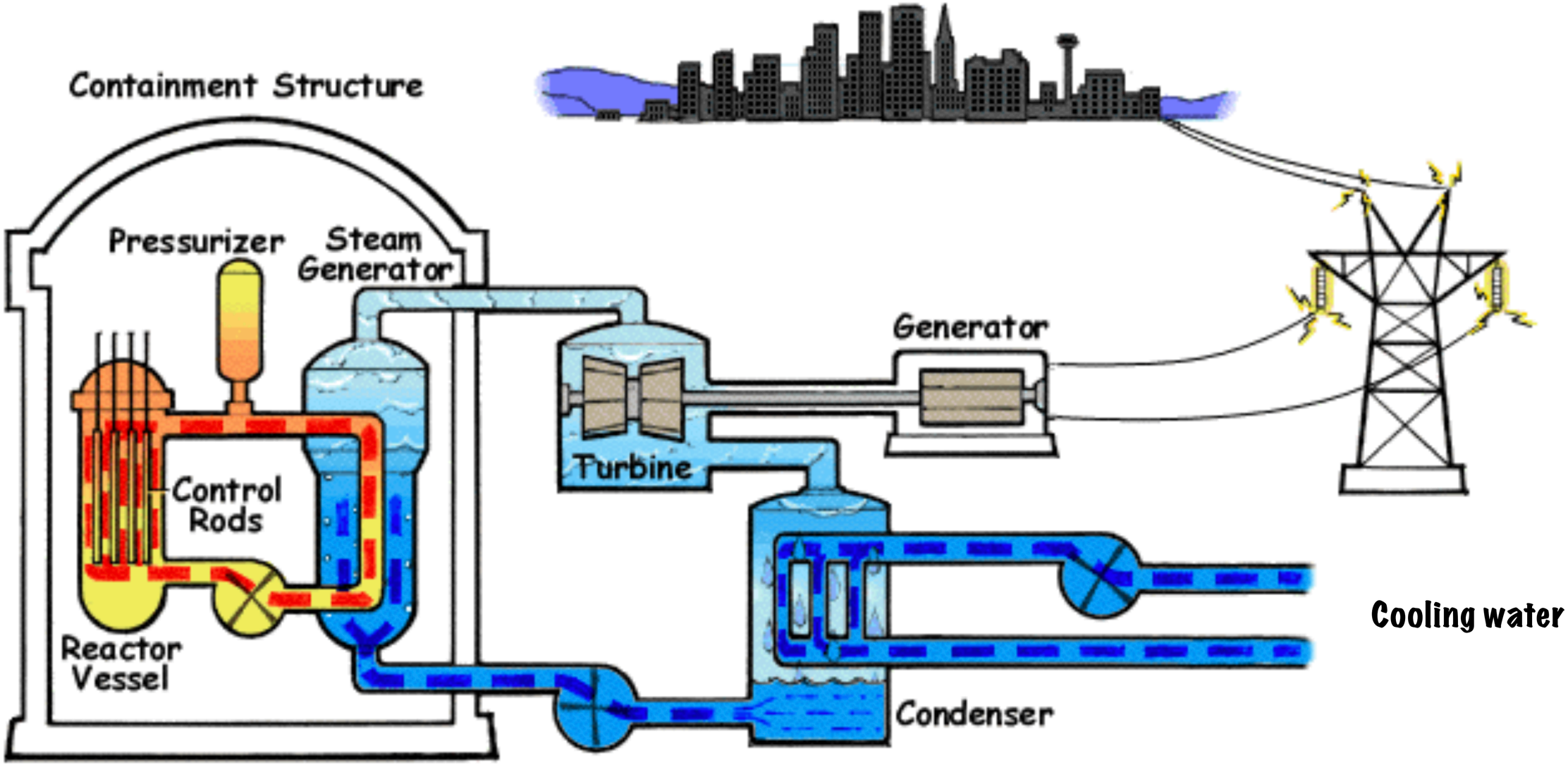
Reactor cycled
off/on, naturally.

Pressurized water reactor (PWR) uses 155 bar 275C water to move heat to steam generator to turn turbine-generator.



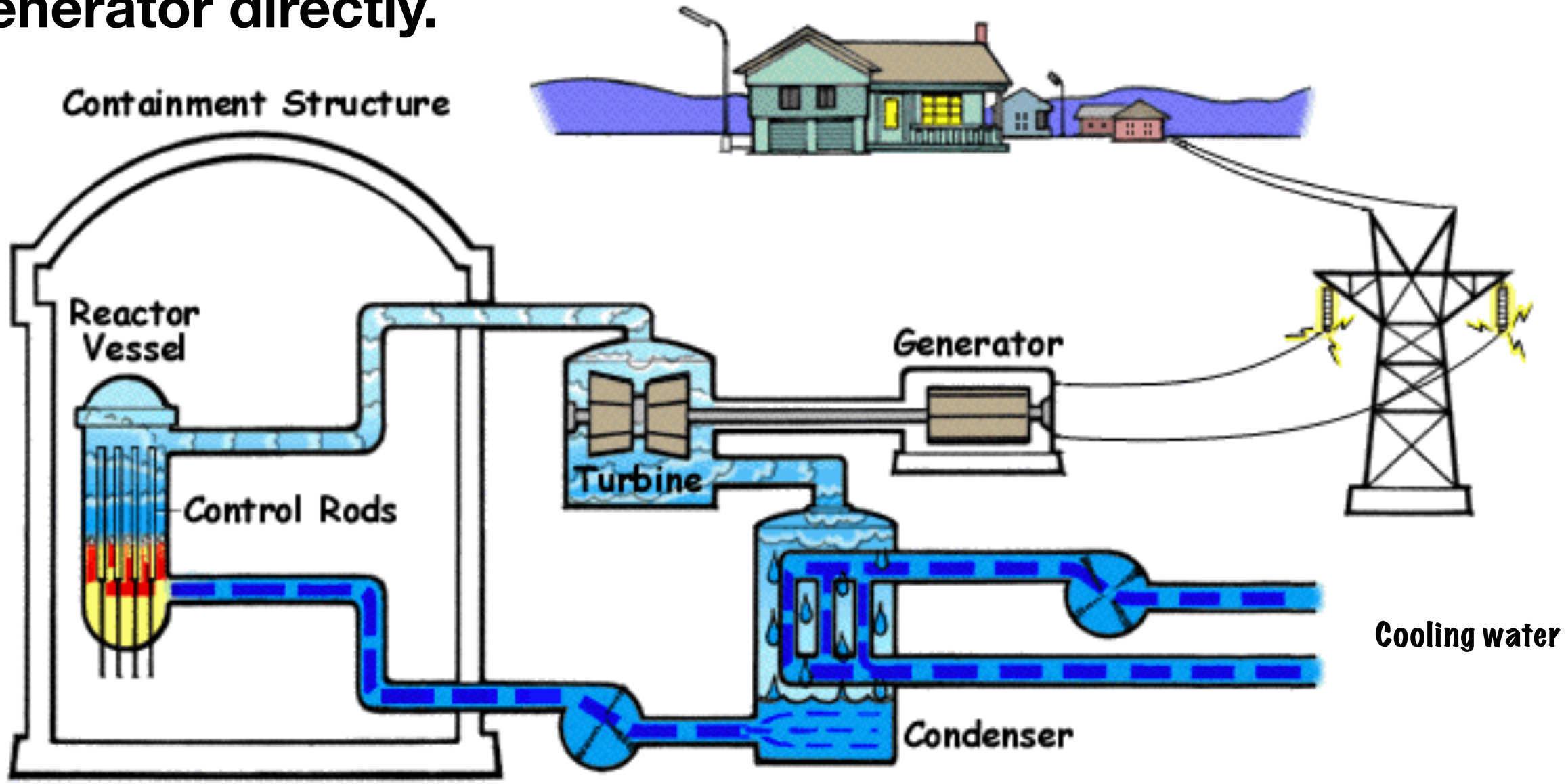
https://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

Pressurized water slows neutrons so they split uranium atoms. Cooling water carries away rejected heat.



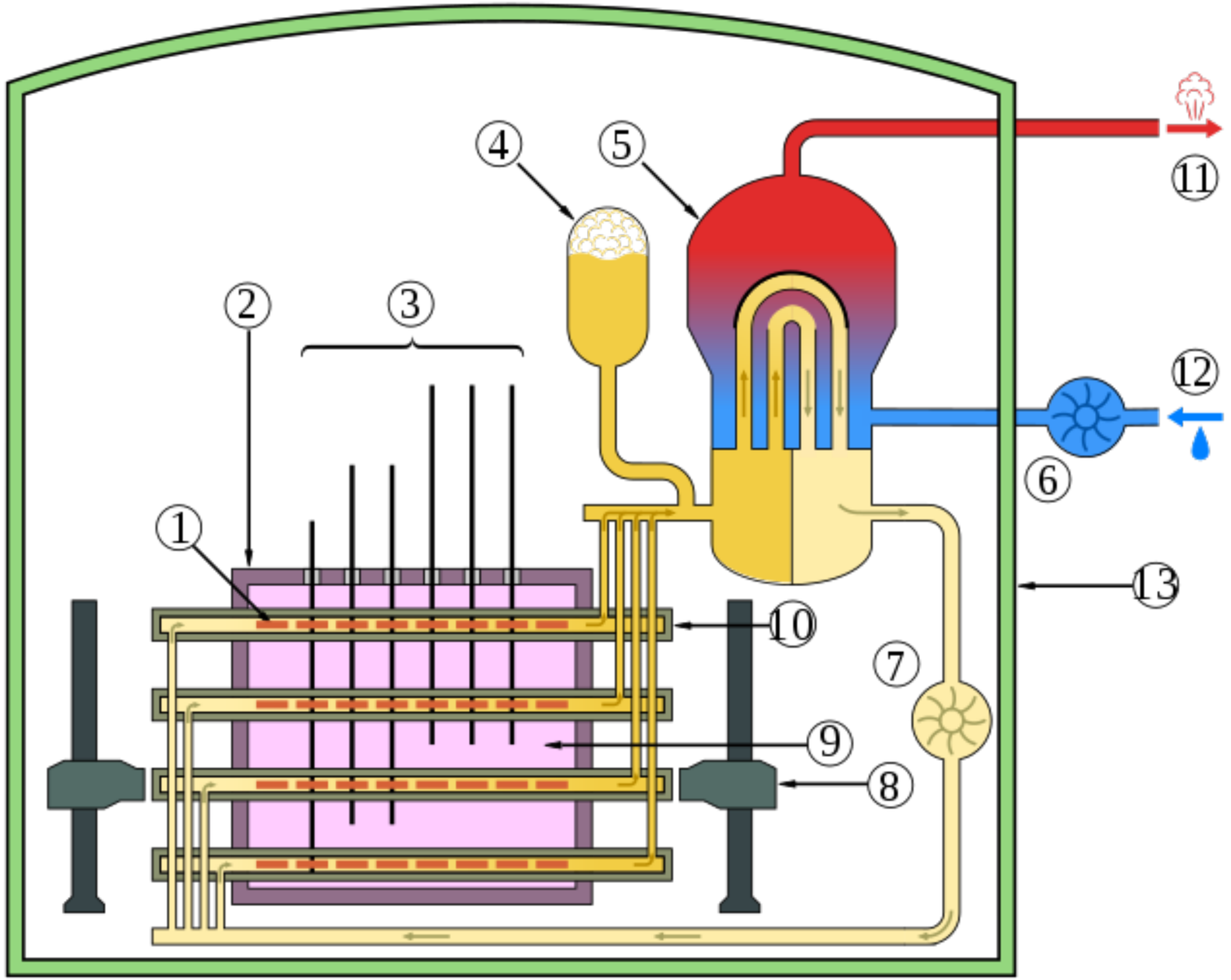
https://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

Boiling water reactor (BWR) 75 bar steam turns turbine-generator directly.



https://www.nrc.gov/reading-rm/basic-ref/students/animated-bwr.html

CANDU reactor moderator is D2O; no large pressure vessel.



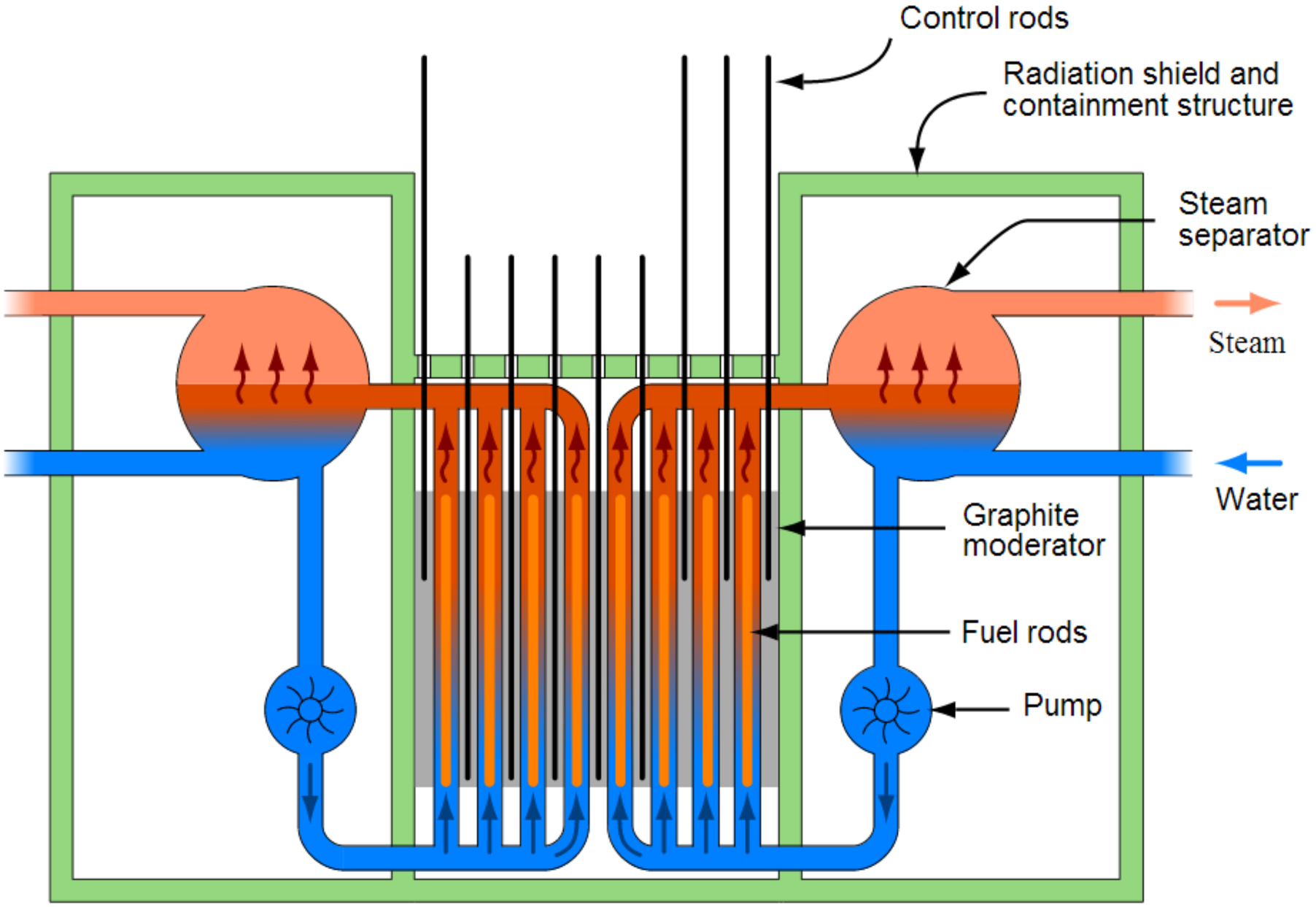
https://en.wikipedia.org/wiki/CANDU_reactor

D2O is heavy water, H2O where each H has 1 proton and 1 neutron, so does not absorb fission neutrons.

CANDU can use natural, unenriched uranium.

- Hot and cold sides of the primary heavy-water loop
- hot and cold sides of secondary light-water loop
- cool heavy water moderator in the calandria,

Russian RBMK is graphite moderated, water cooled



Chernobyl, 1986

Positive void coefficient

Safety systems improved

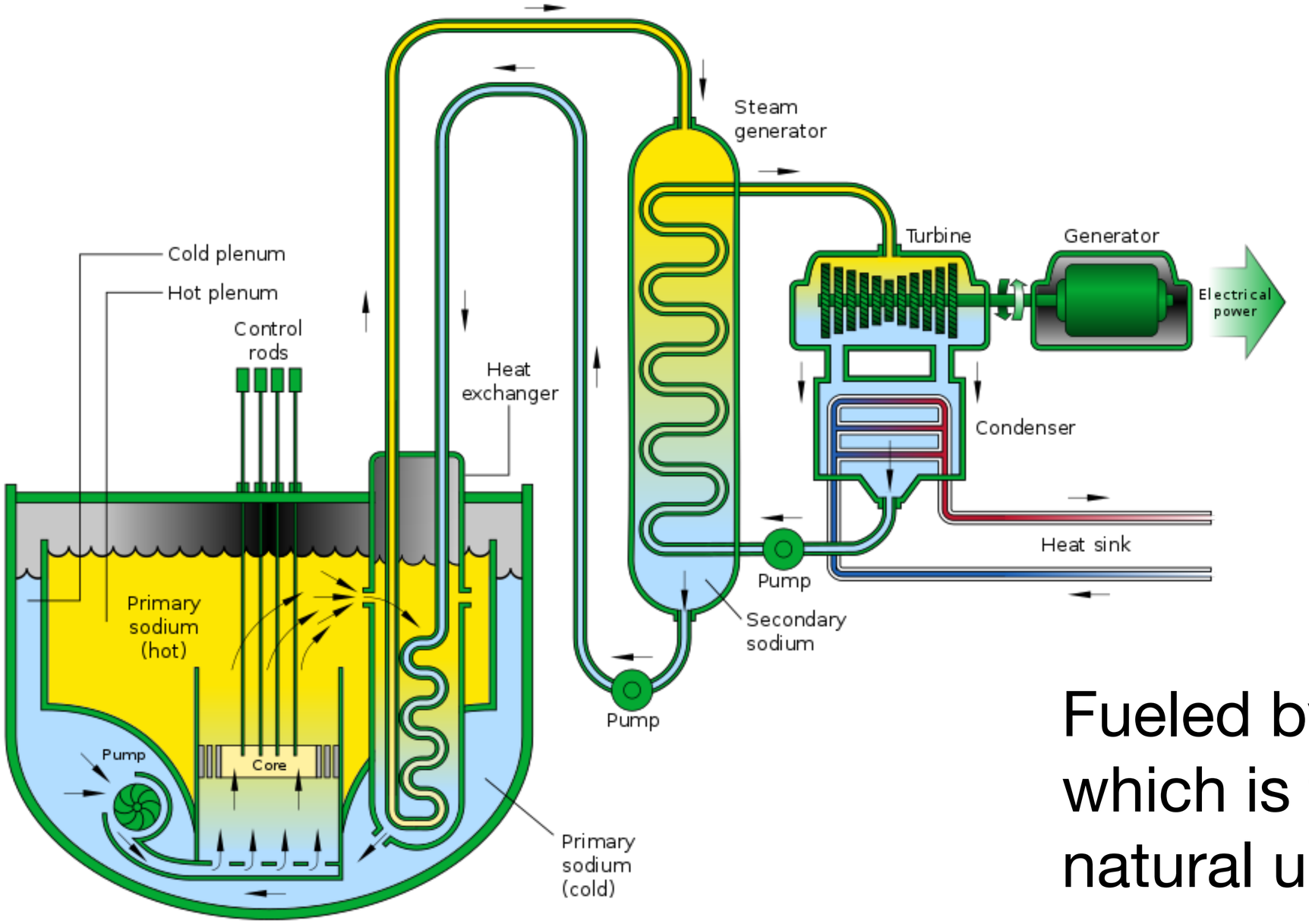
8 RBMK plants still operating in Russia.

VVER (PWRs) are exported.

BN-800 sodium cooled fast reactor in operation

https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/appendices/rbmk-reactors.aspx

Sodium cooled fast reactor has no neutron moderator.

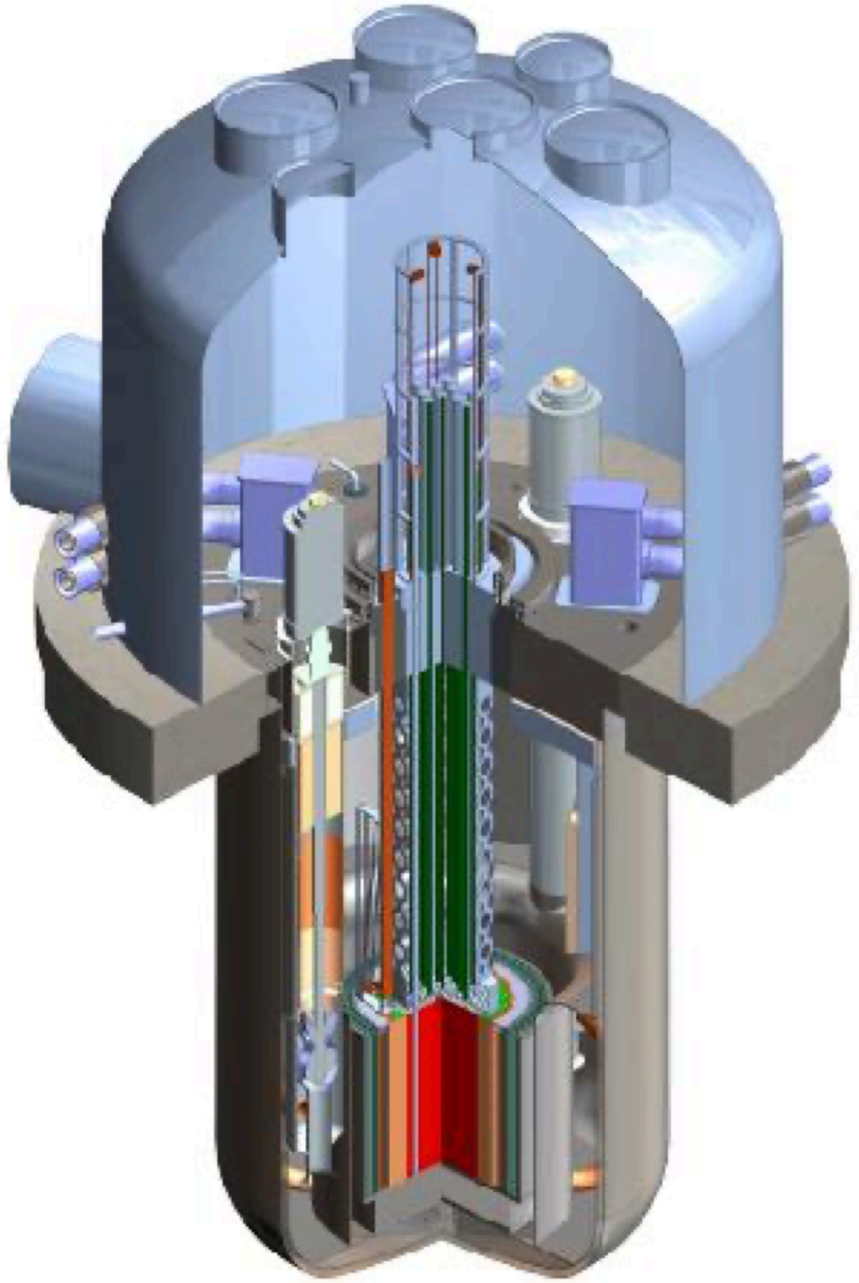


Fueled by U-238, which is 99% of natural uranium

https://en.wikipedia.org/wiki/Sodium-cooled_fast_reactor

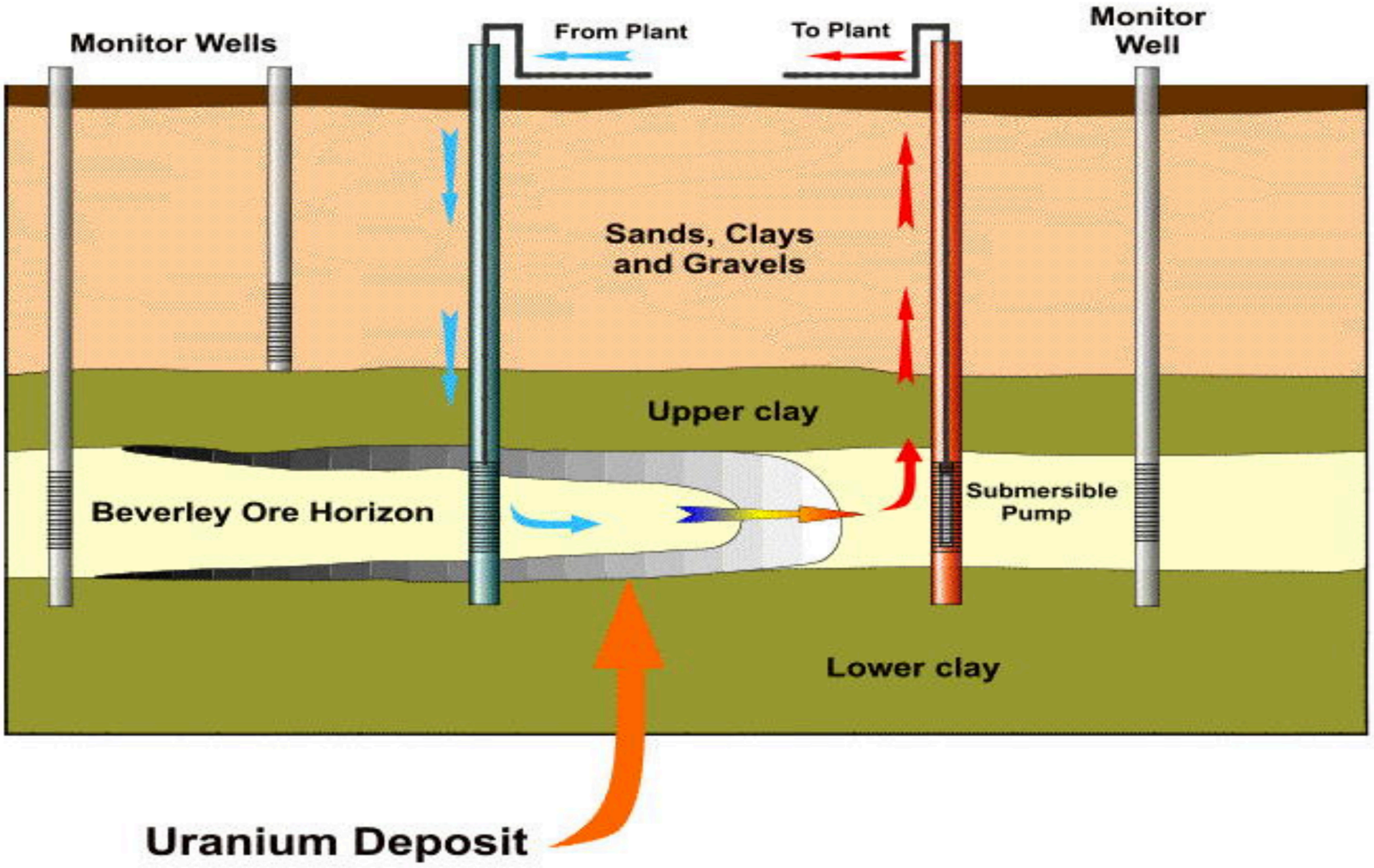
TWR-P (TerraPower)

1. Sodium cooled fast reactor
2. Funded by Bill Gates
3. US, then China, then US
4. 1475MWt, 600 MWe
5. U-238 fuel rods breed Pu-239 then moved internally
6. Ample U-238 fuel, tailings



https://aris.iaea.org/PDF/TWR-P.pdf

In situ leach mining of uranium



https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium.aspx

Many laboratories are developing seawater uranium extraction.

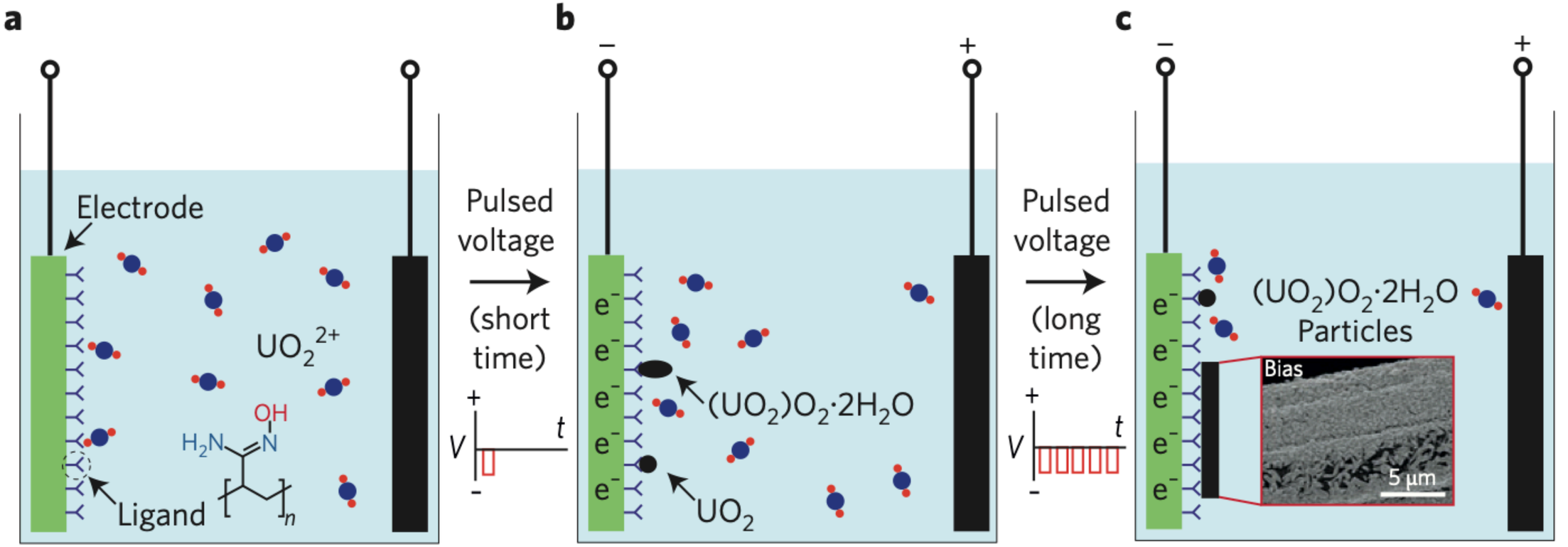


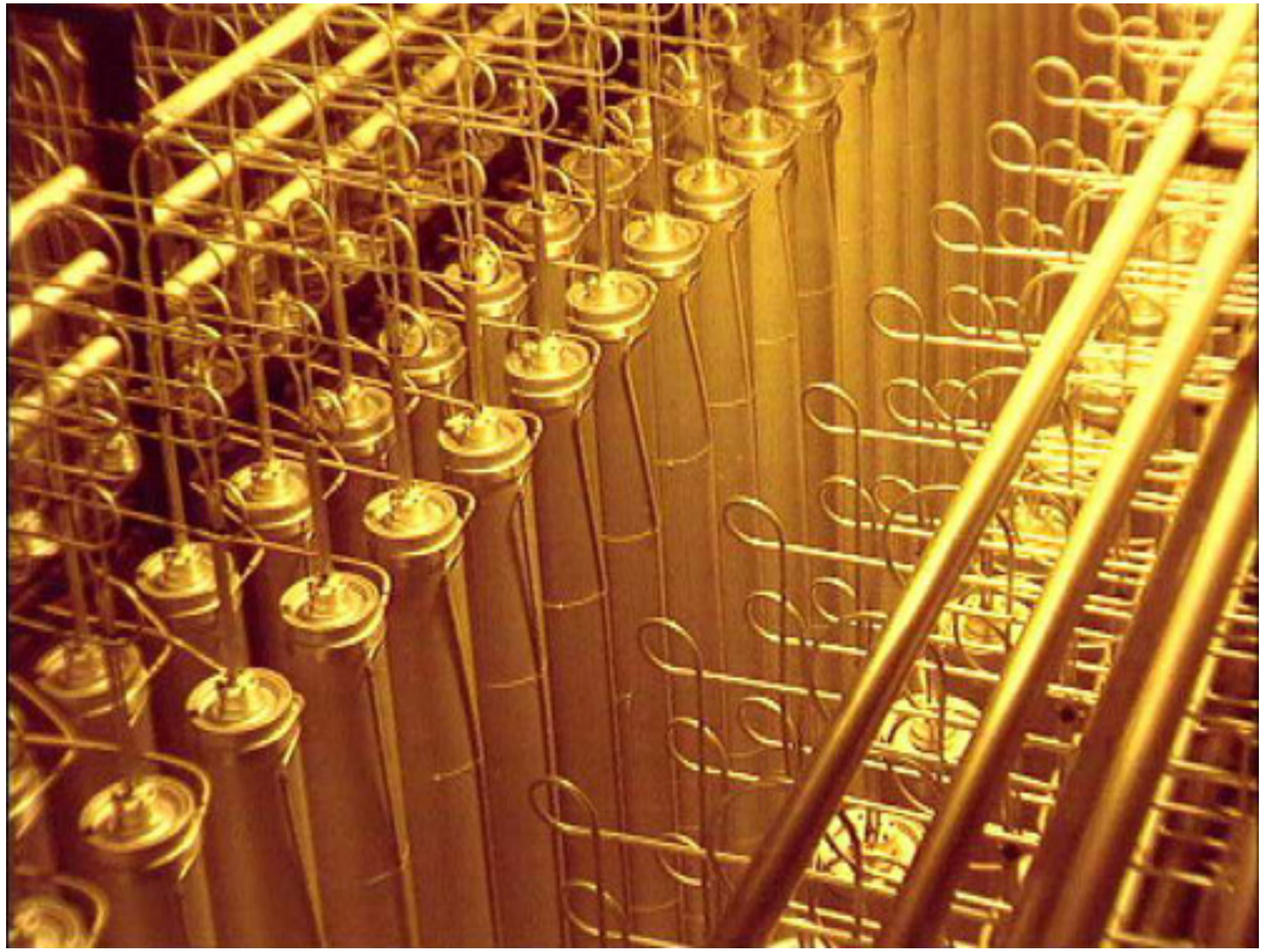
Figure 1 | Alternating-current method for electrochemical extraction of uranium. **a**, The amidoxime-functionalized electrode is submersed in uranium-spiked seawater. **b**, On application of a pulsed voltage, uranyl ions migrate towards the electrode leading to precipitation of uranium-rich particles. **c**, Continued pulsed voltage causes growth of the particles. The inset shows an SEM image of the amidoxime electrode covered by particles after 24 h of extraction with an initial uranium concentration of 1,000 ppm. Figure adapted from ref. 7, Macmillan Publishers Ltd.

https://www.nature.com/articles/nenergy201722.pdf.

Uranium fuel is typically enriched from 0.7% U-235 to 3-5%.

Centrifuge enrichment capacity.

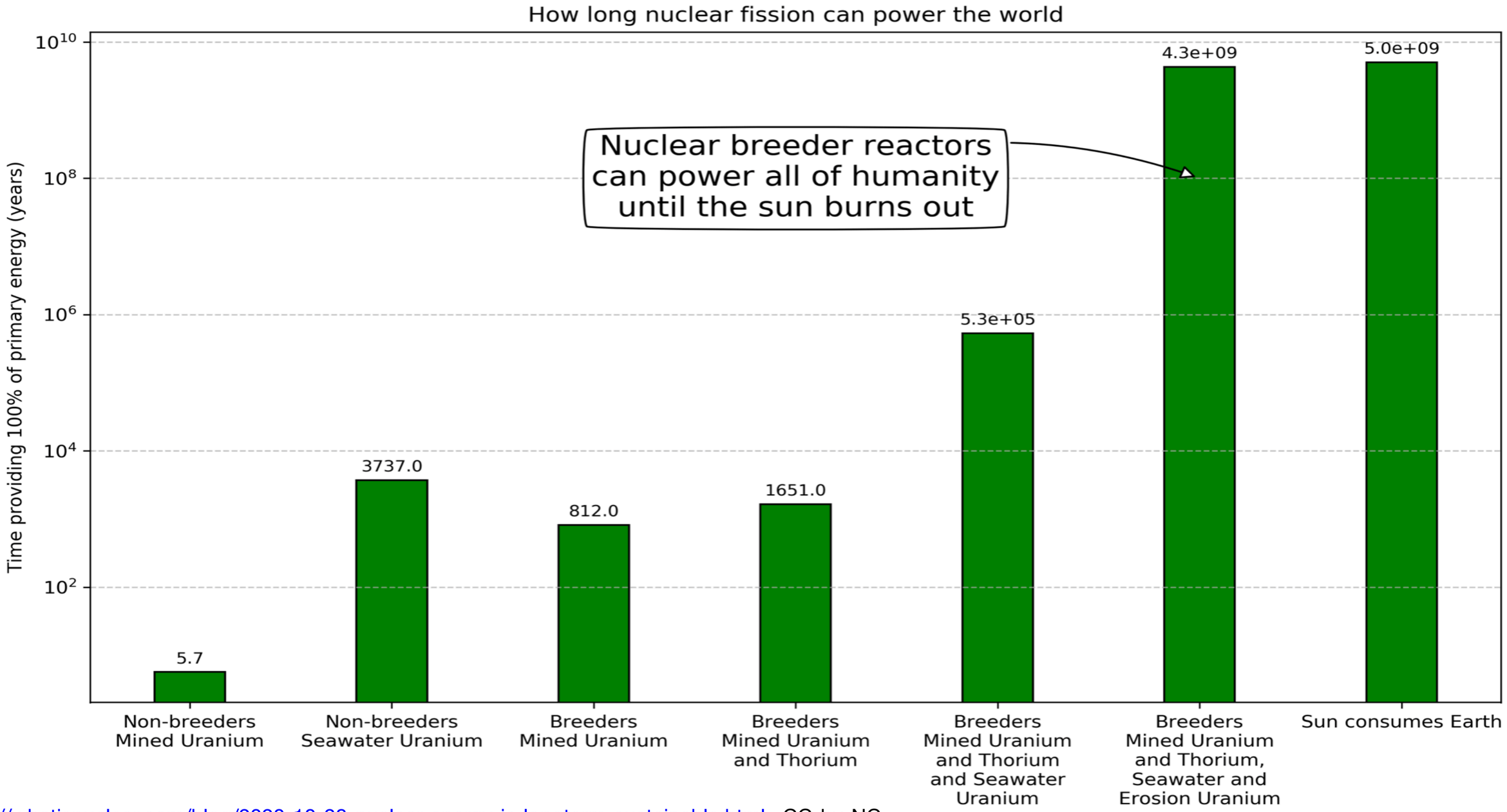
Operator	2018	2020	2030
CNNC	6750	6750	19,644
Orano	7500	7500	7500
Rosatom	28,215	27,654	25,000
Urenco	18,600	18,320	16,487
Other	46	66	450
Total	61,111	60,199	69,081



Series of centrifuges concentrating U235 in UF6

https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx

Nuclear fuel will last us for 4 billion years, writes Nick Touran.



https://whatisnuclear.com/blog/2020-10-28-nuclear-energy-is-longterm-sustainable.html. CC-by-NC

World Nuclear Association

tracks fission power plants in 42 countries.

Power	Status
392 GW	in operation
62 GW	under construction
96 GW	planned
354 GW	proposed

for Country Profile)	2020		March 2022		March 2022		March 2022		March 2022		2021
	TWh	% e	No.	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross	tonnes U
Argentina	10.0	7.5	3	1641	1	29	1	1150	2	1350	167
Armenia	2.6	34.5	1	415	0	0	0	0	1	1060	50
Bangladesh	0	0	0	0	2	2400	0	0	2	2400	0
Belarus	0.3	1.0	1	1110	1	1194	0	0	2	2400	179
Belgium	32.8	39.1	7	5942	0	0	0	0	0	0	790
Brazil †	13.2	2.1	2	1884	1	1405	0	0	4	4000	340
Bulgaria	15.9	40.8	2	2006	0	0	1	1000	2	2000	322
Canada	92.2	14.6	19	13,624	0	0	0	0	2	1500	1492
China	344.7	4.9	53	50,769	19	20,930	34	38,110	168	196,860	9563
Czech Republic	28.4	37.3	6	3934	0	0	1	1200	3	3600	706
Egypt	0	0	0	0	0	0	4	4800	0	0	0
Finland	22.4	33.9	5	4394	0	0	1	1170	0	0	421
France	338.7	70.6	56	61,370	1	1650	0	0	0	0	8233
Germany	60.9	11.3	3	4055	0	0	0	0	0	0	521
Hungary	15.2	48.0	4	1902	0	0	2	2400	0	0	320
India	40.4	3.3	23	6885	8	6700	12	8400	28	32,000	977
Iran	5.8	1.7	1	915	1	1057	1	1057	5	2760	153
Japan †	43.0	5.1	33	31,679	2	2756	1	1385	8	11,562	1396
Jordan	0	0	0	0	0	0	0	0	1	1000	0
Kazakhstan	0	0	0	0	0	0	0	0	2	600	0
Korea RO (South)	152.6	29.6	24	23,136	4	5600	0	0	2	2800	4270
Lithuania	0	0	0	0	0	0	0	0	2	2700	0
Mexico	10.9	4.9	2	1552	0	0	0	0	3	3000	226
Netherlands	3.9	3.3	1	482	0	0	0	0	0	0	69
Pakistan	9.6	7.1	6	3256	0	0	1	1170	0	0	787
Poland	0	0	0	0	0	0	0	0	6	6000	0
Romania	10.6	19.9	2	1300	0	0	2	1440	1	720	185
Russia ‡	201.8	20.6	37	27,653	3	2810	27	23,725	21	20,100	5925
Saudi Arabia	0	0	0	0	0	0	0	0	16	17,000	0
Slovakia	14.4	53.1	4	1837	2	942	0	0	1	1200	359
Slovenia	6.0	37.8	1	688	0	0	0	0	1	1000	127
South Africa	11.6	5.9	2	1860	0	0	0	0	8	9600	277
Spain	55.8	22.2	7	7121	0	0	0	0	0	0	1221
Sweden	47.4	29.8	6	6882	0	0	0	0	0	0	914
Switzerland	23.0	32.9	4	2960	0	0	0	0	0	0	412
Thailand	0	0	0	0	0	0	0	0	2	2000	0
Turkey	0	0	0	0	3	3600	1	1200	8	9500	0
Ukraine †	71.5	51.2	15	13,107	2	1900	0	0	2	2,400	1876
UAE	1.6	1.1	2	2690	2	2800	0	0	0	0	907
United Kingdom	45.9	14.5	11	6848	2	3440	2	3340	2	2300	1259
USA	789.9	19.7	93	95,523	2	2500	3	2550	18	8000	17,587
Uzbekistan	0	0	0	0	0	0	2	2400	2	2400	0
WORLD*	**2553**	**c 10.3****	**439**	**392,279**	**56**	**61,713**	**96**	**96,497**	**325**	**353,812**	**62,496**
	TWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U

https://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx

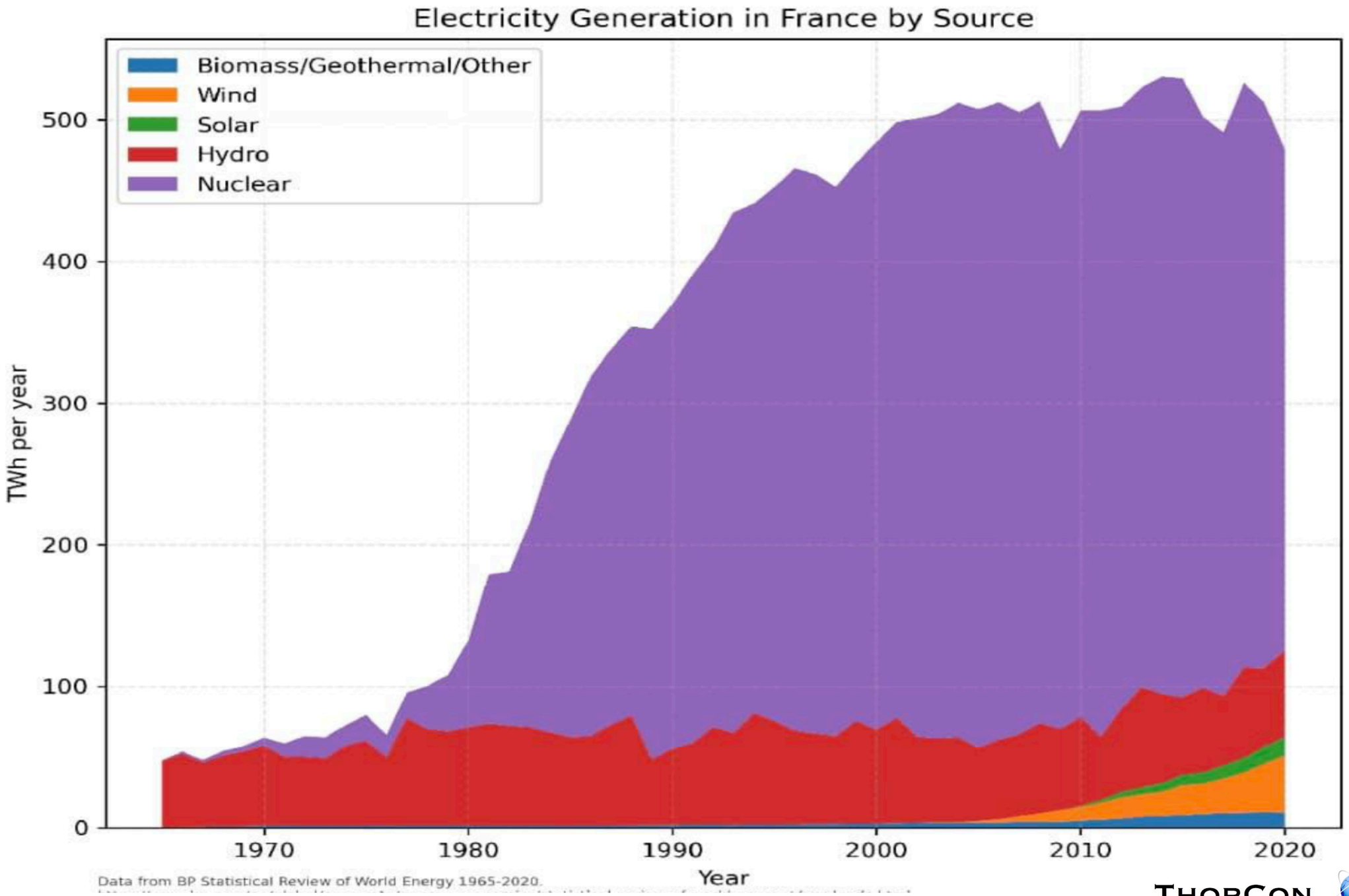
France electric power:

70% atomic fission:

39 GW

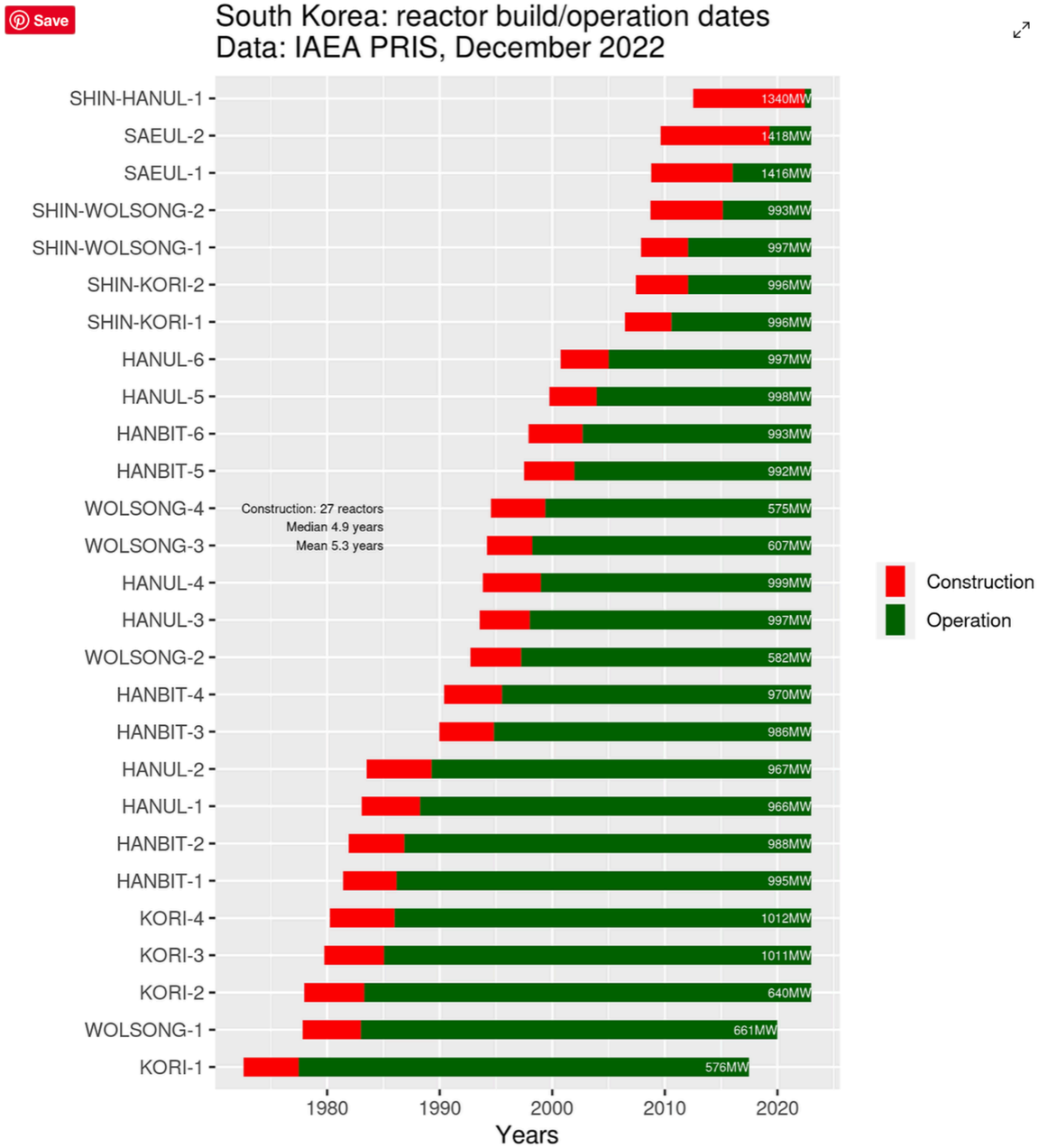
— — — — —

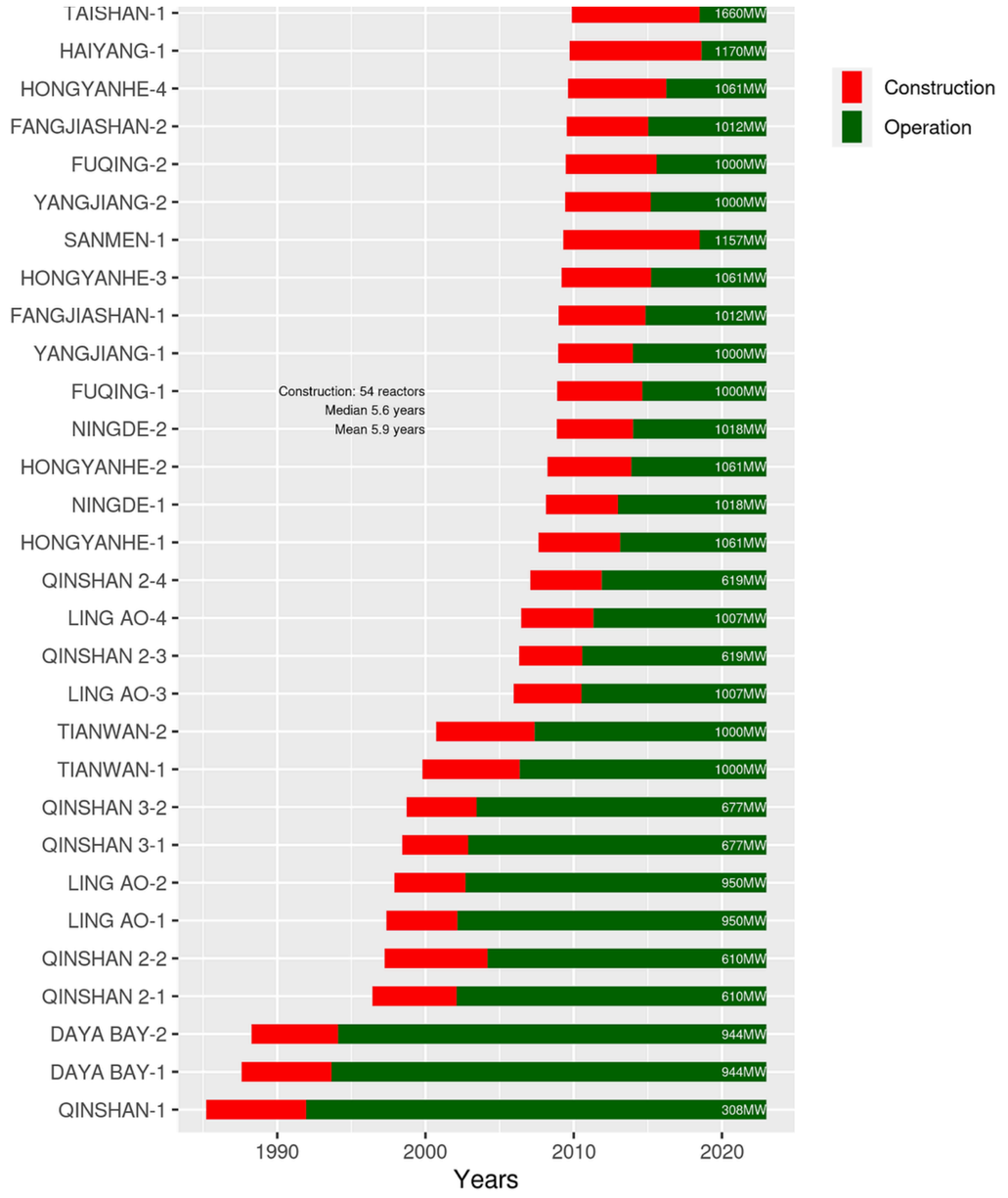
Worldwide 400 GW



https://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx

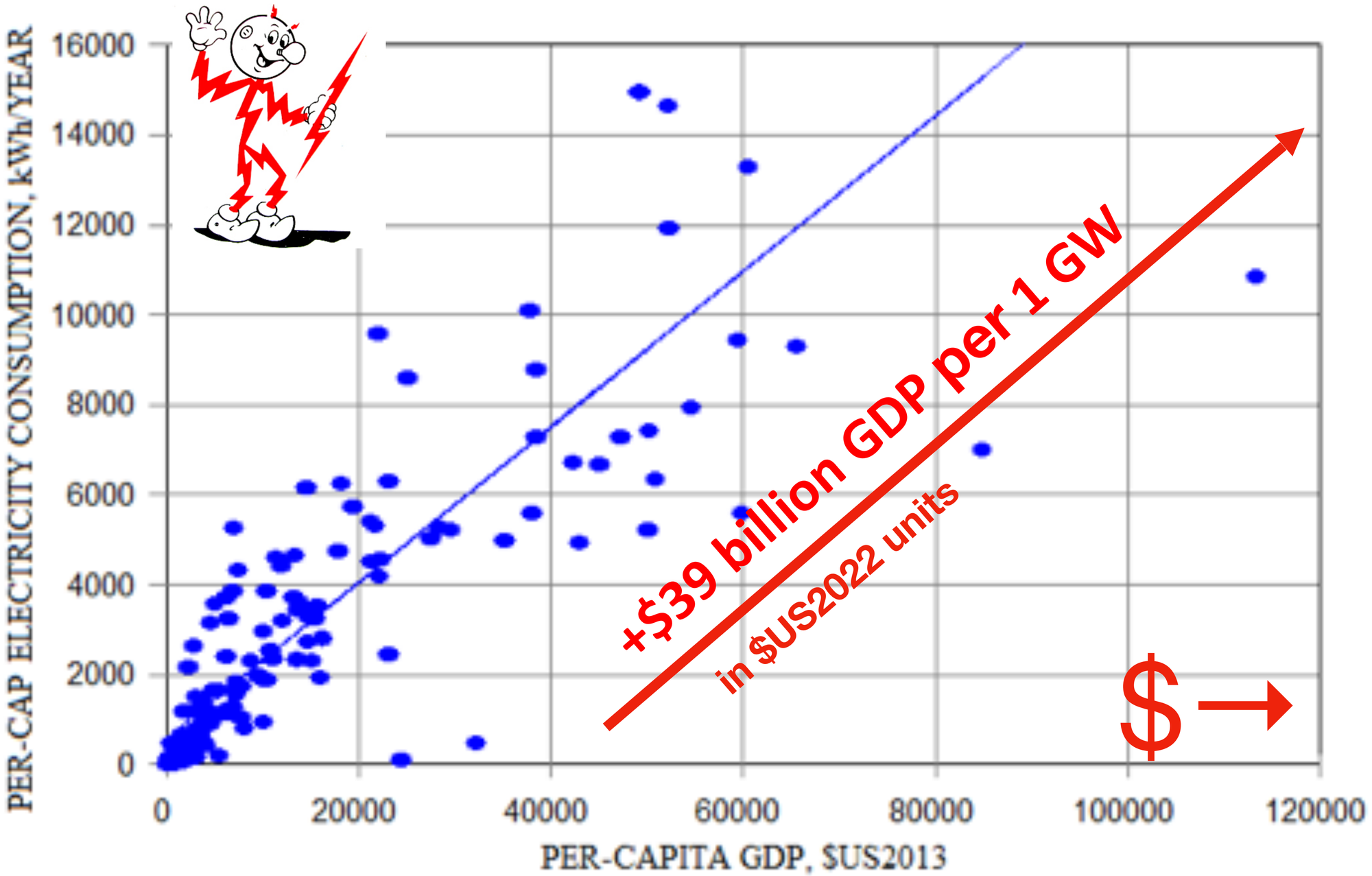
S Korea median build time 5.9 years, China 5.6 years, Japan < 4 years





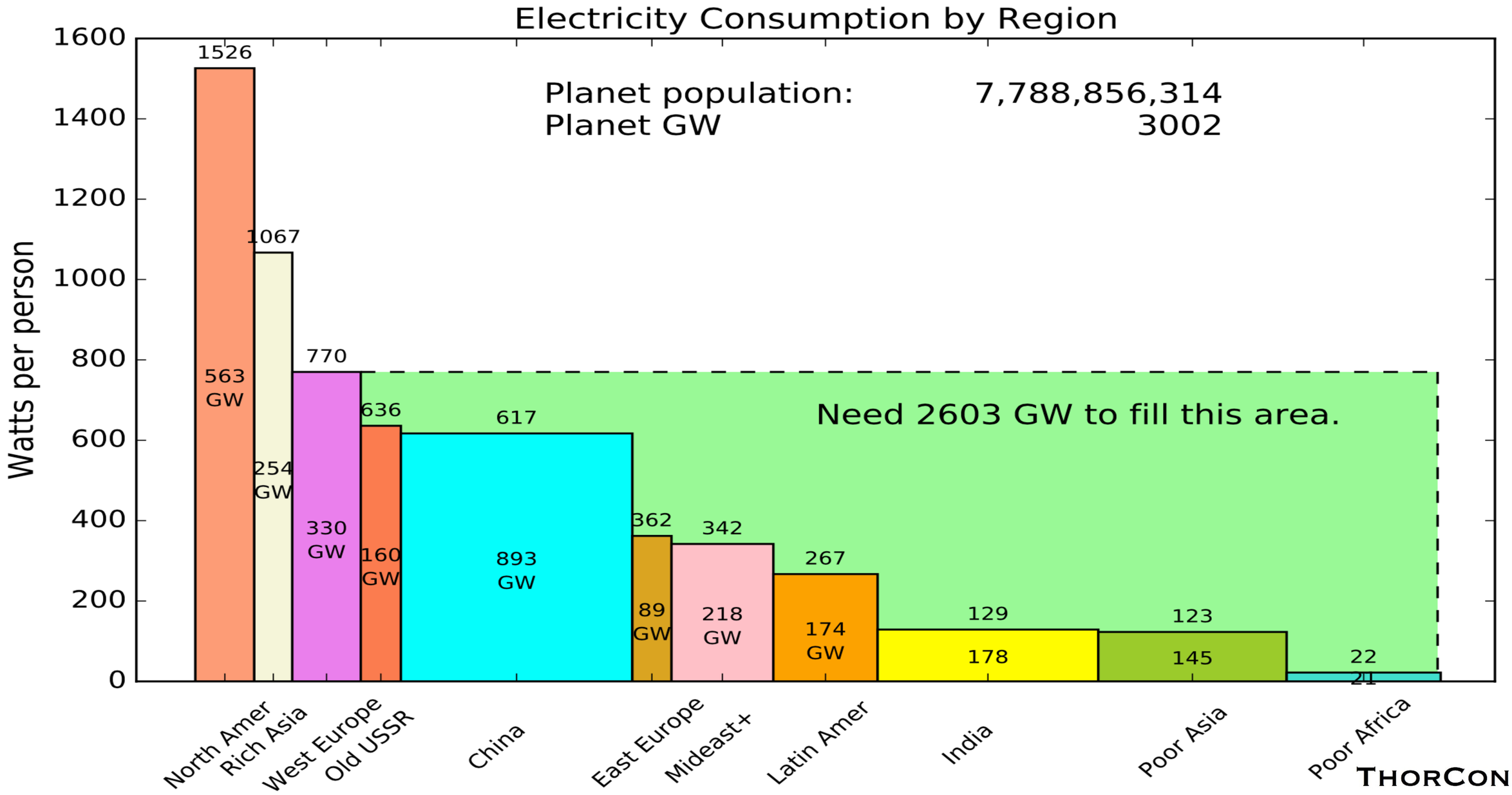
https://www.blog.geoffrussell.com.au/post/merchants-of-doubt-and-merchants-of-fear?postId=c759af77-3886-4cec-ae43-f6882b1f83e7&utm_campaign=ff2cd9b2-5f35-4144-854e-70162fca7a1a&utm_source=so&utm_medium=mail&utm_content=de423800-66a5-4da5-b2f3-6bbbc32d8b00&cid=4830d732-e3fc-4996-83e9-7e5a357e2f79

Nations' GDPs are propotionate to electric power.



THORCON
POWERING UP OUR WORLD

3,000 GW global electricity use may grow by 2,600 GW.



ThorCon
Powering Up Our World


Developing nations now build coal-fired power plants.
Reliable, 24x7, affordable
574 GW in development
ThorCon
Powering Up Our World

Advanced fission power strategy

- to mass-produce fission power plants
- to generate CO2-free, 24x7 electricity
- cheaper than from coal or LNG
- at shipyard scale — 10 GW per year
- helping people achieve prosperity.

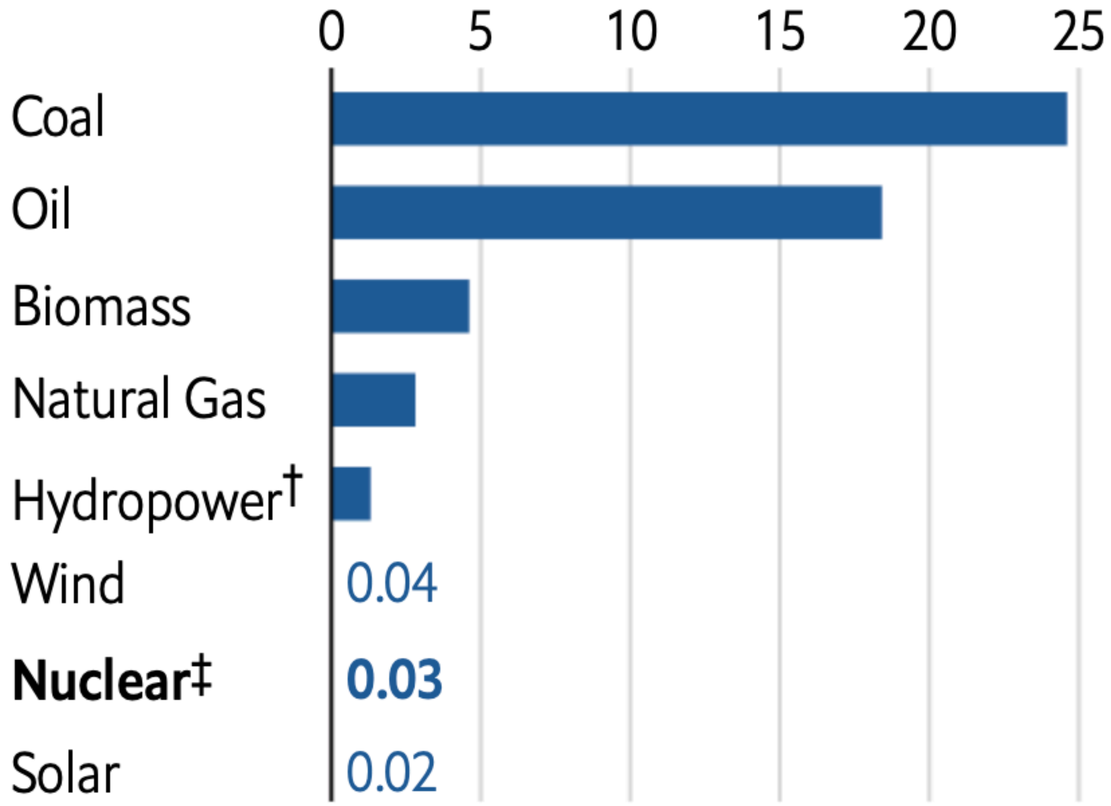
- Nations **will choose** 24x7 fission, if it's **cheaper.**

Economics	**Fission**	**Coal**
Capital cost, $/Watt	1.0	2.0
Fuel cost, cents/kWh	0.53	2.27
Electricity, cents/kWh	**3**	**5**

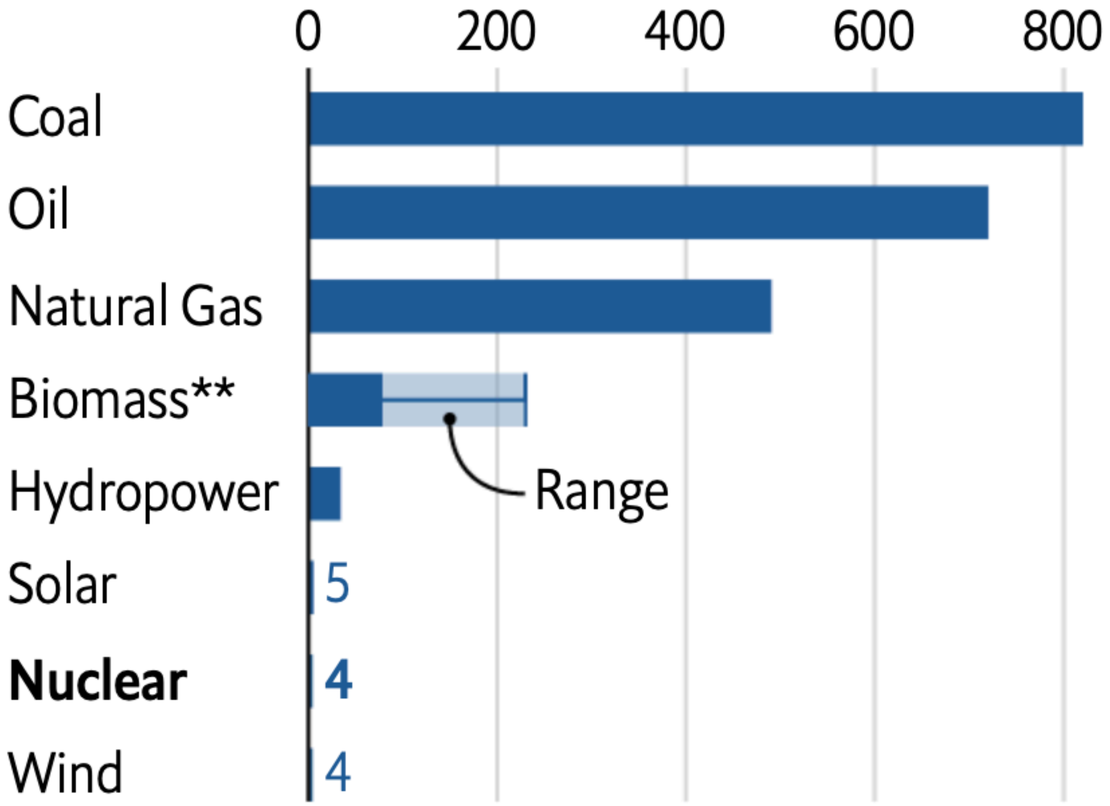
Fission power is safe.

The Economist, July 19, 2022

Deaths per TWh of energy produced*
1990-2014



Greenhouse-gas emissions, 2017 or latest
CO2 equivalent per GWh of electricity produced§, tonnes



https://www.economist.com/graphic-detail/2022/07/19/how-safe-is-nuclear-energy

Two ThorCon 500 MW molten salt reactor plants

24x7

zero CO_2

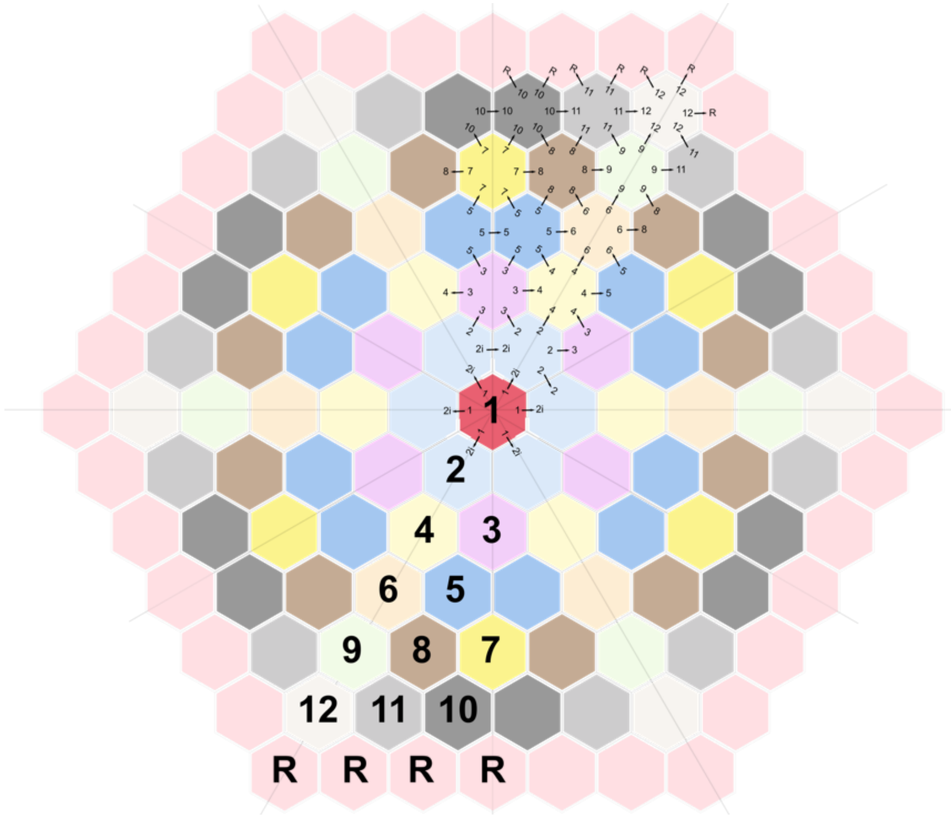
20 plants per year

3 cents/kWh, cheaper than coal or LNG

ThorCon

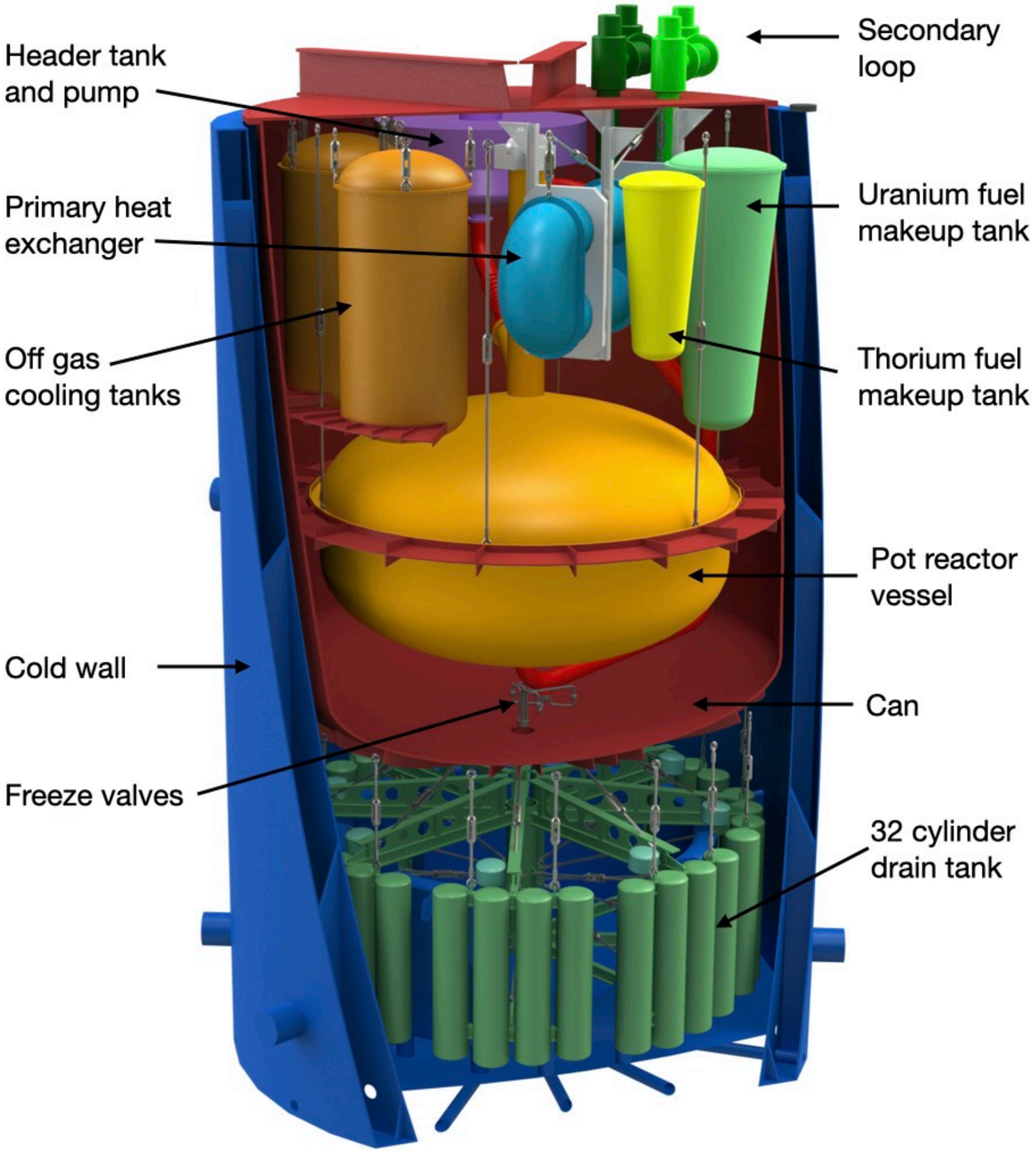
Powering Up Our World

Oak Ridge National Labs' molten salt reactor used uranium fuel in salt flowing up in channels in a graphite moderator.



- Physics stops fission if salt temperature rises much over 700°C, well below boiling.
- High temperature allows more electric power with less cooling water.

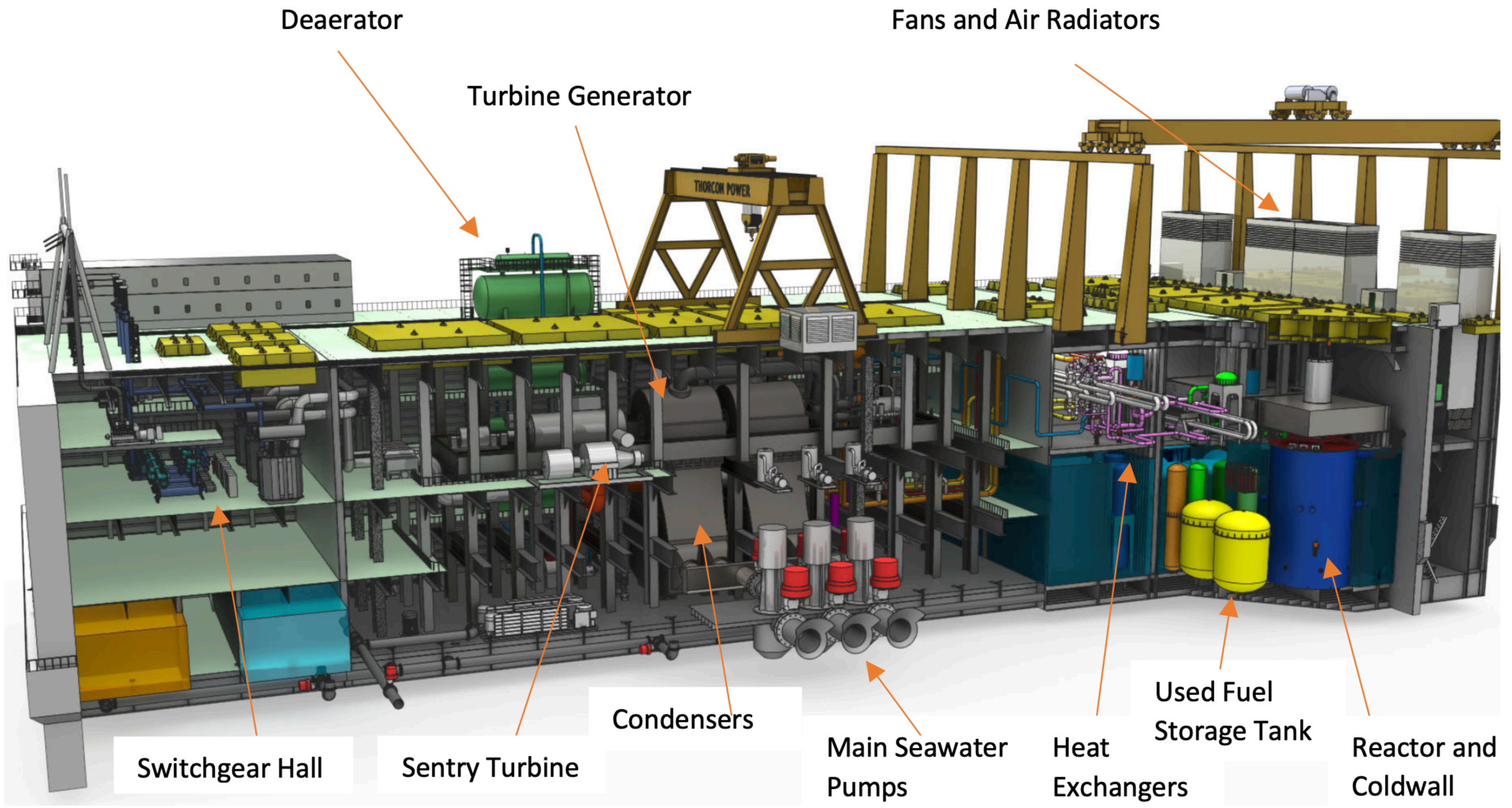
ThorCon
Powering Up Our World



Replaceable Can, in Silo Cold Wall

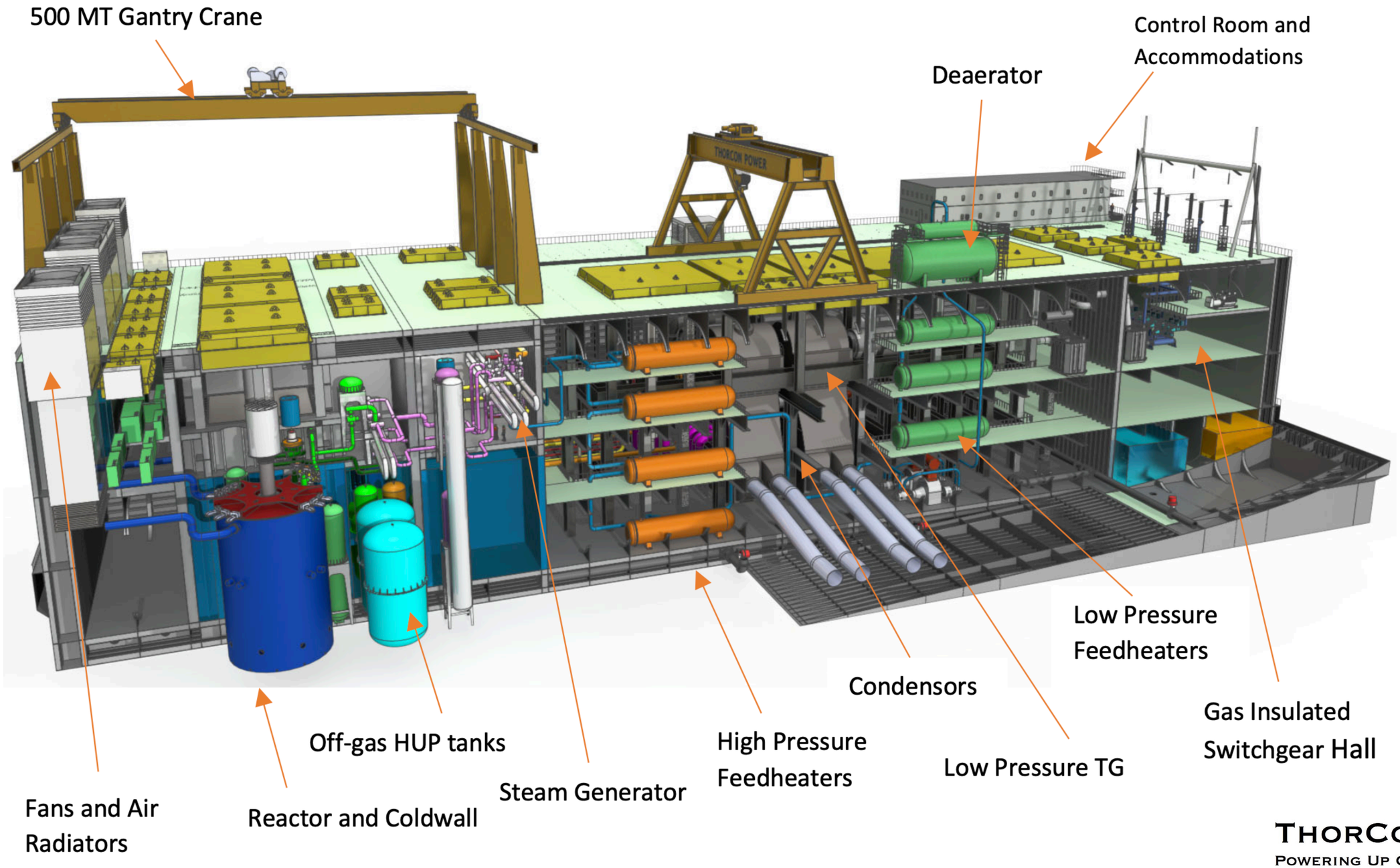
- The reactor Pot contains the graphite moderator with channels for molten salt flow.
- Overheat drains salt to drain tank.
- Cold wall absorbs heat radiated from drain tank.
- Cold wall is cooled by natural water circulation.

ThorCon 500 MW liquid fuel fission power plant (starboard side)



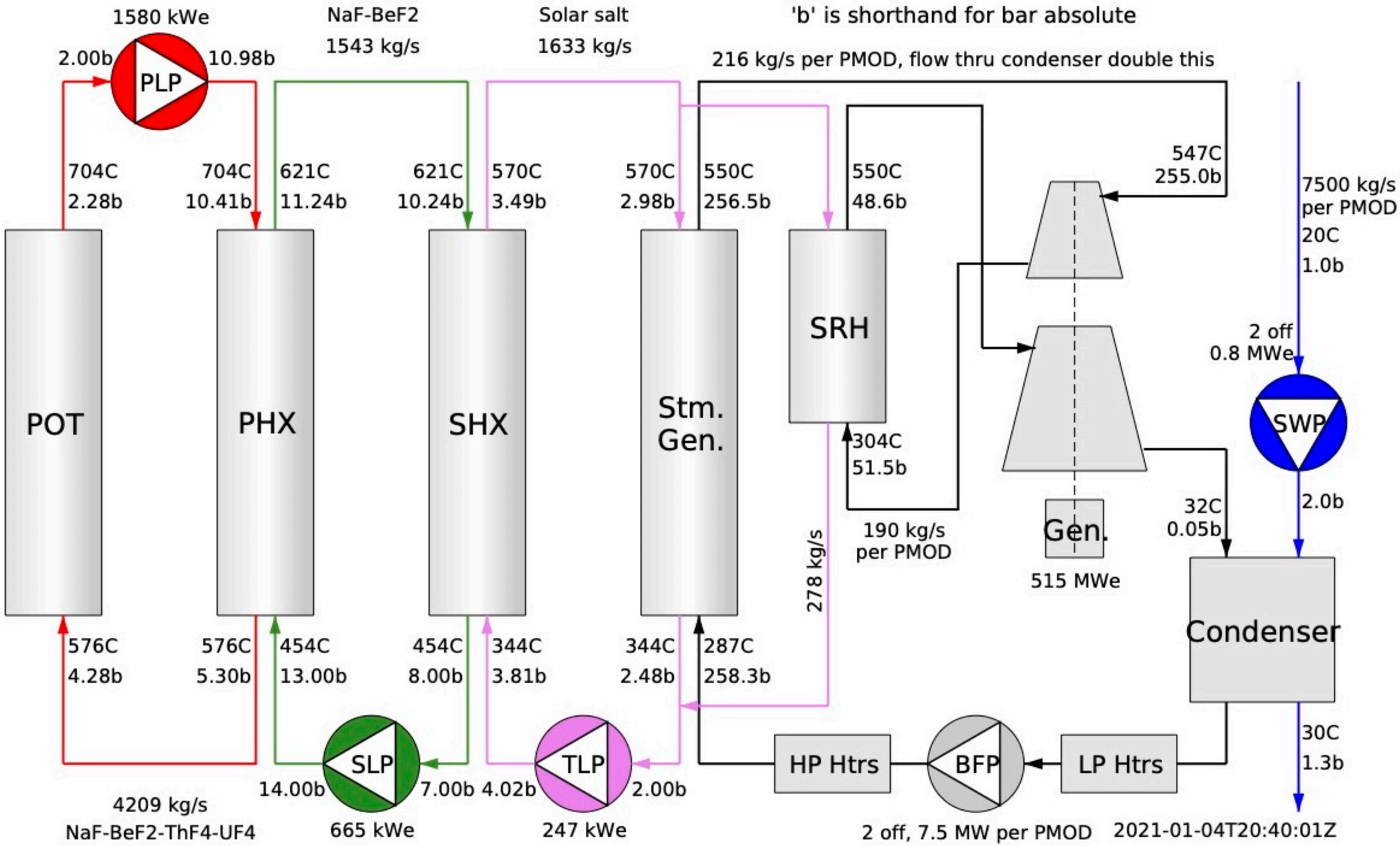
ThorCon
Powering Up Our World

ThorCon 500 MW liquid fuel fission power plant (port side)



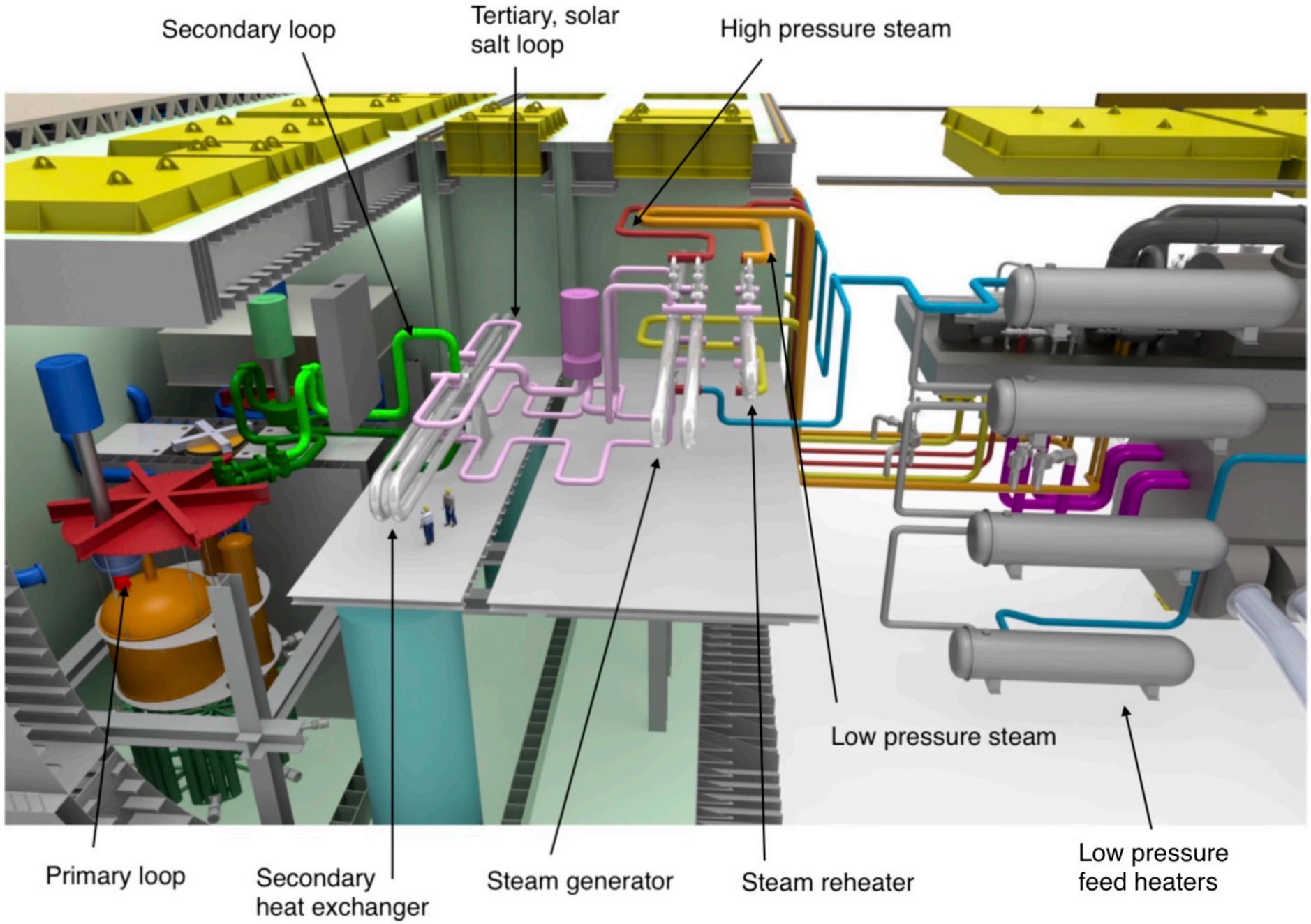
ThorCon
Powering Up Our World

Convert 2 x 557 MW thermal —> 515 MW electrial



ThorCon
Powering Up Our World

Convert 2 x 557 MW thermal —> 515 MW electrial



ThorCon
Powering Up Our World

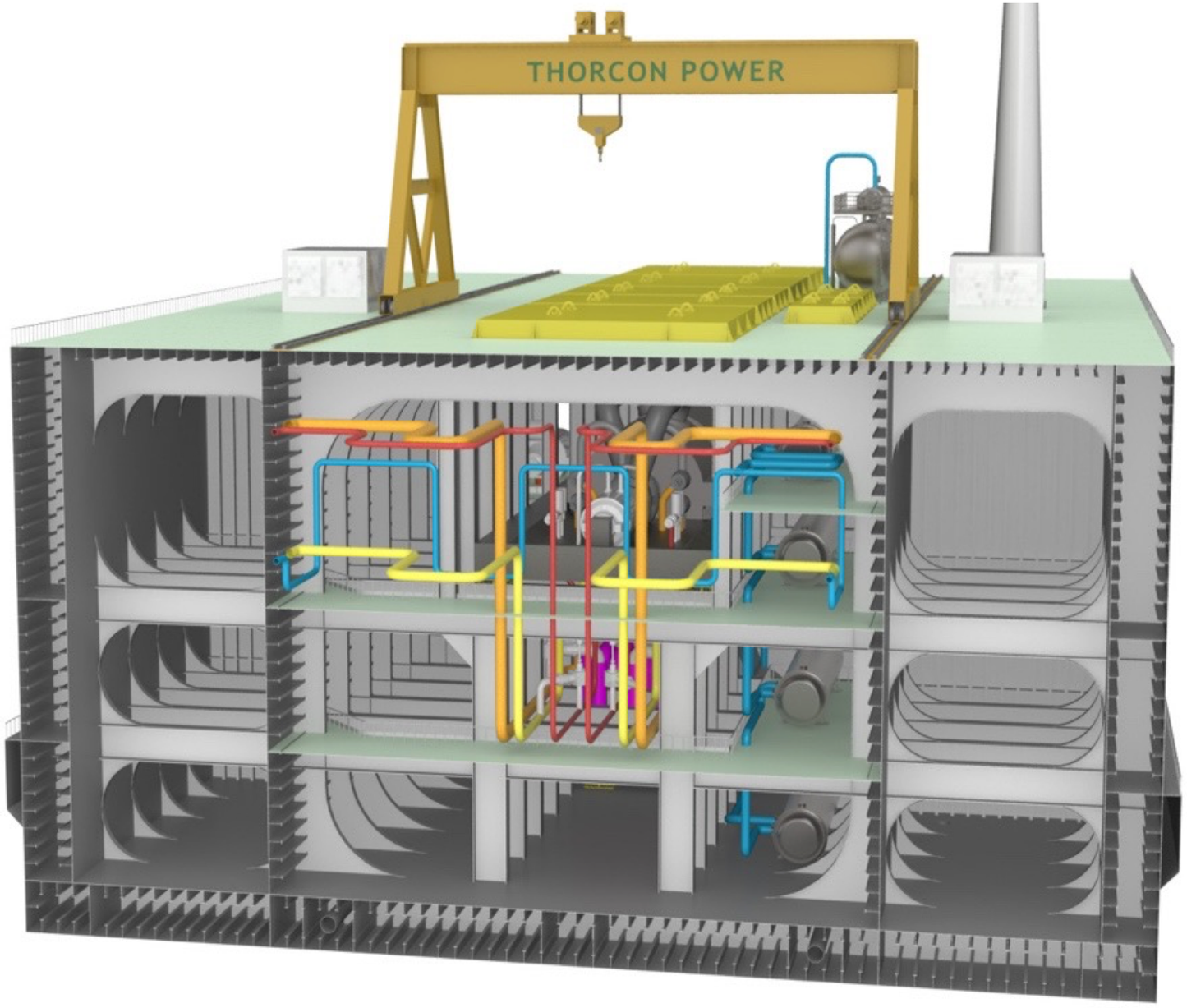
Devanney Ultra Large Crude Carrier cost $89 million, built in 10 months

ThorCon designers are experienced in shipyard construction technology.

- Built eight of the world's largest supertankers
- $600 million program
- responsible for all specifications, financing, yard negotiations and supervision
- Built on firm, fixed price, fixed schedule project.

ThorCon
Powering Up Our World

Same structural design as double-hull oil tanker.



- Important for structural design to match shipyard practice.
- Reduces costs.
- Enables 1-year shipyard fabrication, and
- Mass production of 20 plants per year.

Shipyards fabricate vessels at 5 labor-hours per ton of steel.

THORCON
POWERING UP OUR WORLD

Daewoo Shipbuilding and Marine Engineering will be ThorCon EPC.

ThorCon
Powering Up Our World

Prototype will be towed to Indonesia.

ThorCon
Powering Up Our World


Sea
THAILAND
South China Sea
Strait of Malacca
MALAYSIA
BRUNEI
MALAYSIA
Borneo
Pulau Ligitan
Pulau Sipadan
Celebes Sea
Medan
Sungaipakning
SINGAPORE
Pekanbaru
Pontianak
Equator
Padang
Kalimantan
Sulawesi (Celebes)
Sumatra
Banjarmasin
Palembang
Java Sea
Makassar
Ciwandan
JAKARTA
Semarang
Madura
Banda Sea
Bandung
Java
Surabaya
INDIAN OCEAN
Denpasar
Kupang
THORCON
POWERING UP OUR WORLD

Bangka-Belitung governor approved island site.

- Power company's PLN-Engineering carried out site feasibility study.
- Bapeten, the nuclear regulator, has promised efficient regulation.
- A MOU has been signed with PLN for a 30-year PPA for the demo plant.
- A MOU signed with BRIN regarding co-development of the demonstraton plant.
- Recent poll: 74% of the public in Bangka are in favor of nuclear power.

ThorCon
Powering Up Our World

ThorCon power plant costs in production, revenue

Total Cost in USD Millions of 1 GW Plant: 2 x 500 MW Units

Capital Costs		Consumables	
Plant	790.3	Fuel	413.0 per 4 yrs
2nd Loop, Solar and Flush Salts	68.8	Cans	60.0 per 4 yrs
Breakwater and Site Work	95.0	FDT	2.1 per 4 yrs
Transmission Lines	10.0		
Delivery and Installation	26.0		
Total	990.1	Total	475.1
Plant on Site with Consumables		1,465.2	

4 yrs gross revenue: 4 x 1,000,000 kW x 0.9 x 24 x 365 x $0.05/kWh = $6,308 millon

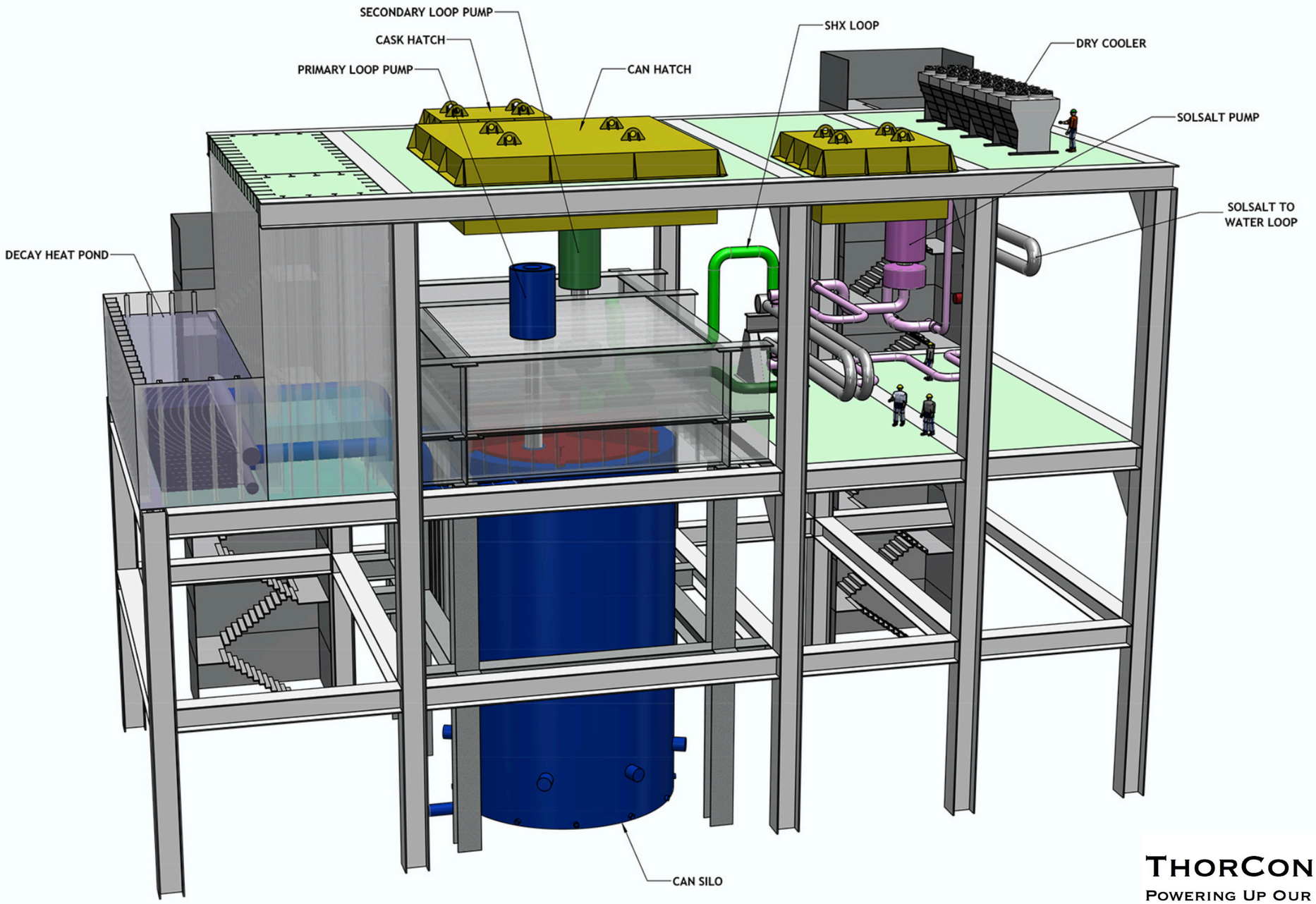
Launch schedule for ThorCon technology

Year 1	PTP specs to vendors, demo site selection, IAEA safety study, site feasibility study, ITB lab started, negotiations with PLN, negotiations with Bapeten, salt characteristics studies, raise 2nd tranche for PTP build and tests.	$ 10 M
Year 2	Contracts signed with vendors, build PTP, salt characteristic studies, salt production for PTP, test protocols agreed with Bapeten, formal PPA negotiations with PLN started, permits obtained for Kelasa Island, demo project given national priority status.	$ 70 M build NFT plant
Year 3	Pre-fission testing of the PTP, testing witnessed by IAEA and Bapeten, sign PPA with PLN for demo, fission test protocols agreed with Bapeten and construction license for demo issued, funding for demo plant raised, start of on-site work for the demo, contracts signed with vendors for the demo plant.	$ 90 M test NFT plant
Year 4	Build the demo plant at DSME, finish on-site construction work, complete transmission lines, raise funding for demo testing.	$ 608 M build 500 MW demo plant
Year 5	Preliminary testing of plant at yard, then tow plant to site and install. Operational testing. Sites selection for 3 GW of follow-on power for PLN. Studies for 3GW approvals initiated.	$ 273 M fuel and test demo plant
Year 6	Examination of Reactor A after 12 months operation, severe testing of Reactor B, design license granted. PPA for 3 GW signed with PLN.	
Year 7	Start construction of 3 GW of power at DSME.	
Year 8	Tow 3 GW of power to Indonesian sites and install, start construction on 5 GW of power for Indonesia and other SE Asian countries.	+3 GW Indonesia
Year 9	Tow 5 GW to sites in SE Asia and install, start construction on 10 GW, start construction of Indonesian assembly line.	+5 GW SE Asia
Year 10	Tow 10 GW to sites and install, finish assembly line.	+10 GW

clip from ThorCon business plan

ThorCon
Powering Up Our World

Next step: Build and test non-fission test platform.



ThorCon
Powering Up Our World

Compare to water reactor technology

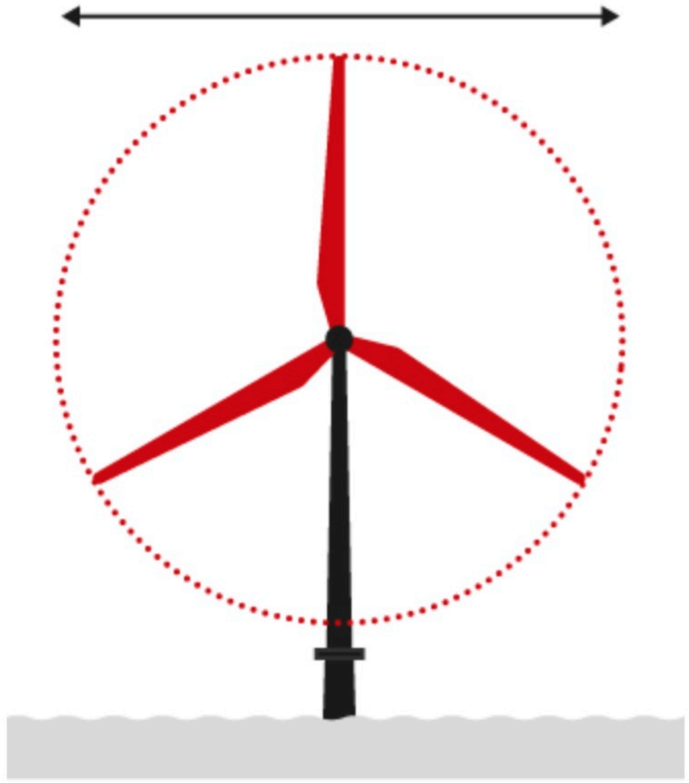
ThorCon	Conventional nuclear
Low pressure	High pressure
Liquid fuel	Solid fuel
High temperature	Low temperature
46.5% efficiency	32% efficiency
Inherent safety	Engineered safety systems
2 years to build	Many years to build
$ 1 per watt	$ 3.5 to 7 per watt
3 cents/kWh	6-10 cents/kWh
Shipyard mass production	On-site construction

ThorCon
Powering Up Our World

GE Haliade X
12 MW intermittent

Rotor diameter

220m

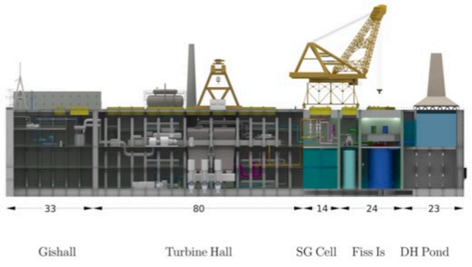


12MW turbine

260m high

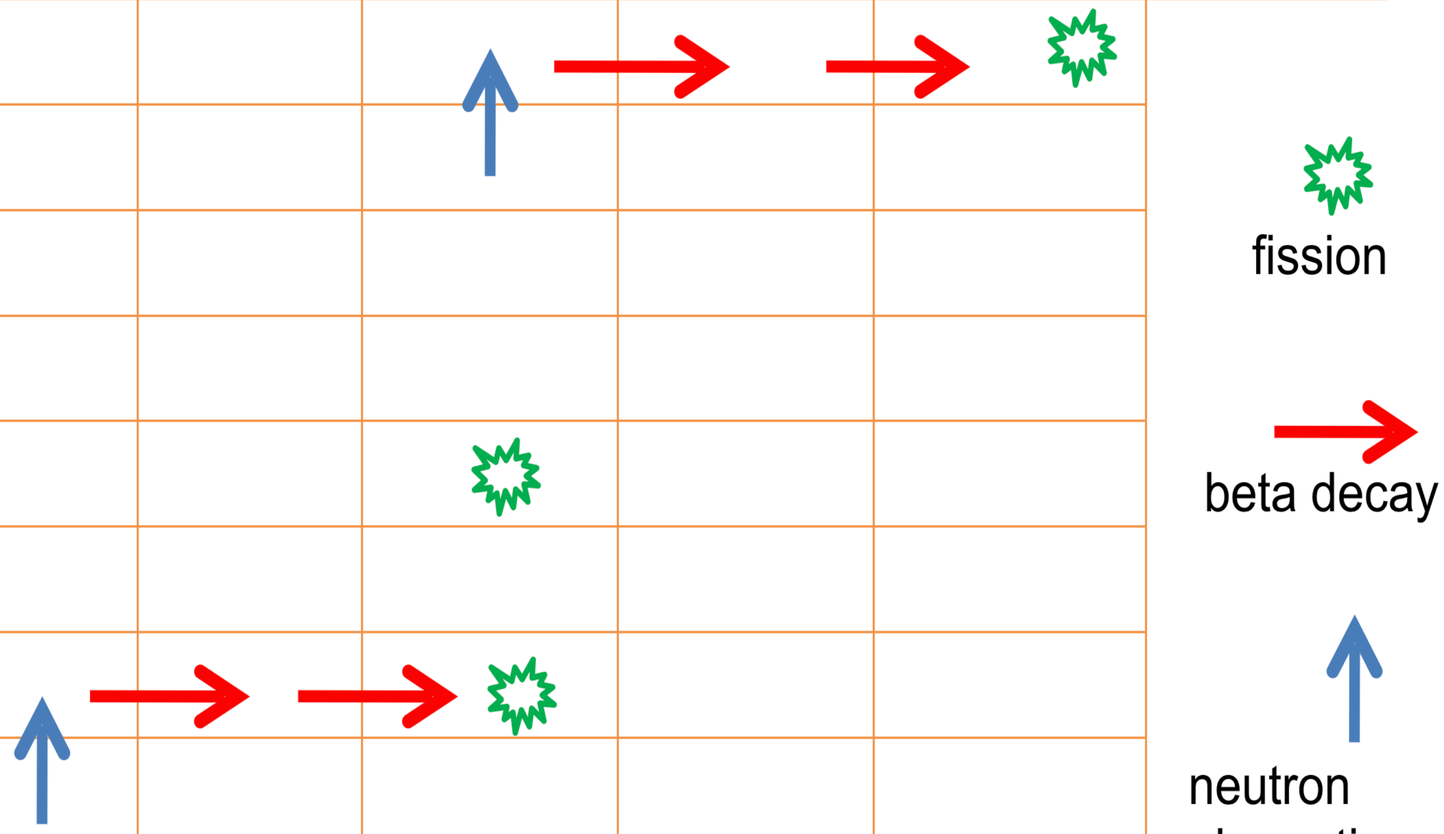
ThorCon liquid fission
500 MW full time
length 165 m

to scale



ThorCon can be a Thorium Converter, with more-enriched uranium.

nucleons	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95
241						
240						
239						
238						
237						
236						
235						
234						
233						
232						



Fission power sources

Uranium
- 19.75% U-235
- 50%

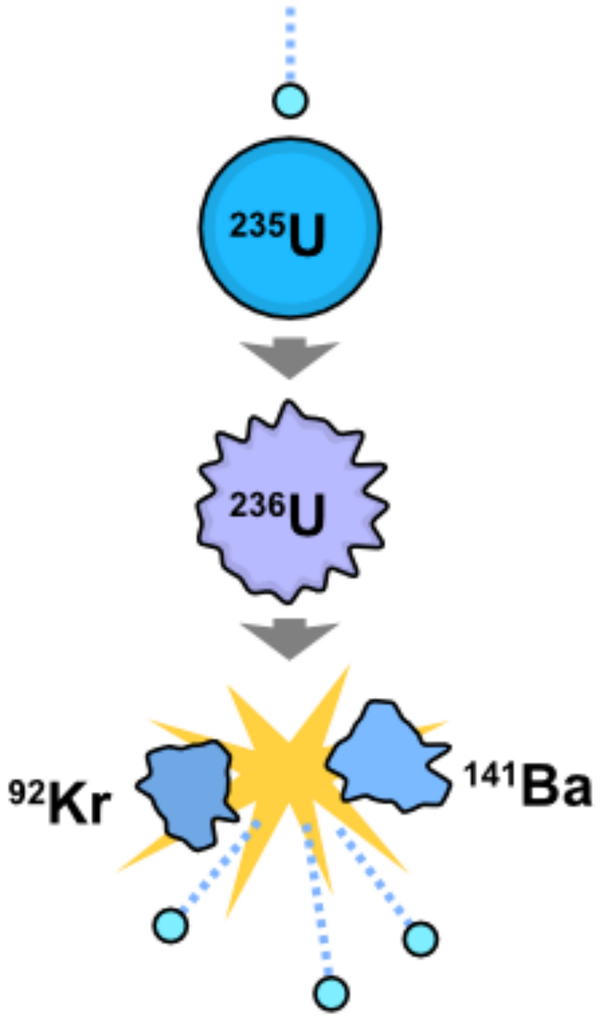
Thorium
Th-232 —> U-233
- 25%

Plutonium
U-238 —> Pu-239
- 25%

But what about the waste?


RADEX
0.12
MENU
OFF
QUARTA

Uranium-235 is split into fission products, releasing energy.



Fission example

The total mass of the resulting

barium-141 <— fission product
krypton-92 <— fission product
neutrons (3)

is a bit less than the mass of the U-235 + neutron.

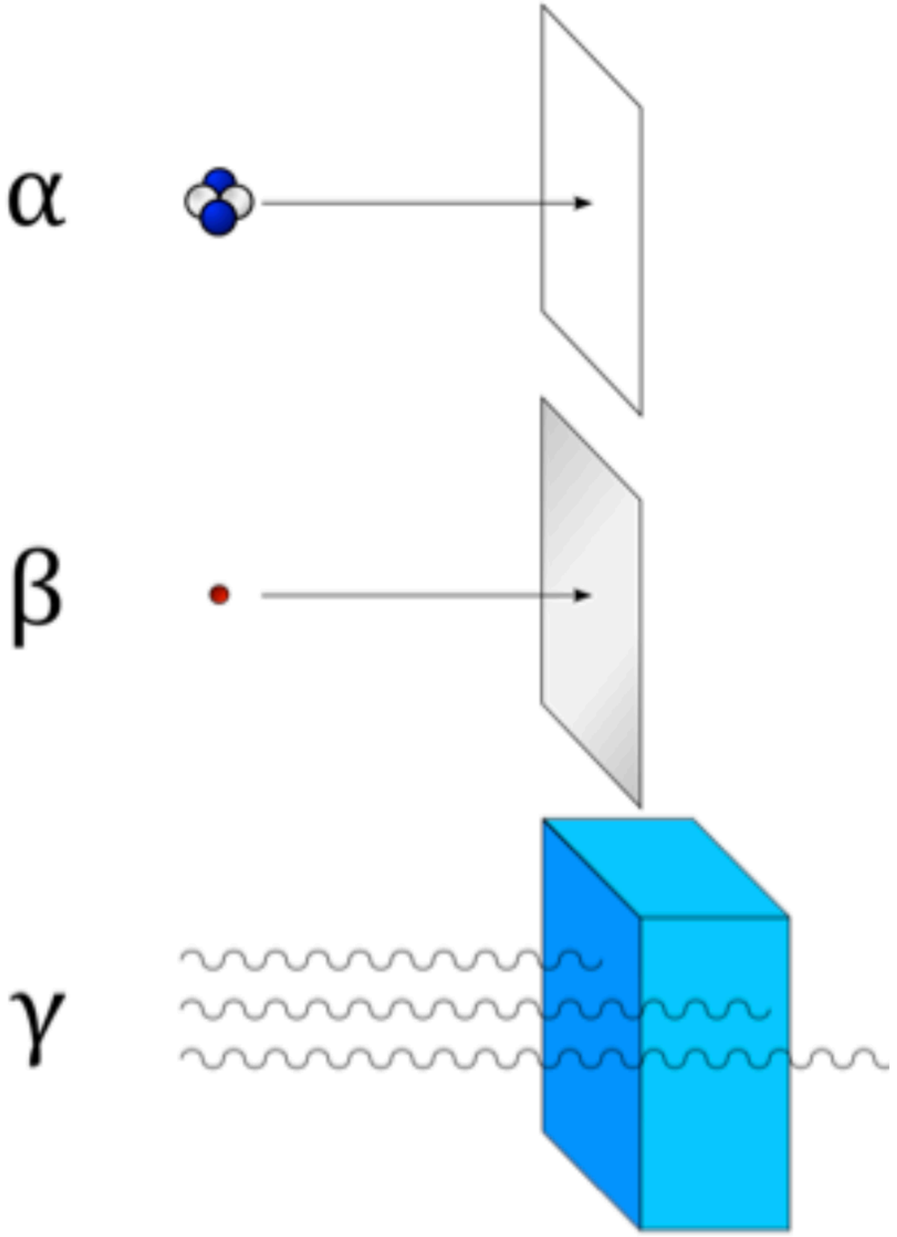
By Einstein's famous $e = mc^2$

releases 166 MeV of energy, then 34 MeV more by decay of Kr and Ba fission products.

1 tonne U-235 fissioned -> 79,000 TJ heat,
= 2.6 GW-years heat, to make 1 GW-year electricity


Fission product decays make used nuclear fuel hazardous, so removal is done under water.

Radiation results from each atom's decay.

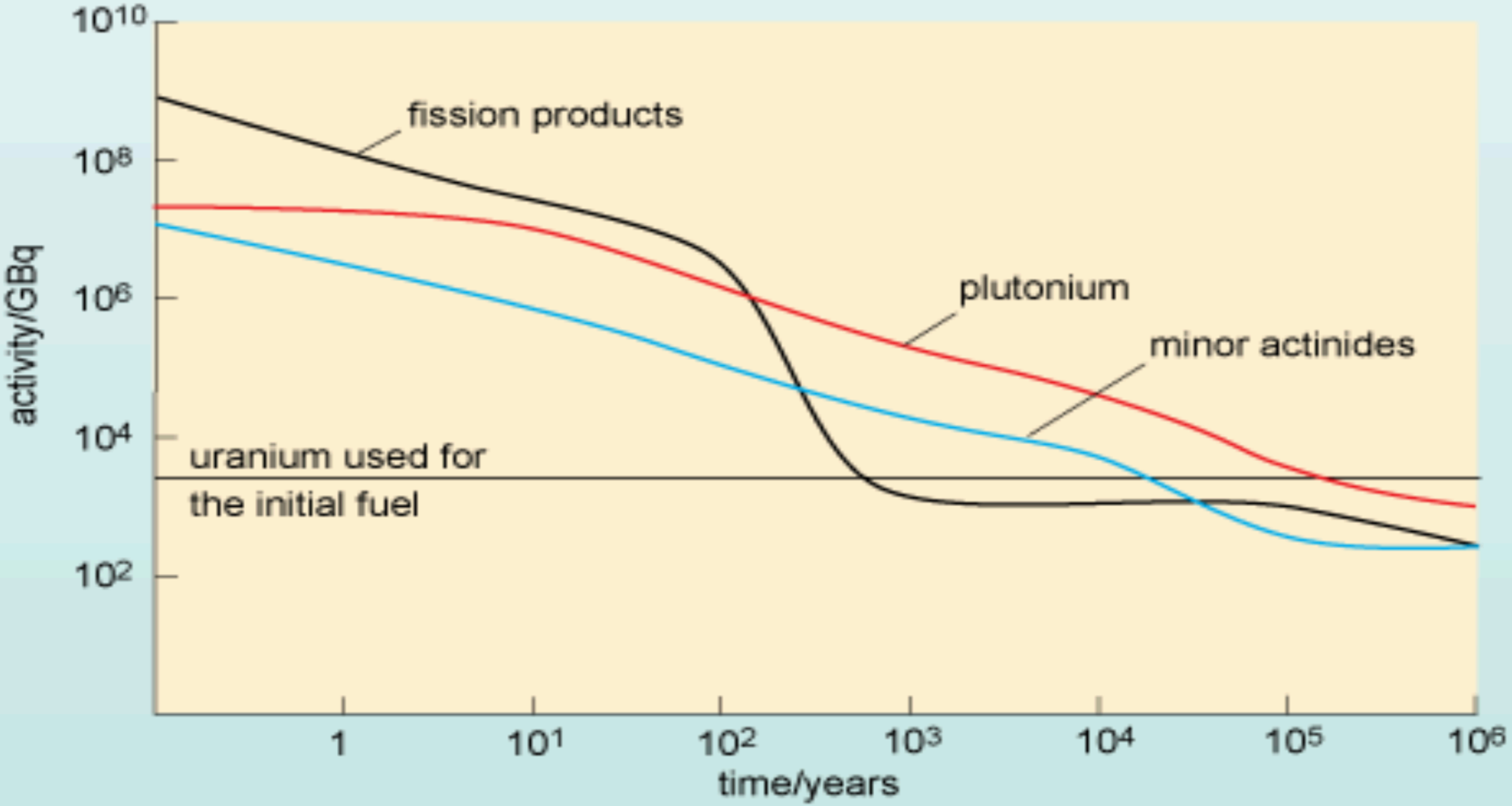


Alpha particles (two protons + two neutrons) can not penetrate skin.

Beta particles (electrons ejected from nuclei) do not penetrate metal foil.

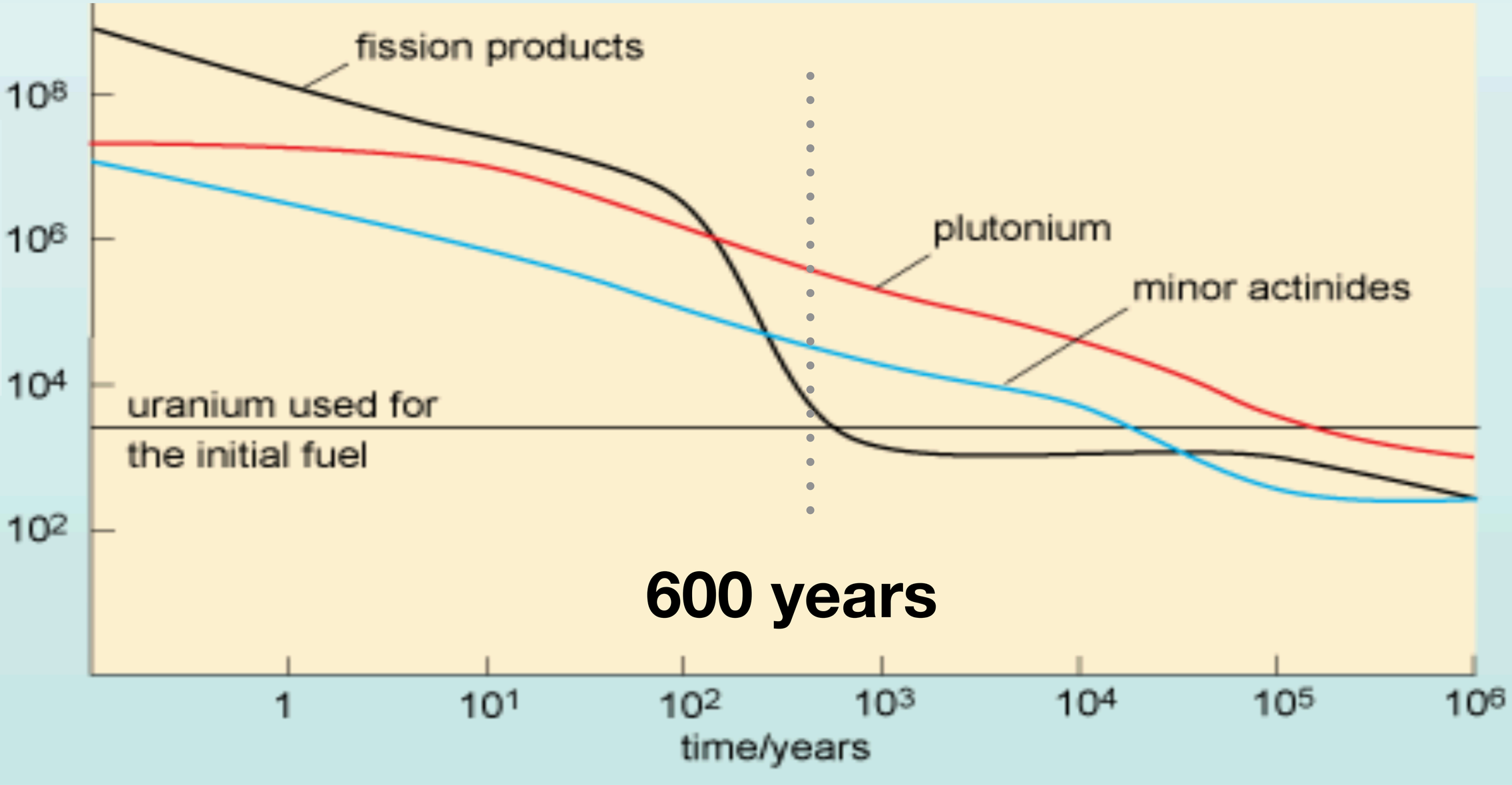
Gamma radiation (energetic photons) is partly absorbed by bone to make X-ray images.

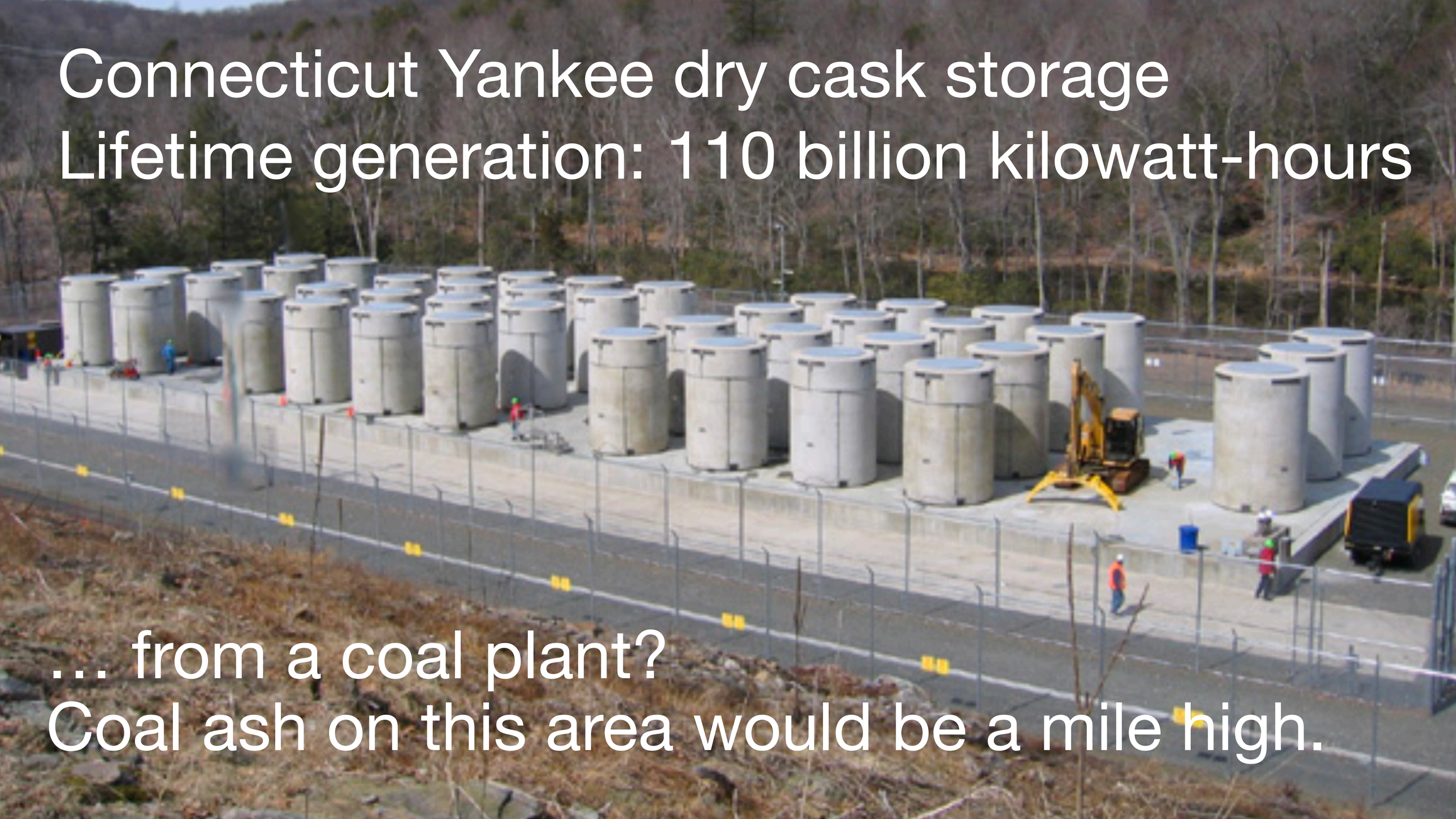
Fission products emit the penetrating photons.

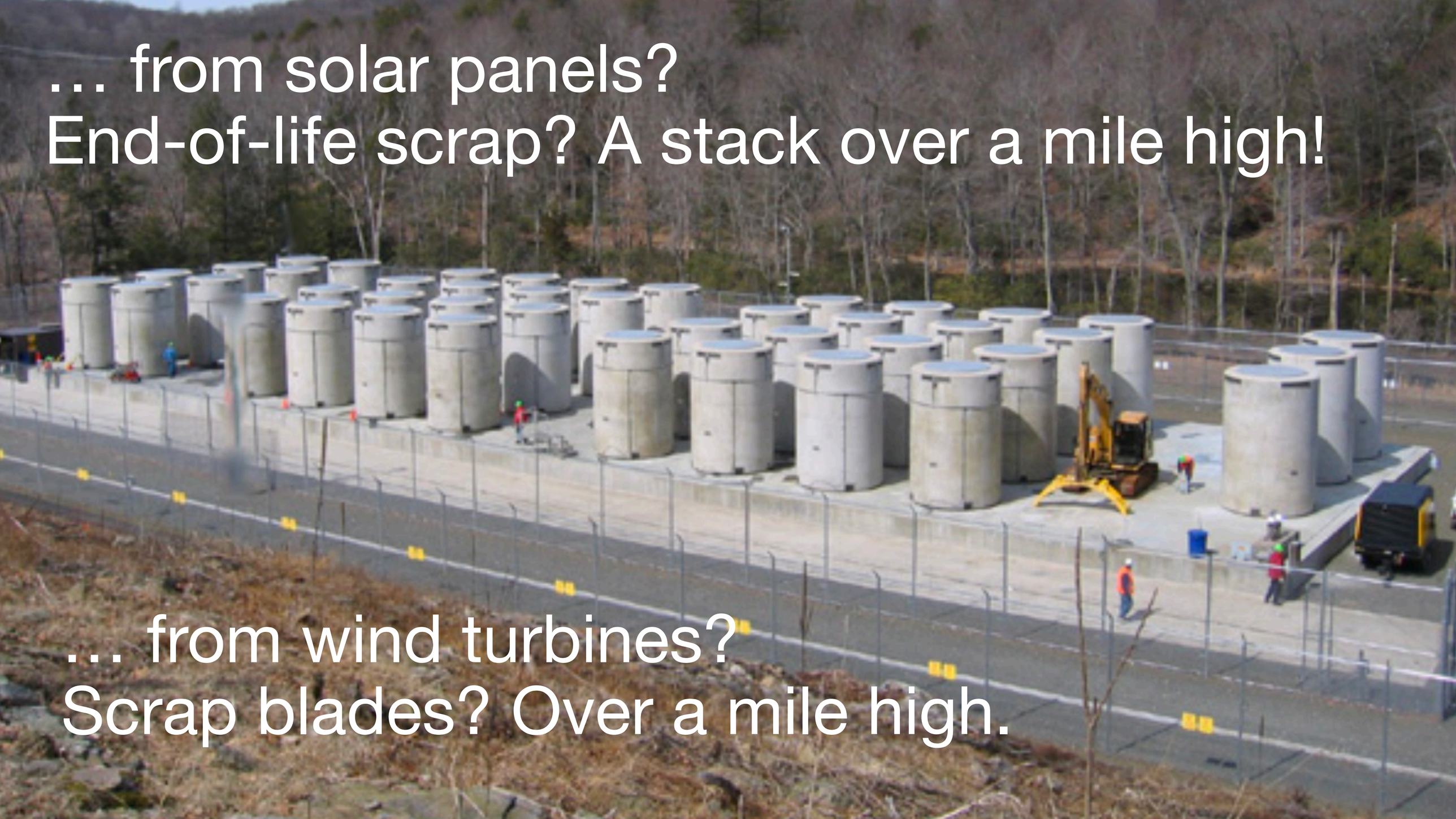



Steel and concrete casks intercept the photons.
By year 600, 99.999% of photon emitters are gone

After 600 years you'd have to eat the plutonium and minor actinides to be harmed.

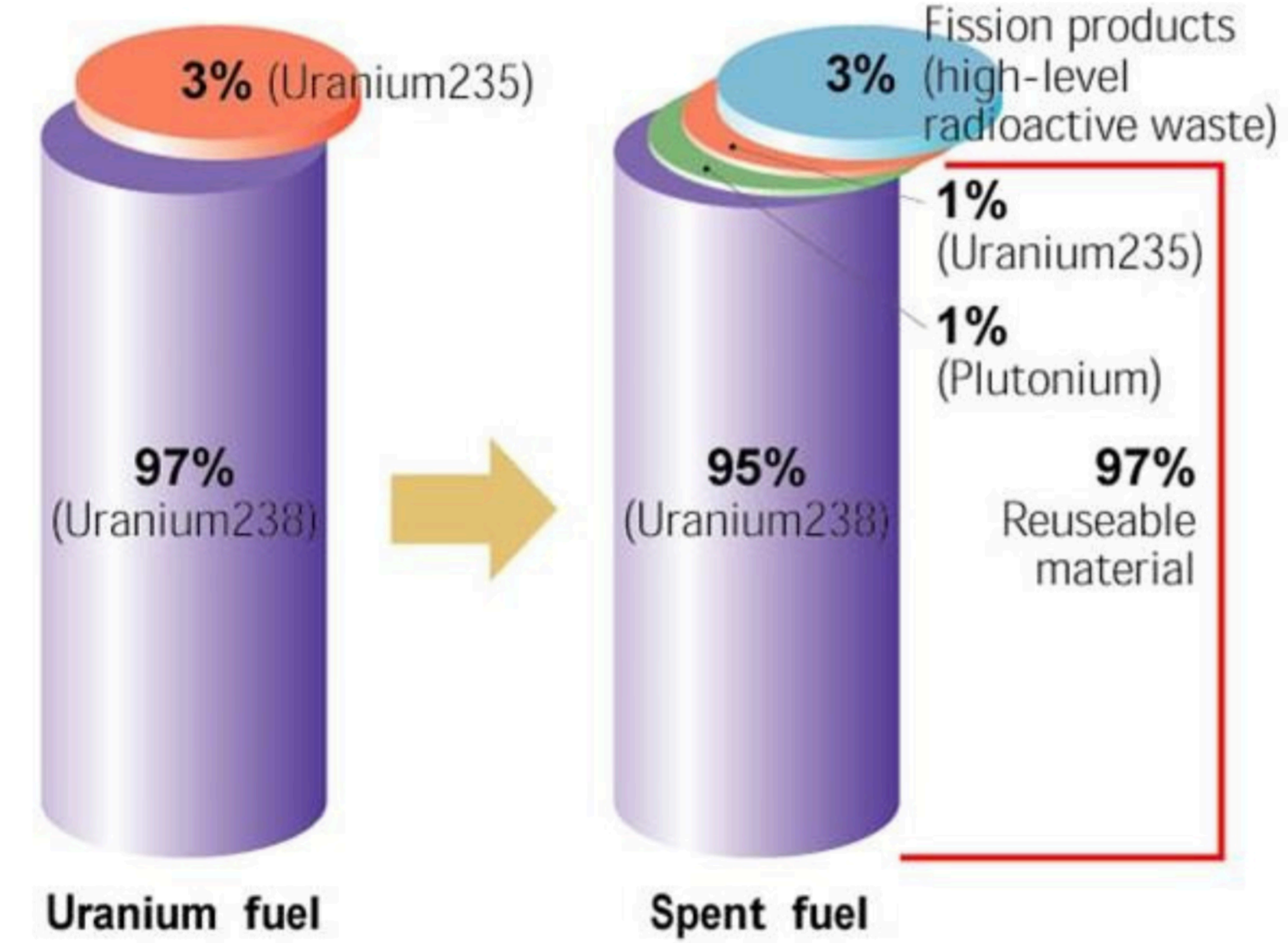



Connecticut Yankee dry cask storage
Lifetime generation: 110 billion kilowatt-hours
… from a coal plant?
Coal ash on this area would be a mile high.


… from solar panels?
End-of-life scrap? A stack over a mile high!
… from wind turbines?
Scrap blades? Over a mile high.

Connecticut Yankee fuel casks now

97% of the spent fuel can be reused in new reactors.




Unfounded radiation fear is the ignored elephant in the room.
https://www.2lo.co.uk/Elephant-in-the-room/

New York Times prints radiation scares.

We Are Giving Ourselves Cancer

By RITA F. REDBERG and REBECCA SMITH-BINDMAN JAN. 30, 2014

"a 2009 study from the National Cancer Institute estimates that CT scans conducted in 2007 will cause a projected 29,000 excess cancer cases and **14,500 excess deaths** over the lifetime of those exposed."

https://www.nytimes.com/2014/01/31/opinion/we-are-giving-ourselves-cancer.html

New York Times prints radiation scares.

ANXIETY

Showdown at the Airport Body Scanner

BY NATHANIEL RICH MAY 25, 2013 1:00 PM Comment

I create delays, futzing with my shoes or laptop, until the line has bottlenecked at the cancer machine.

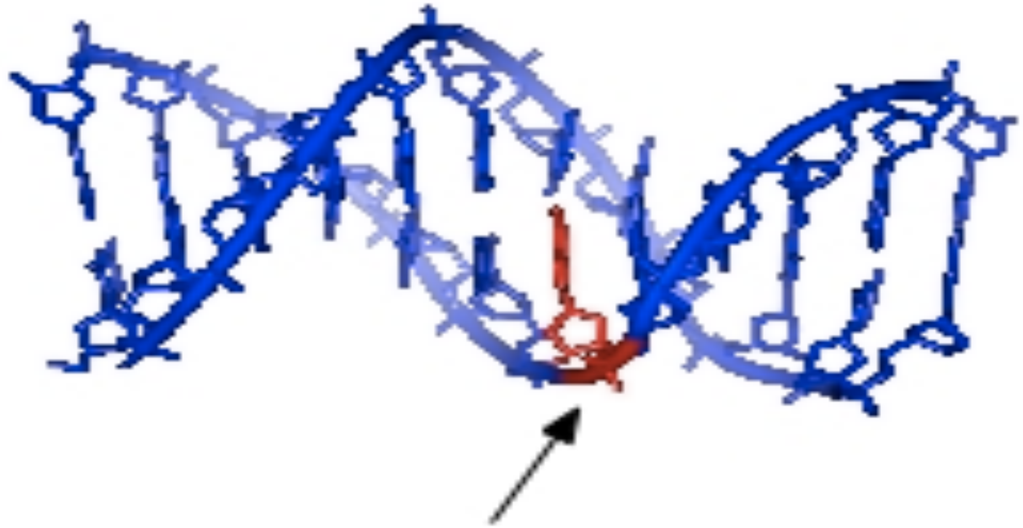
…

I note that there is a correlation between radiation absorption over a lifetime and cancer rate.

…

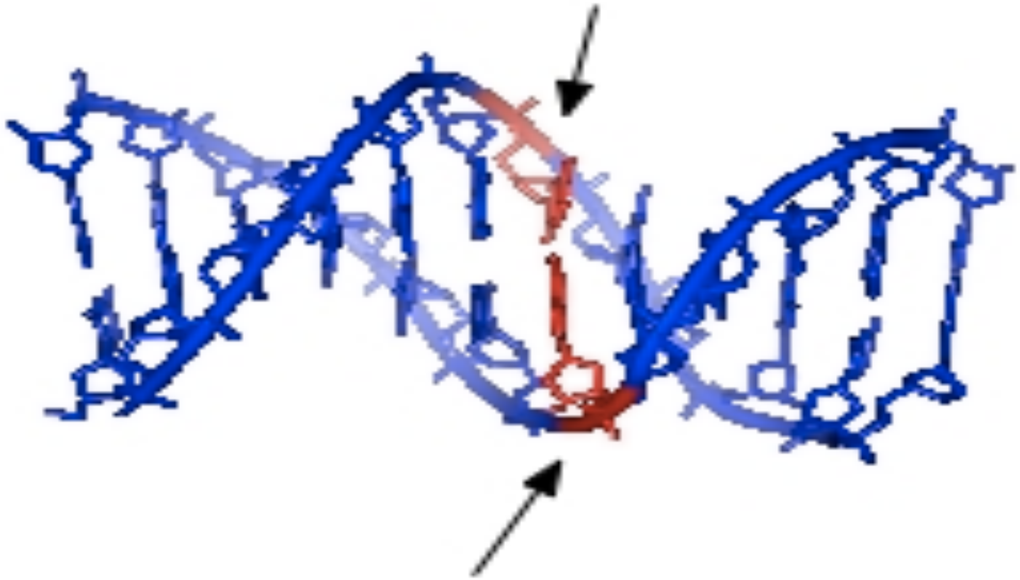
ProPublica and PBS NewsHour concluded that the X-ray scanners, then still in use, could cause cancer in 6 to 100 United States airline passengers every year

DNA strand breaks occur frequently, by ionized oxygen molecules from metabolism.



Single strand breaks occur **10,000 times per day per cell**.

100 mSv/y radiation adds 12 per day.

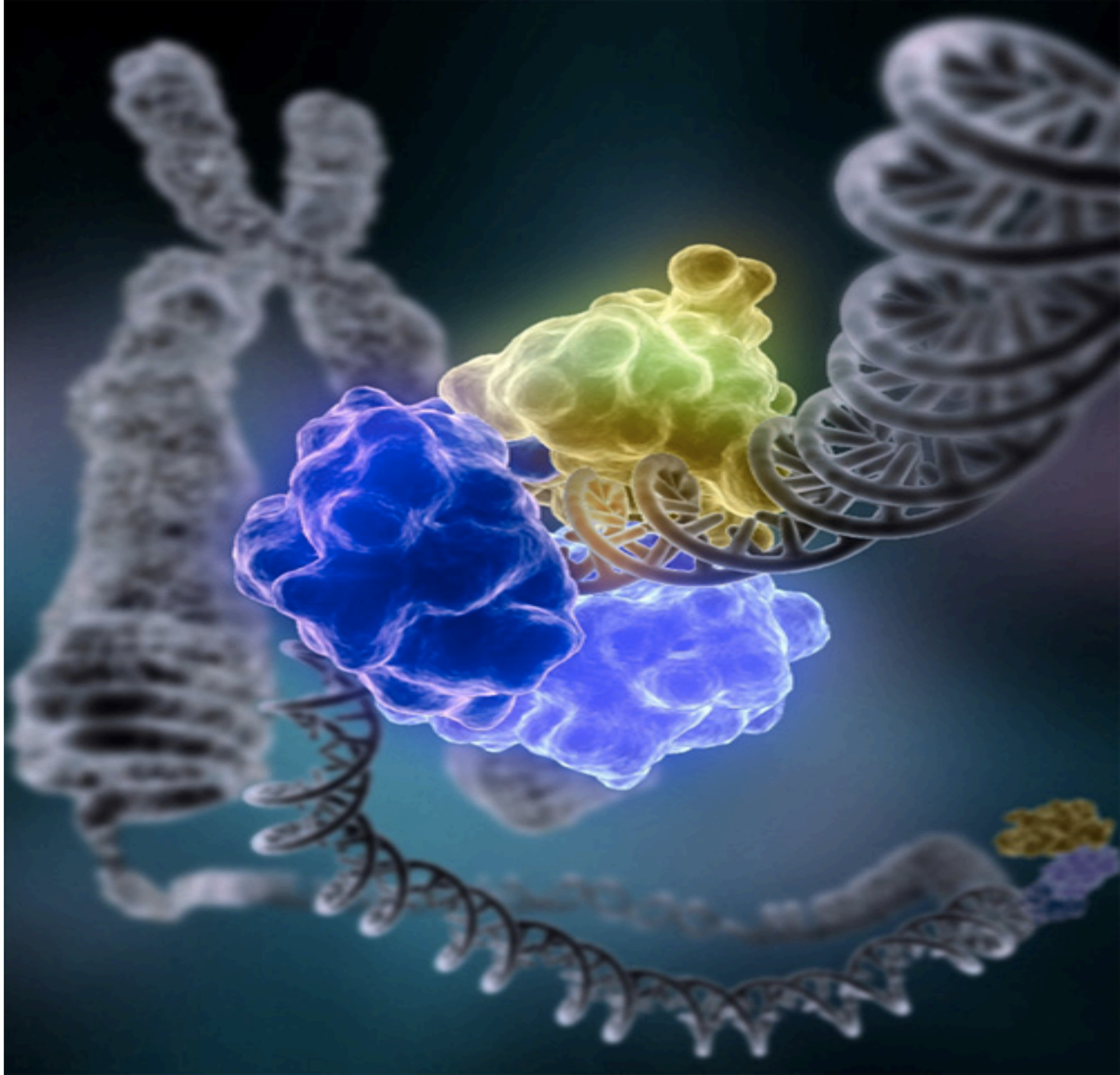


Double strand breaks occur **10 times per day per cell**.

100 mSv/y radiation adds 1 per year.

DNA is repaired.

Special enzyme DNA ligase encircles the double helix to repair a broken strand of DNA.



2015 Nobel Prize: How DNA is repaired.

Lindahl: excision ***repair*** — the cellular mechanism that repairs damaged DNA during the cell cycle.

Modrich: how cells ***correct errors*** that occur when DNA is replicated during cell division.

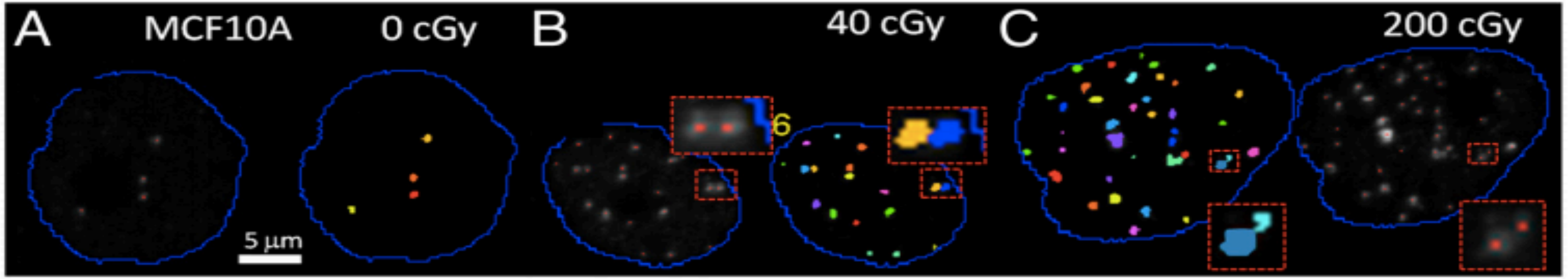
Sancar: mapping the mechanism cells use to ***repair*** ultraviolet damage to DNA.

http://www.nytimes.com/2015/10/08/science/tomas-lindahl-paul-modrich-aziz-sancarn-nobel-chemistry.html

DNA repair times are ~ 1 hour.

Evidence for formation of DNA repair centers and dose-response nonlinearity in human cells

Teresa Neumaier[a], Joel Swenson[b,c], Christopher Pham[d], Aris Polyzos[d], Alvin T. Lo[d], PoAn Yang[d], Jane Dyball[d], Aroumougame Asaithamby[e], David J. Chen[e], Mina J. Bissell[d,1], Stefan Thalhammer[a], and Sylvain V. Costes[d,1]

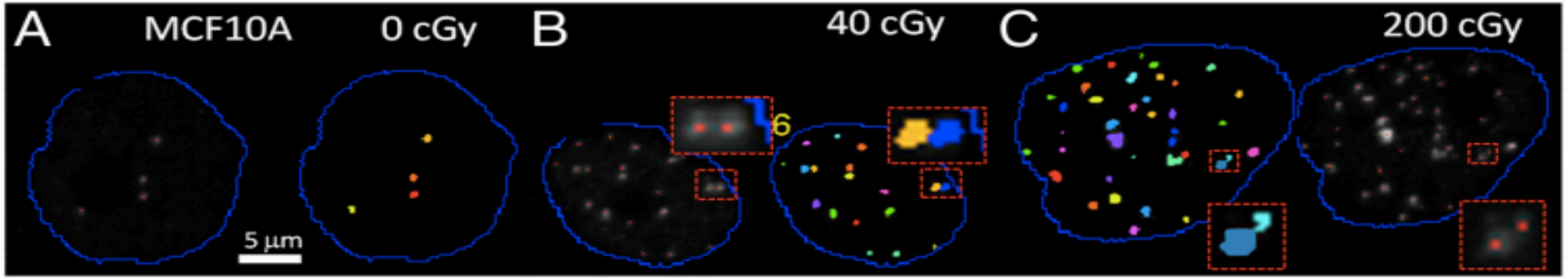


UC Berkeley pictures of DSB repair process

https://www.pnas.org/doi/10.1073/pnas.1117849108

- Bright spots are RIF's, Radiation Induced Foci, clusters of damage sensing/repair proteins.
- RIFs are repair centers for Double Strand Breaks (DSBs).

Each RIF can accurately repair ~ 1 DSB.



Observe/expect ~ 25-40 DSBs per Gy.
Study reveals RIF/Gy, repairability, decreases with radiation exposure:
100 mGy: 73 RIF/Gy
1000 mGy: 28 RIF/Gy

@ 100 mGy, get 7.3/4 RIF/Gy, >1, so repairability OK.
@1000 mGy, get 28/40 RIF/Gy, <1, so repair system overwhelmed.

Repairs are nonlinear with dose rate.

Jack Devanney

Fukushima evacuation killed 2,000 citizens.

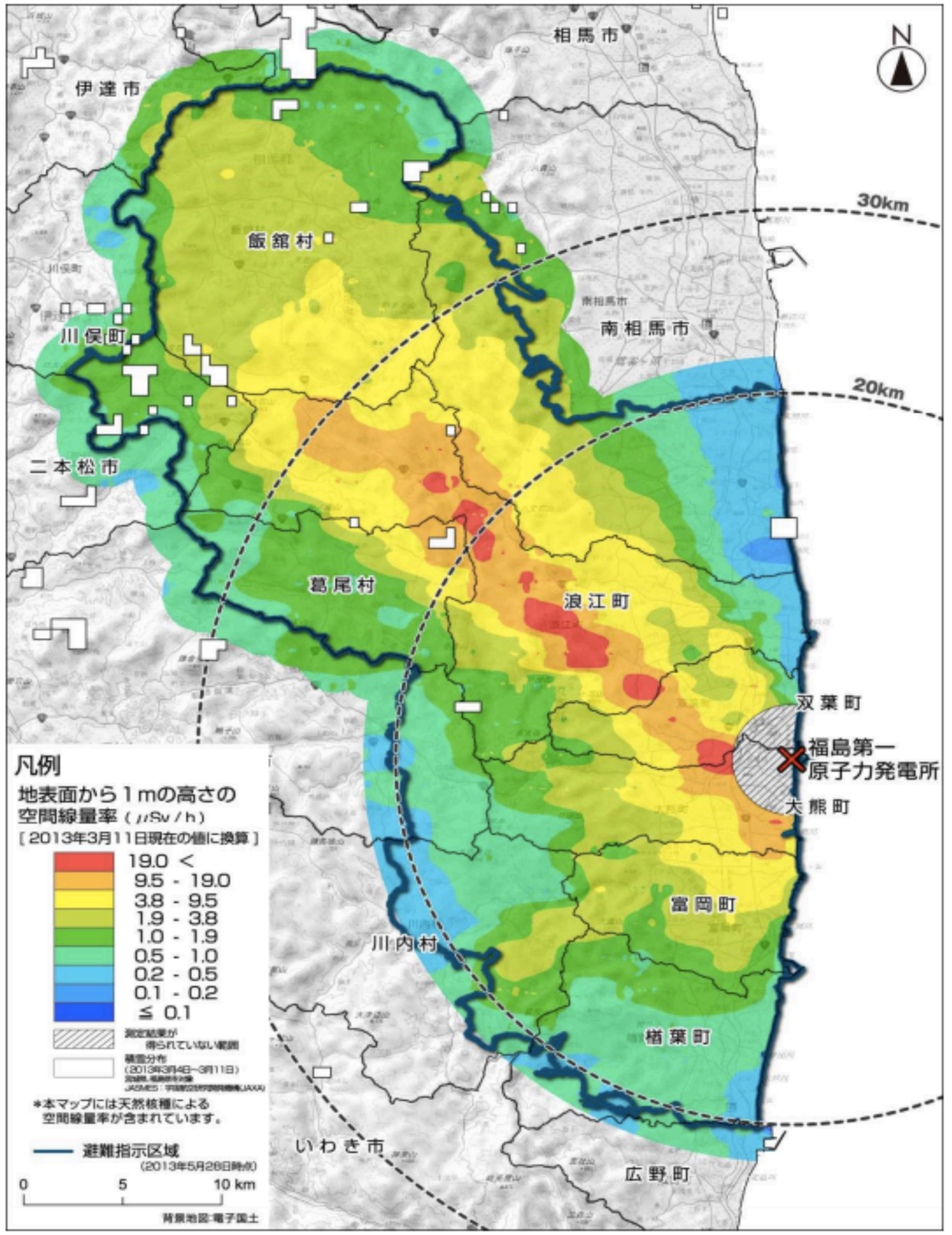
Japan evacuated the black-lined area.

IAEA published recommendation: evacuate the red area.

Evacuation was unnecessary anywhere.

No one died from radiation.

20,000 died from the tsunami.



IAEA Boss Met With Laughter At COP26

"No one died from radiation at Fukushima," Grossi said, **provoking laughter from the audience**.

"I don't know why you're laughing, it's a fact. Thousands of people died because of the tsunami but there were no deaths attributable to exposure to radiation. People died also because of the evacuation, it was very traumatic," he continued.

IPCC ignorance is appalling.

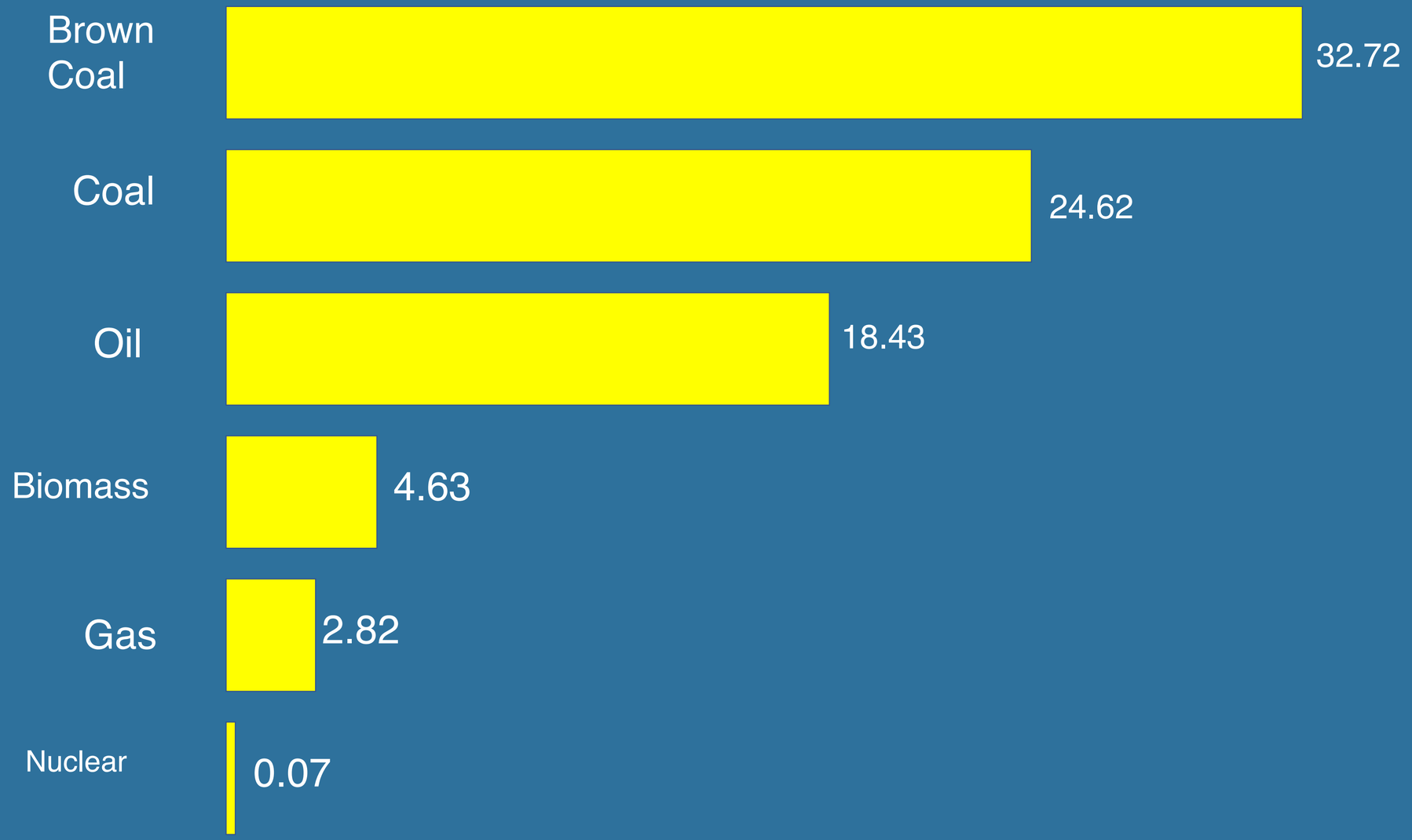
https://www.forbes.com/sites/sofialottopersio/2021/11/04/no-one-died-from-radiation-at-fukushima-iaea-boss-statement-met-with-laughter-at-cop26/?sh=697b8ba27a47

How Much Radiation Is Too Much?

Regulators have set exposure limits far too low, inspiring irrational fear of a cheap, clean energy source.

> …The Dirty Harry atomic bomb test in 1953 dropped **two to three times as much radioactive fallout** on the residents of St. George, Utah, than people near Fukushima were exposed to. There was no evacuation in Utah. People were asked to stay indoors that day; there was **no increase in cancer** rates. …

Fission power is the safest energy source.



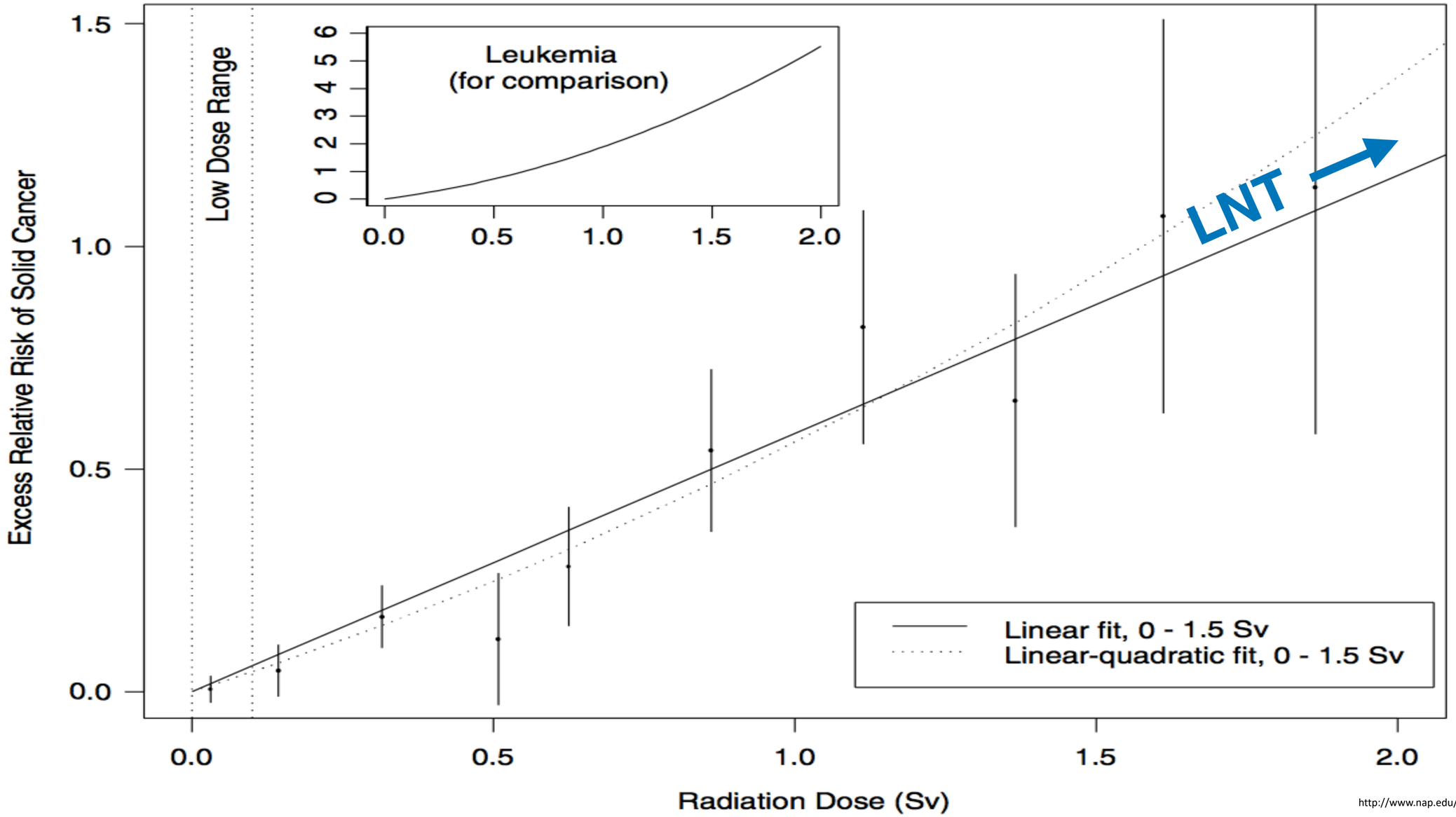
Deaths per thousand gigawatt hours

https://ourworldindata.org/energy#what-are-the-safest-sources-of-energy

Jim Conca: CalTech, NASA, PNNL, WSU, LANL, ANS, Forbes…

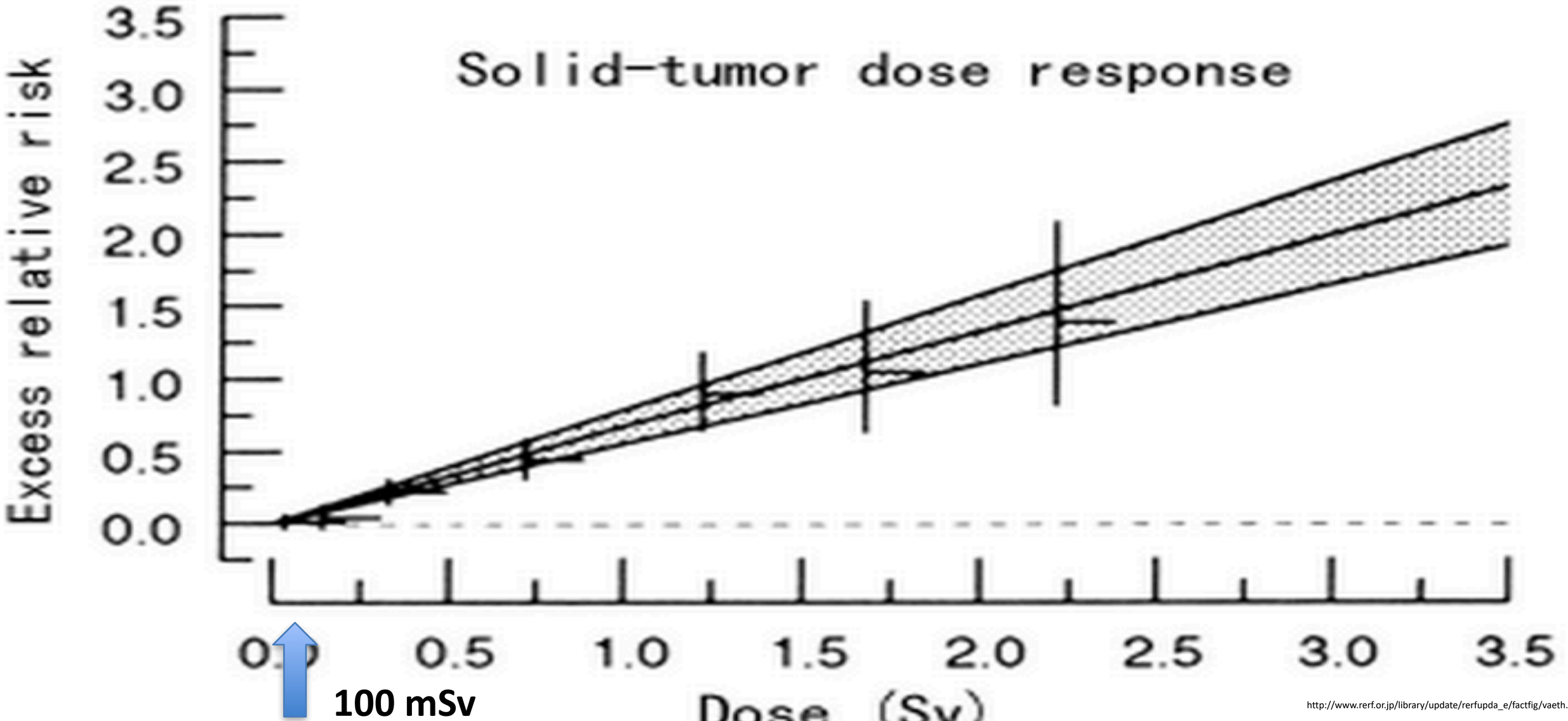
https://www.youtube.com/watch?v=0JfJEK3R1k0

National Academy report said cancer risk is proportional to radiation dose (Linear No Threshold).



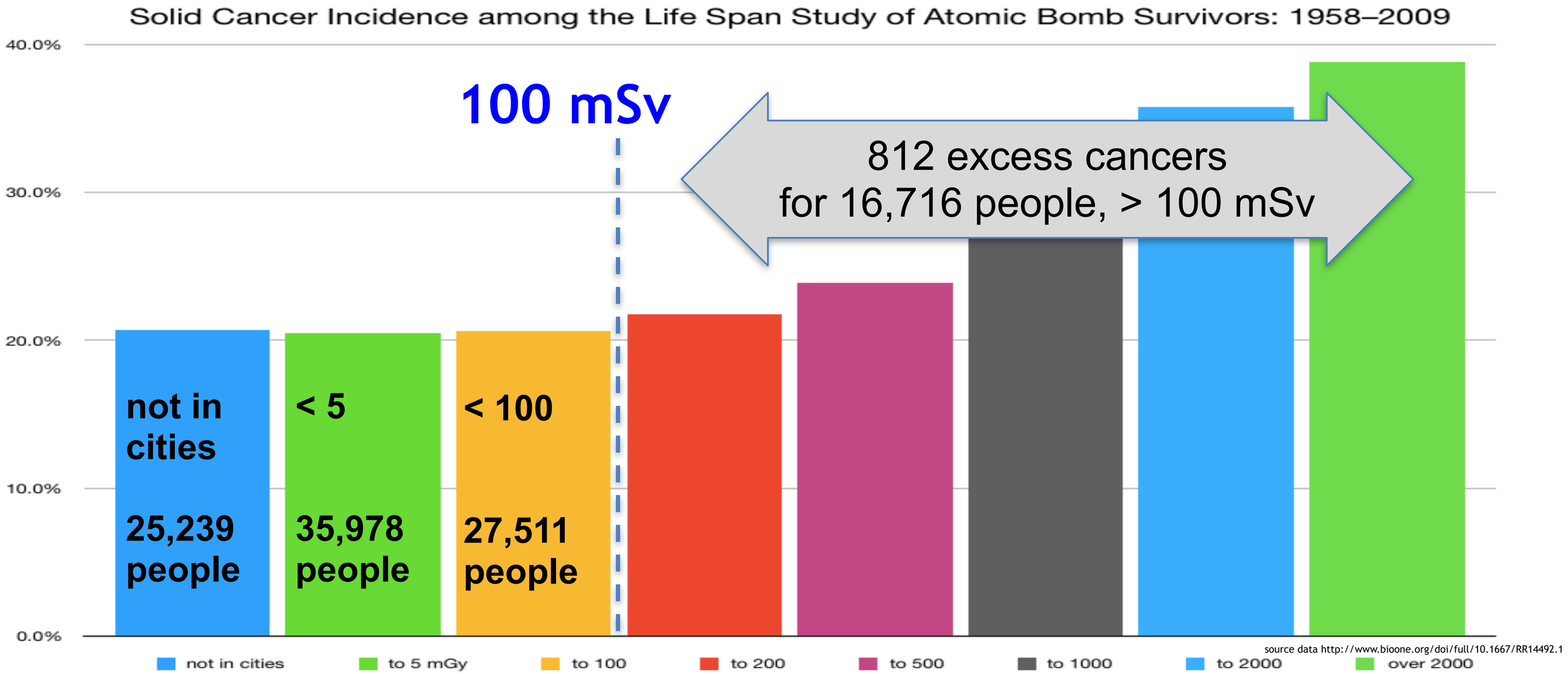
http://www.nap.edu/catalog.php?record_id=11340

Atomic bomb survivor publications do not show the details of doses < 100 mSv.



http://www.rerf.or.jp/library/update/rerfupda_e/factfig/vaeth.html

Atom bomb survivors exposures < 100 mSv caused no observed excess cancers.

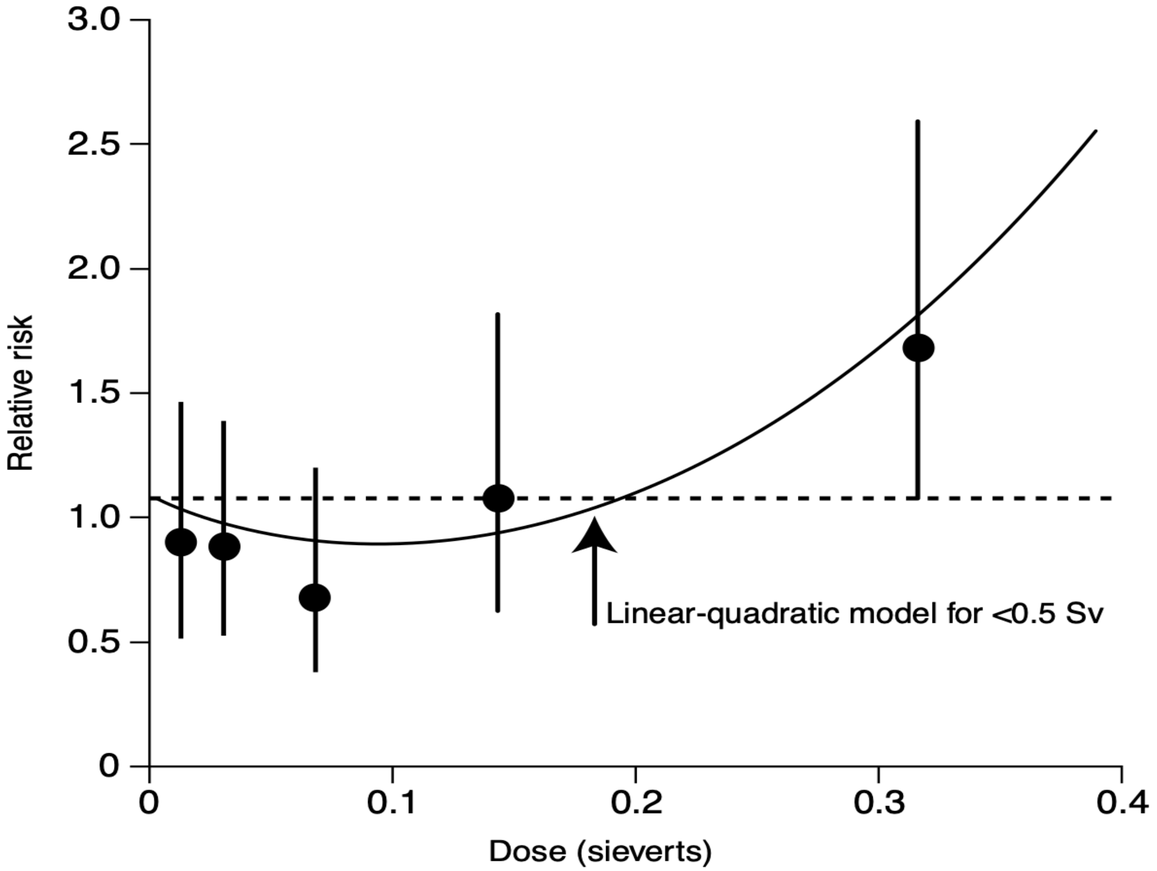


source data http://www.bioone.org/doi/full/10.1667/RR14492.1

National Council on Radiation Protection hides data.

FIGURE 1a

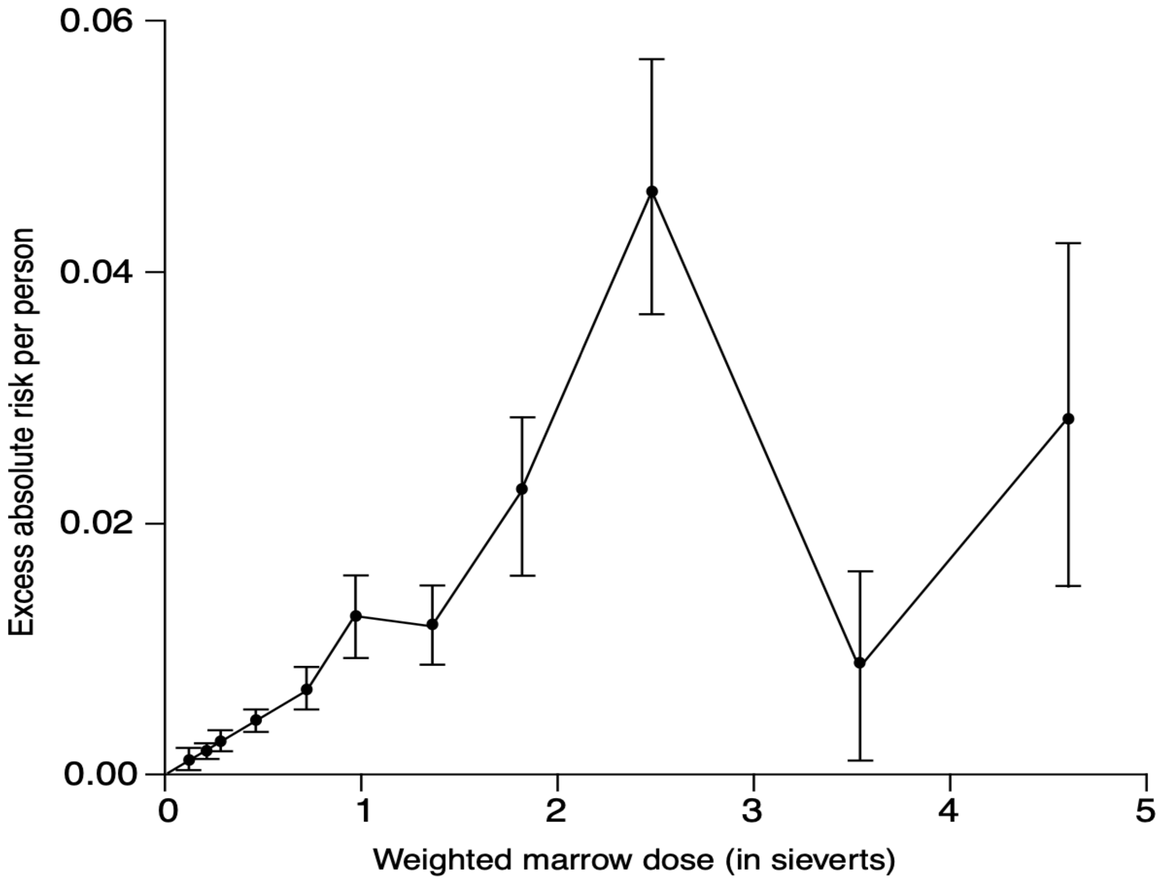
Mortality from Leukemia in Hiroshima and Nagasaki—Data as Presented by UNSCEAR



Source: UNSCEAR 1994, p. 257.

FIGURE 1b

Mortality from Leukemia in Hiroshima and Nagasaki—NCRP Version of the Same Data



Source: NCRP Report No. 136, p. 146.

https://larouchepub.com/eiw/public/2003/eirv30n19-20030516/eirv30n19-20030516_018-problems_of_us_policy_on_radiati.pdf

Bad science is decried by editors.

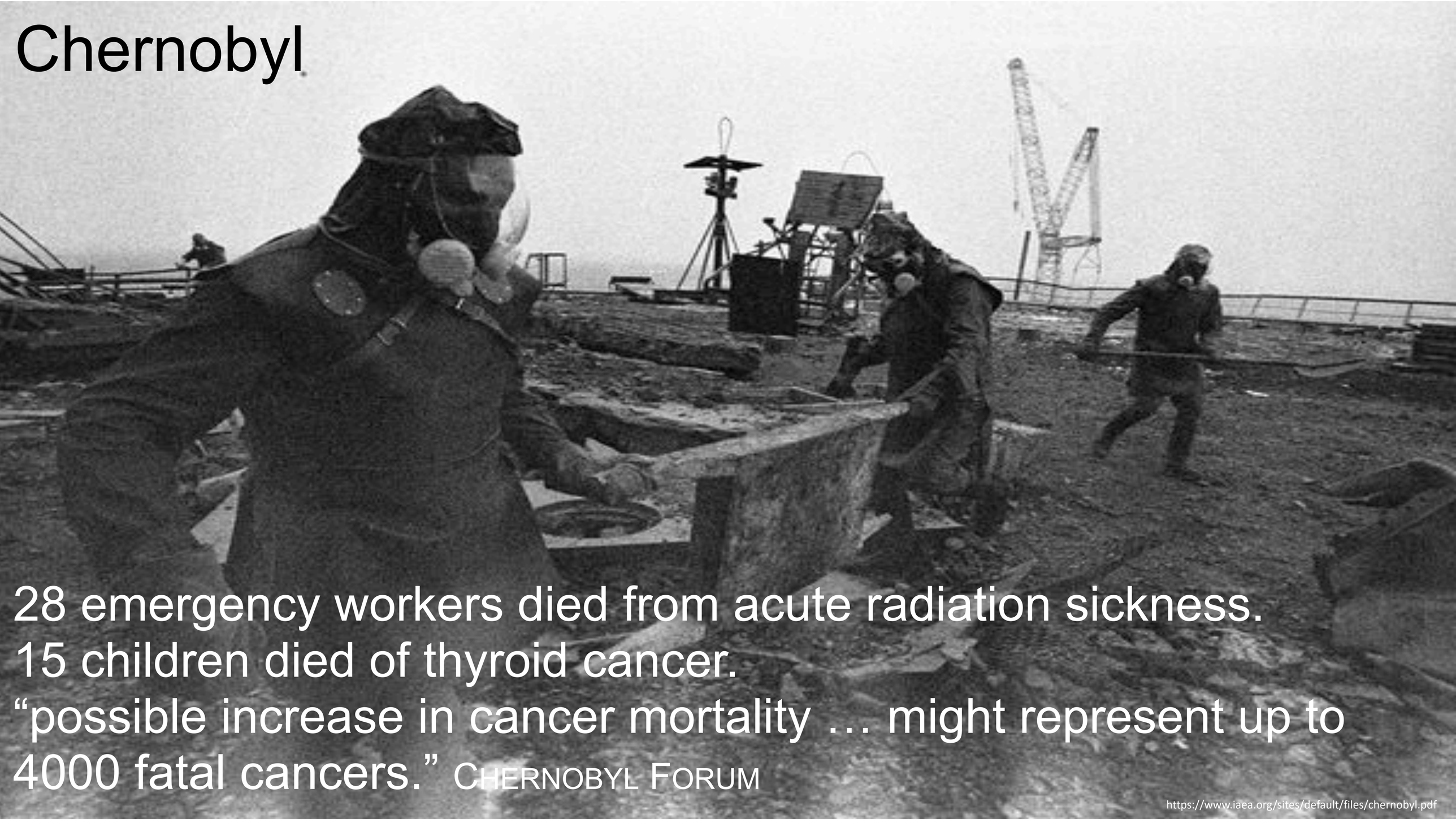
"The case against science is straightforward: **much of the scientific literature, perhaps half, may simply be untrue**. Afflicted by studies with small sample sizes, tiny effects, invalid exploratory analyses, and flagrant conflicts of interest, together with an obsession for pursuing fashionable trends of dubious importance, science has taken a turn towards darkness."

Richard Horton, Lancet editor

"It is simply **no longer possible to believe much of the clinical research that is published**, or to rely on the judgment of trusted physicians or authoritative medical guidelines. I take no pleasure in this conclusion, which I reached slowly and reluctantly over my two decades as an editor of the New England Journal of Medicine"

Marcia Angell, New England Journal of Medicine editor

Chernobyl



28 emergency workers died from acute radiation sickness.
15 children died of thyroid cancer.
“possible increase in cancer mortality … might represent up to 4000 fatal cancers.” CHERNOBYL FORUM

https://www.iaea.org/sites/default/files/chernobyl.pdf

A rotating X-ray beam focused on cancer tissue delivers up to 80,000 mSv.

To minimize the small risk of causing cancer in nearby tissue

- radiologists divide the radiation dose into fractions
- administered daily rather than all at once

giving healthy tissue time to recover. (3 million therapies/yr)

If LNT were true, fractionated radiation therapy wouldn't work.

28,000 nuclear shipyard workers exposed to ~8 mSv had a 24% lower death rate.

- Controls - age-matched
  - job-matched

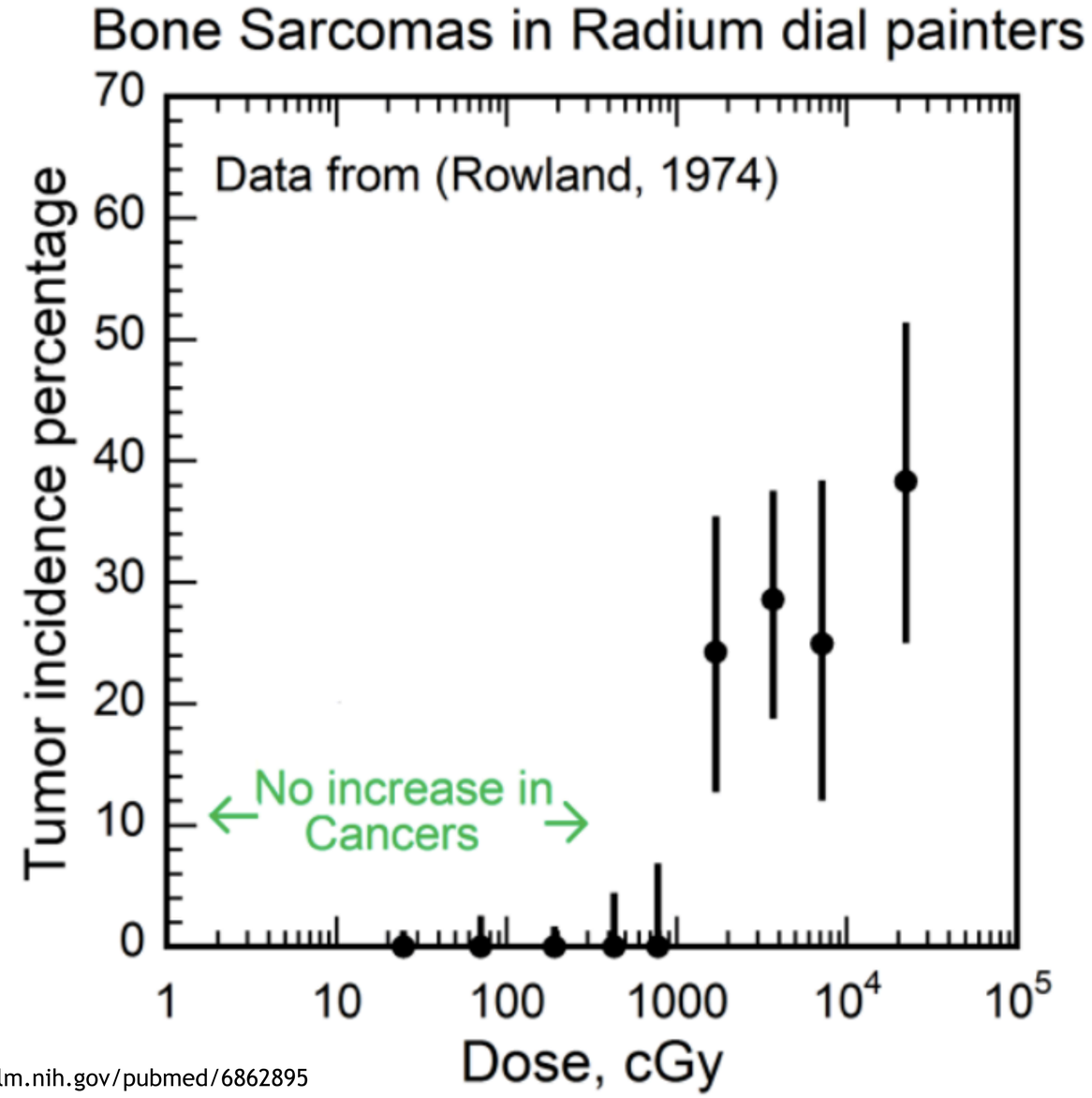
.ecolo.org/documents/documents_in_english/low-dose-NSWS-shipyard.pdf

7,271 Taiwan apartment dwellers exposed to ~48 mSv had 55 fewer cancers than 150 predicted by LNT.

http://www.ncbi.nlm.nih.gov/pubmed/17178625
http://taiwan-apt-cancer-data-analysis.blogspot.com/

Cancer site	Men			Women			All		
	Cases			Cases			Cases		
	Observed	Expected	SIR (95% CI)	Observed	Expected	SIR (95% CI)	Observed	Expected	SIR (95% CI)
All cancers	42	53.8	0.8 (0.5, 1.0)	53	60.9	0.9 (0.7, 1.1)	95	114.9	0.8† (0.7, 1.0)
All cancers except Leukemia	36	52.0	0.7‡ (0.5, 0.9)	52	59.3	0.9 (0.7, 1.2)	88	111.6	0.8‡ (0.6, 0.9)
Solid cancers	32	50.9	0.6‡ (0.4, 0.8)	50	58.5	0.9 (0.6, 1.1)	82	109.5	0.7‡ (0.6, 0.9)

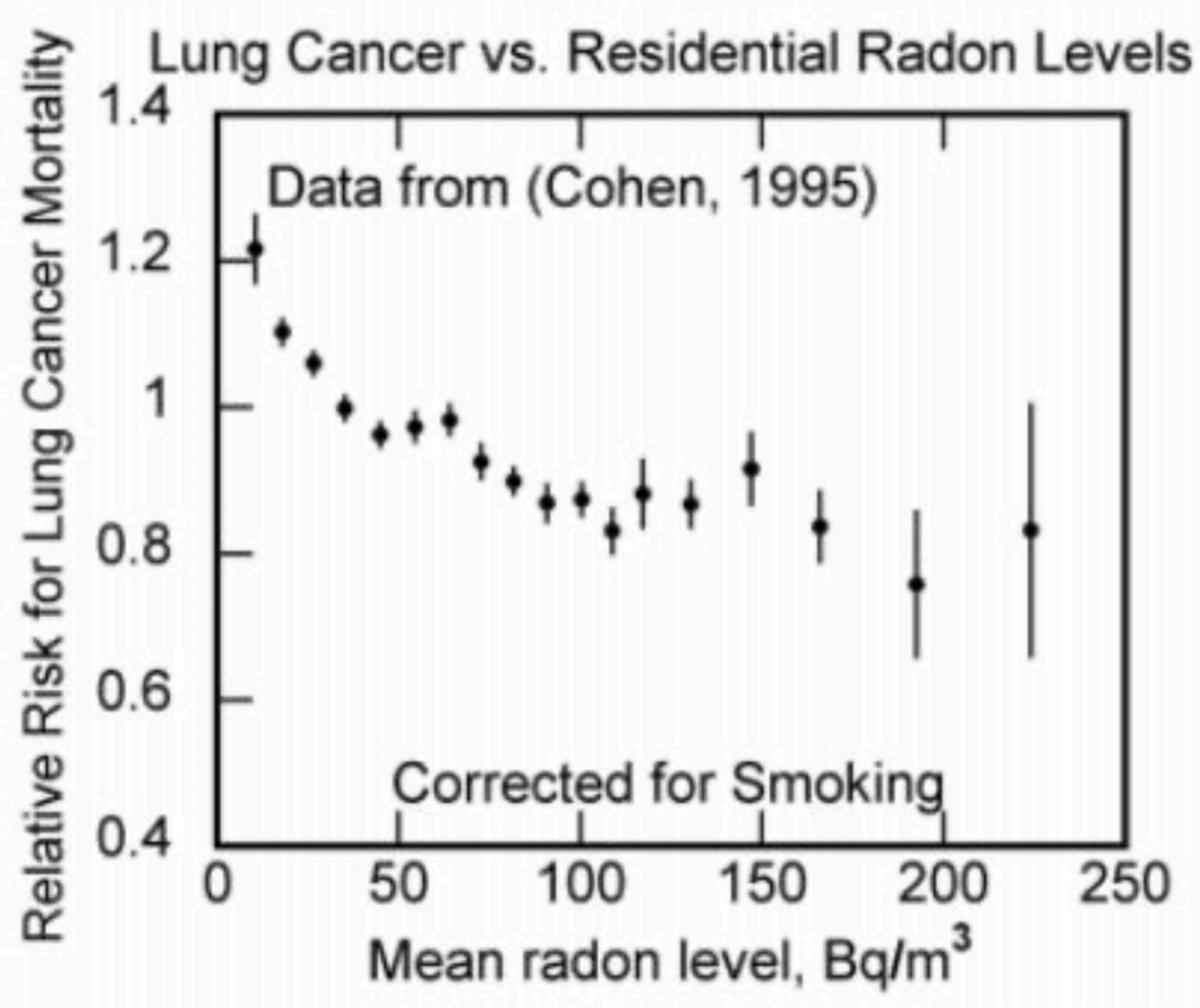
56 radium dial painters' bone sarcomas occurred at a threshold over ~ 10,000 mGy. (1412 unharmed)

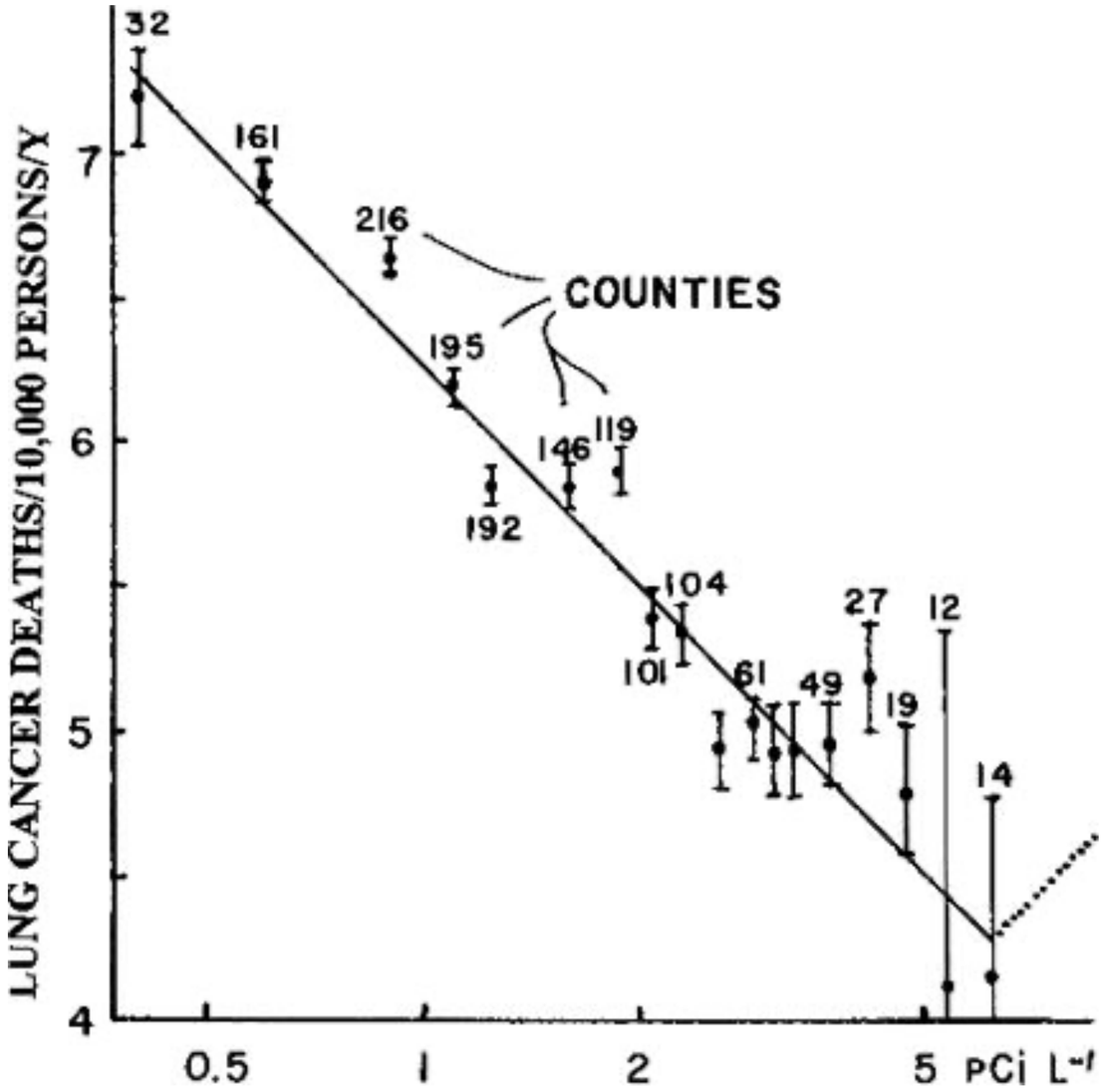


http://journals.lww.com/health-physics/Abstract/1974/11000/Radium_in_Man_.10.aspx

http://www.ncbi.nlm.nih.gov/pubmed/6862895

Lung cancer rates decrease with increasing residential radon levels.

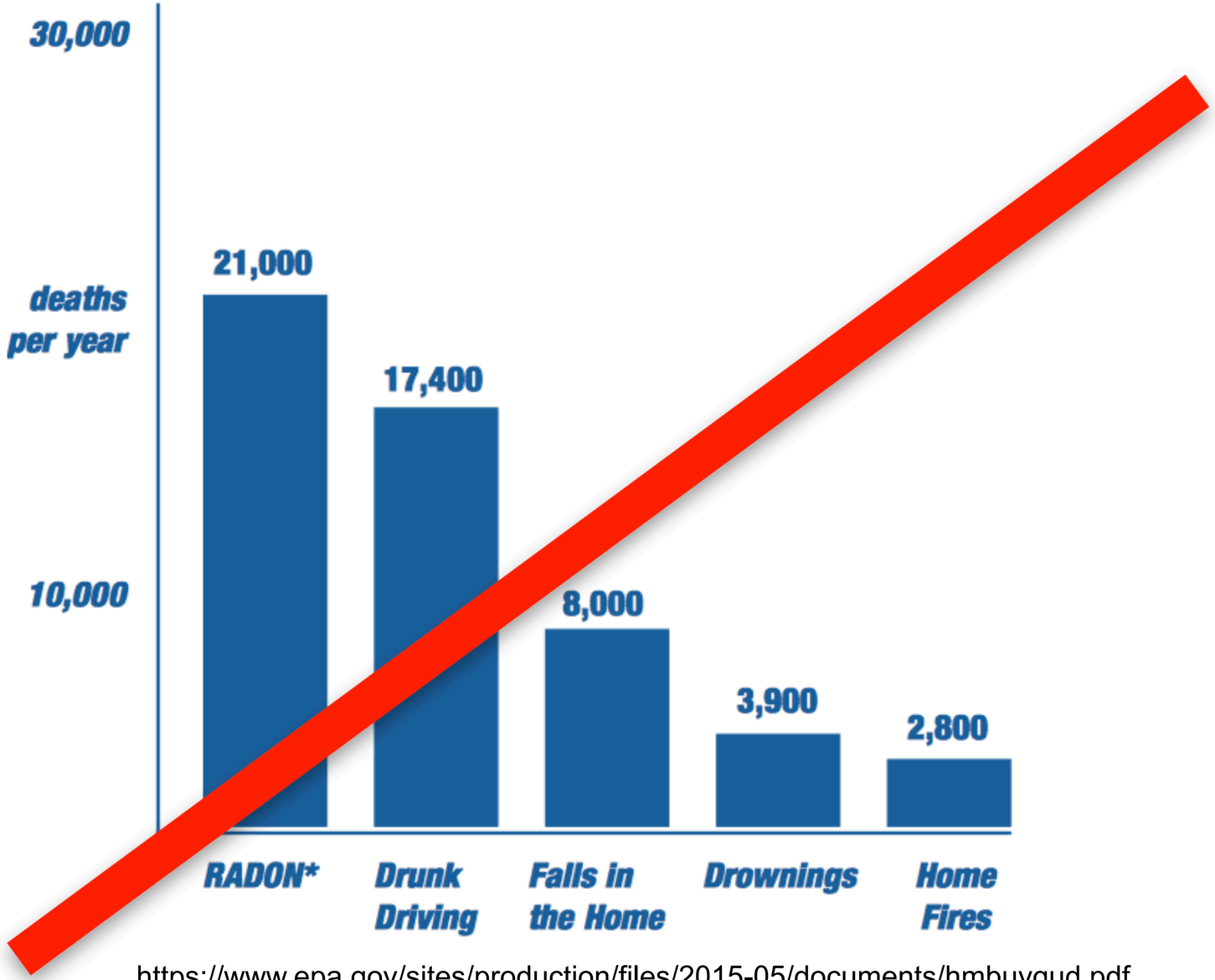




https://www.x-lnt.org/debate-announcement

https://www.ncbi.nlm.nih.gov/labs/pmc/articles/PMC2477686/

Ignoring science, with no observed evidence, EPA claims radon deaths exceed those from drunk driving.



EPA recommends radon testing and remediation if radioactivity exceeds 4 pico-curies per liter of air.
= 0.15 Bq/liter, 20 mSv/yr
1 Bq = 1 decay/sec

Note: humans are naturally slightly radioactive at about 2,700 pico-curies per liter.
= 100 Bq/liter

https://www.epa.gov/sites/production/files/2015-05/documents/hmbuygud.pdf

https://hps.org/publicinformation/ate/q11963.html

Radiation 45-175 mSv/a

Known locally as "Health City"

Tourists visit for "medicinal sands"

Radiation 250-260 mSv/a

Hot springs known as "health spas"

Low rates of lung cancer

Radiation 5-6 mSv/a

City of 2,500,000

Lower than average rates of cancer

Radiation 6-8 mSv/a

Hotspot for holidays and surfing

Known for pasties and clotted cream

Radiation 20-35 mSv/a

Occupied since ancient times

Population 45,000

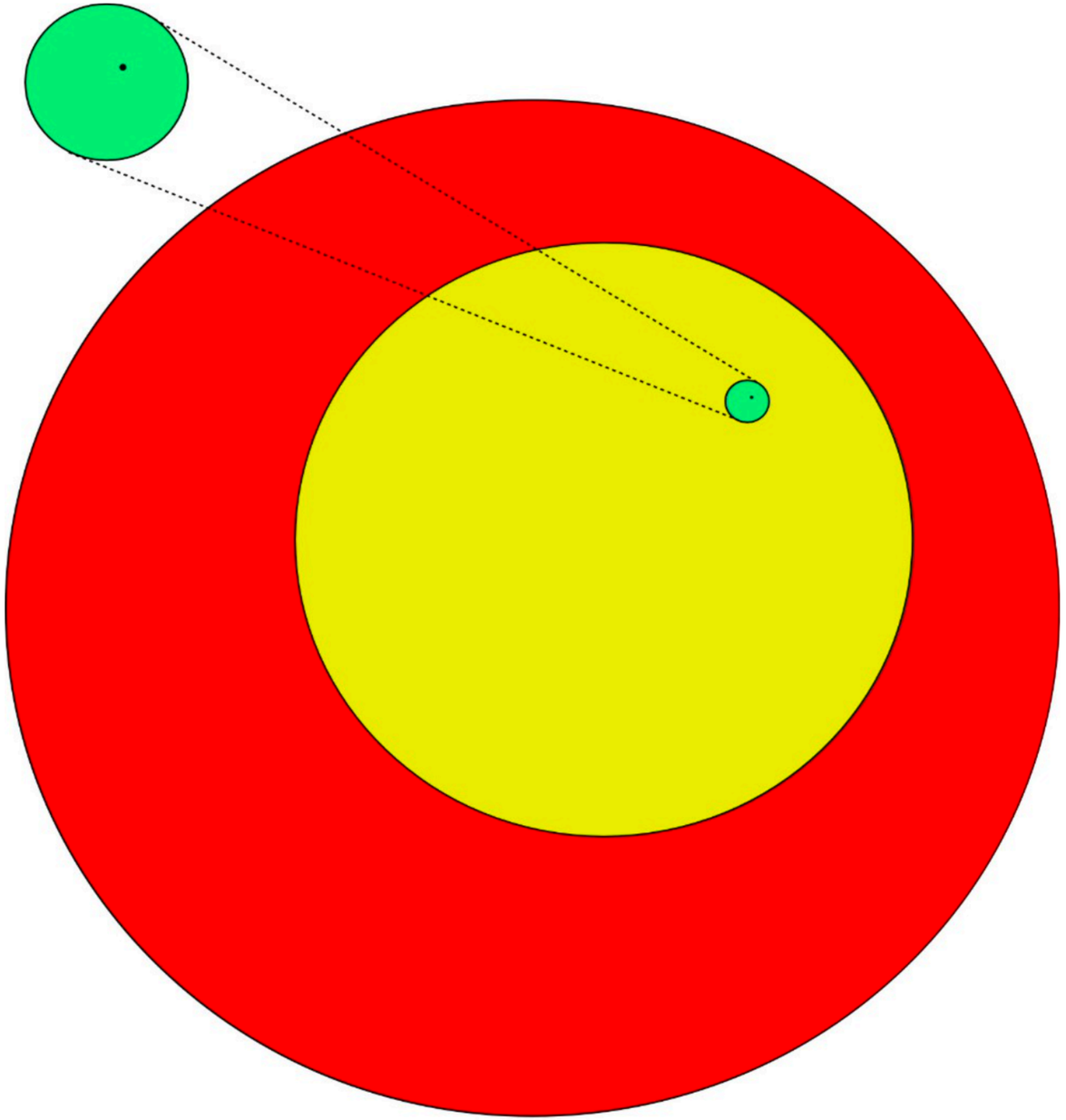
Radiation 2-8 mSv/a

"Dangerous and toxic wasteland"

"Uninhabitable for centuries"

Population 500

What radiation exposure is safe? 100 mGy per month



Red: 80,000 mGy/mo
- deadly to cancer tumors

Yellow: 30,000 mGy/mo
- healthy tissue recovers, rarely causing second cancer

Green: 100 mGy/mo
- harmless

Black dot: < 0.08 mGy/mo
- ICRP, EPA, NRC public limit

Wade Allison

Twenty-five male subjects who worked with plutonium during World War II under extraordinarily crude working conditions have been followed medically for a period of 27 years.

TABLE III

RESULTS OF URINE ASSAYS AND NOSE SWAB COUNTS CONDUCTED ON LOS ALAMOS PLUTONIUM OPERATORS SHOWING POSITIVE EXPOSURE

Subject Number[a]	Average Date of Exposure	Estimated Body Burden (μg ± 50%)	Total Number High Nose Swabs	Total Activity in[b] High Nose Swabs (cpm)
1	Late 1944	0.5 - 1.0	1[c]	11,606
2	Late 1944	0.1 - 0.5	3[c]	290
3	May 1945	1.2	37	4,267
4	June 1945	1.2	24	14,968
5	June 1945	1.2	55	27,246
6	June 1945	1.0	32	8,859
7	June 1945	1.0	28	15,699
8	June 1945	0.7	60	36,407
9	July 1945	1.0	22	39,778
10	July 1945	0.8	24	5,334

What radiation exposure is safe? 3 mGy per day

People	Cum Exposure	Daily Exposure	Health Effect
Eben Beyers	366,000 mSv	300 mSv/d	Dead in 3 years
Dial painters, high	>190,000 mSv	>35 mSv/d	96/373 bone cancers
Dial painters, low	<160 mSv	<30 mSv/d	zero bone cancers
Abert Stevens	61,000 mSv	8 mSv/d	heart failure age 71
UPPU club	1250-7200	0.3-2 mSv/d	mortality < Los Alamos coworkers
Taipai Apt high	<4000 mSv	<3 mSv	decrease in cancers
Taipai Apt medium	420 mSv	<0.16 mSv/d	decrease in cancers
Taipai Apt low	<120 mSv	<0.05 mSv/d	decrease in cancers
Kerala residents	50-650 mSv	0.016-0.160 mSv/d	insignificant decrease in cancers

https://jackdevanney.substack.com/p/the-two-lies-that-killed-nuclear

Carol Marcus et al 2015 petition to end LNT *2022: denied!*

There has **never been scientifically valid support for this LNT hypothesis** since its use was recommended by the U.S. National Academy of Sciences Committee on Biological Effects of Atomic Radiation (BEAR I)/Genetics Panel in 1956. The **costs of complying with these LNT- based regulations are enormous.** Prof. Dr. Gunnar Walinder has summed it up: "**The LNT is the greatest scientific scandal of the 20th century.**"

Regulators use the LNT assumption because nationally and internationally respected bodies recommend and advocate it. NCRP, ICRP, IAEA, and NAS-NRC's BEIR Committee come to mind. However, they appear to have lost their sheen of expertise and appear mostly committed to maintaining the status quo. **An army of regulators at NRC, EPA, FDA, as well as DOE, would be unbudgeted if the LNT disappeared.** In addition, there are politicians whose anti-nuclear stand gets them votes.

I am not talking about a few **scientific papers that show that the LNT model is in error. We are talking about thousands**. There are a couple of textbooks in this field, and journals that publish scientific findings that refute the LNT model. This is a **whole field of science that regulators pretend does not exist.** The attitude of today's regulators is reminiscent of the Catholic Church at the time of Galileo.

https://issuu.com/johna.shanahan/docs/150209_nrc_petition_to_end_lnt_and_

Consequence: US NRC certification of an advanced reactor design costs $1 billion.

"It is a multi-decade process, with costs up to $1 billion to $2 billion, to design and certify or license the reactor design, … "

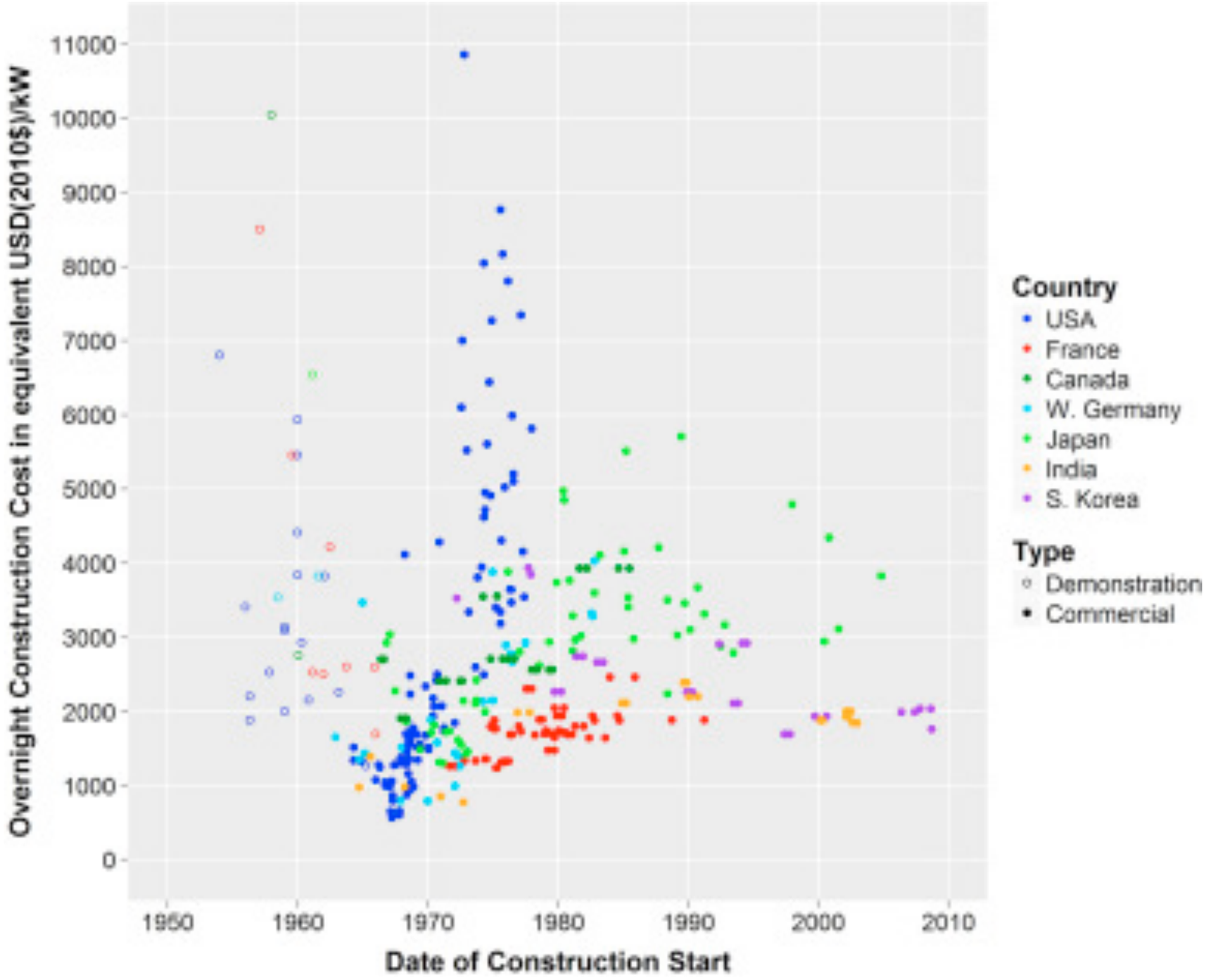
GAO, July 2015

…and then you may be allowed to build and test it.

<u>Consequence</u>: Fission power plants became too expensive in the US.

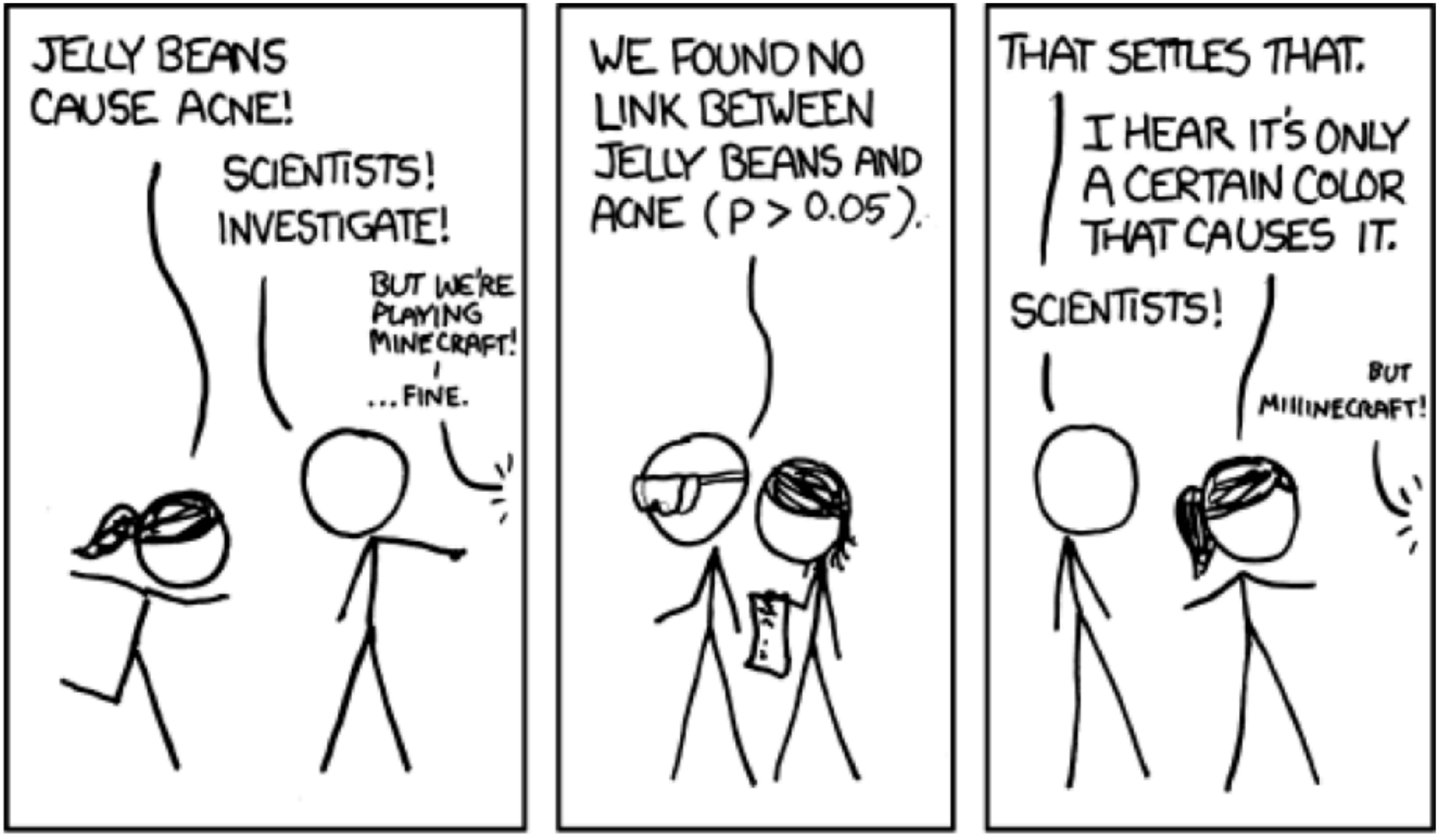
$2/W --> $11/W

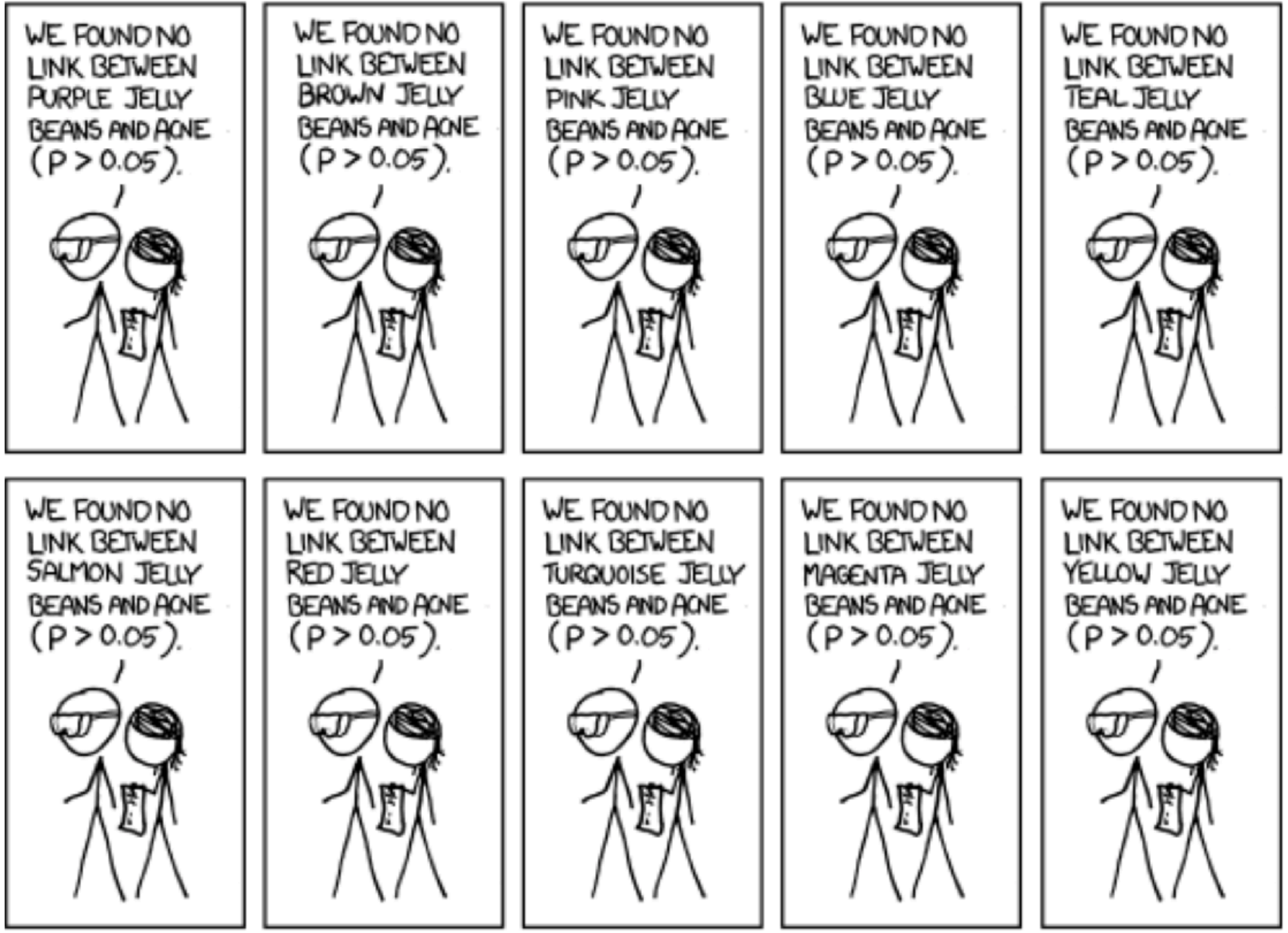
- regulation
- inexperience
- delays



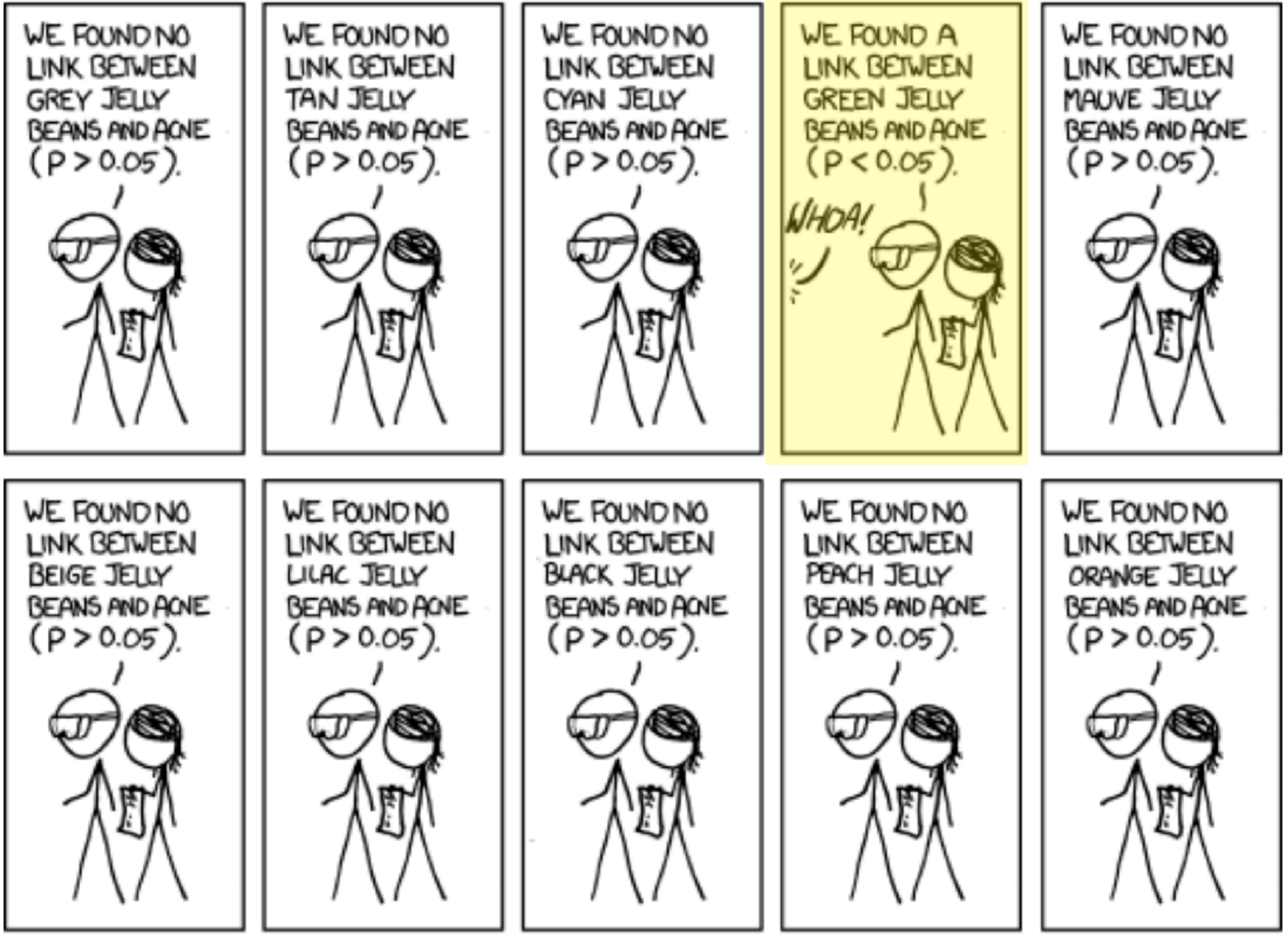
https://www.sciencedirect.com/science/article/pii/S0301421516300106

For the **great enemy of the truth** is very often not the lie—deliberate, contrived, and dishonest—but the myth—persistent, persuasive, and unrealistic. Too often we hold fast to the clichés of our forebears. We subject all facts to a prefabricated set of interpretations. We enjoy the comfort of opinion without the discomfort of thought. (1966)

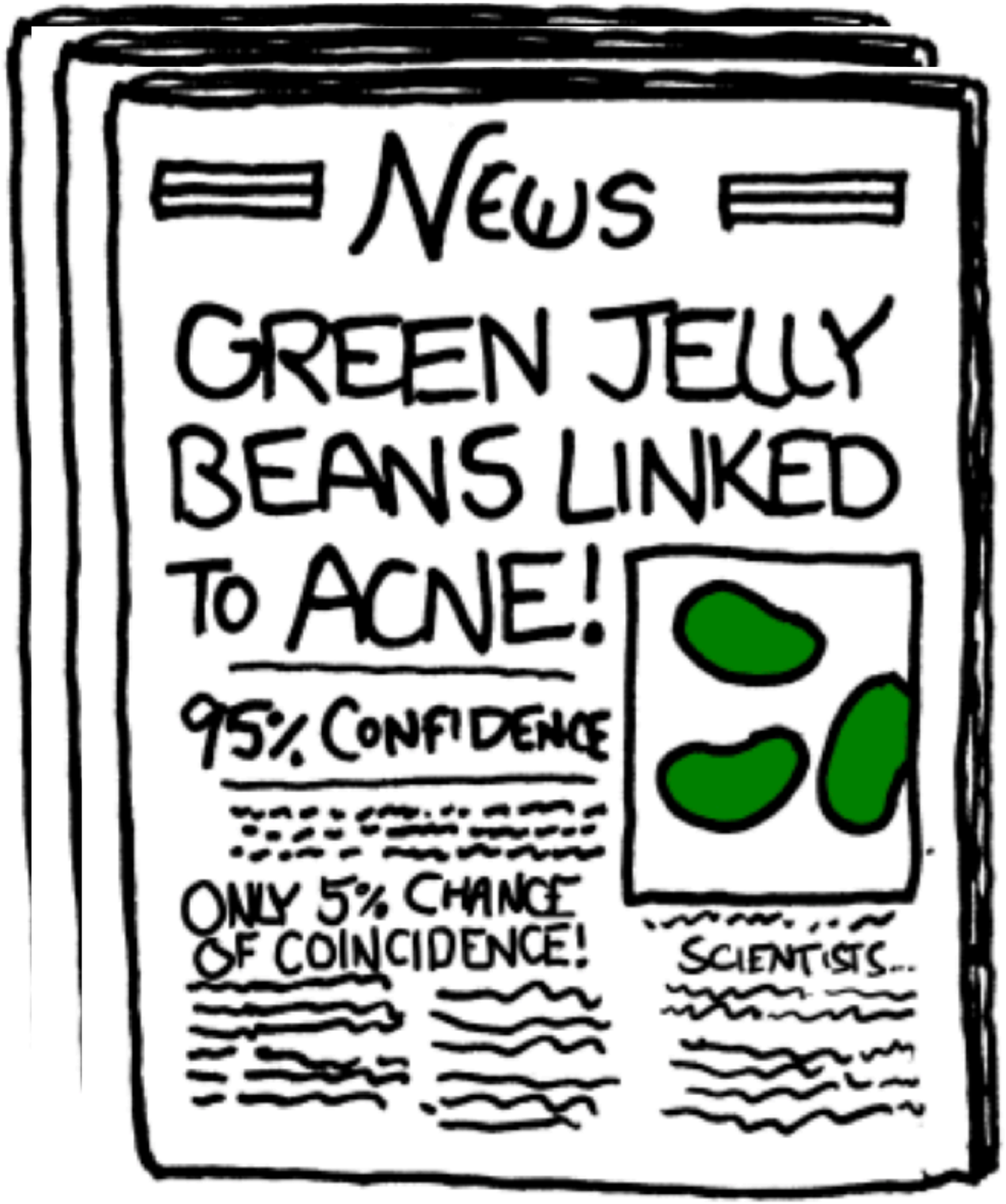

JELLY BEANS CAUSE ACNE!
SCIENTISTS! INVESTIGATE!
BUT WE'RE PLAYING MINECRAFT!
... FINE.
WE FOUND NO LINK BETWEEN JELLY BEANS AND ACNE (P > 0.05).
THAT SETTLES THAT.
I HEAR IT'S ONLY A CERTAIN COLOR THAT CAUSES IT.
SCIENTISTS!
BUT MIIINECRAFT!

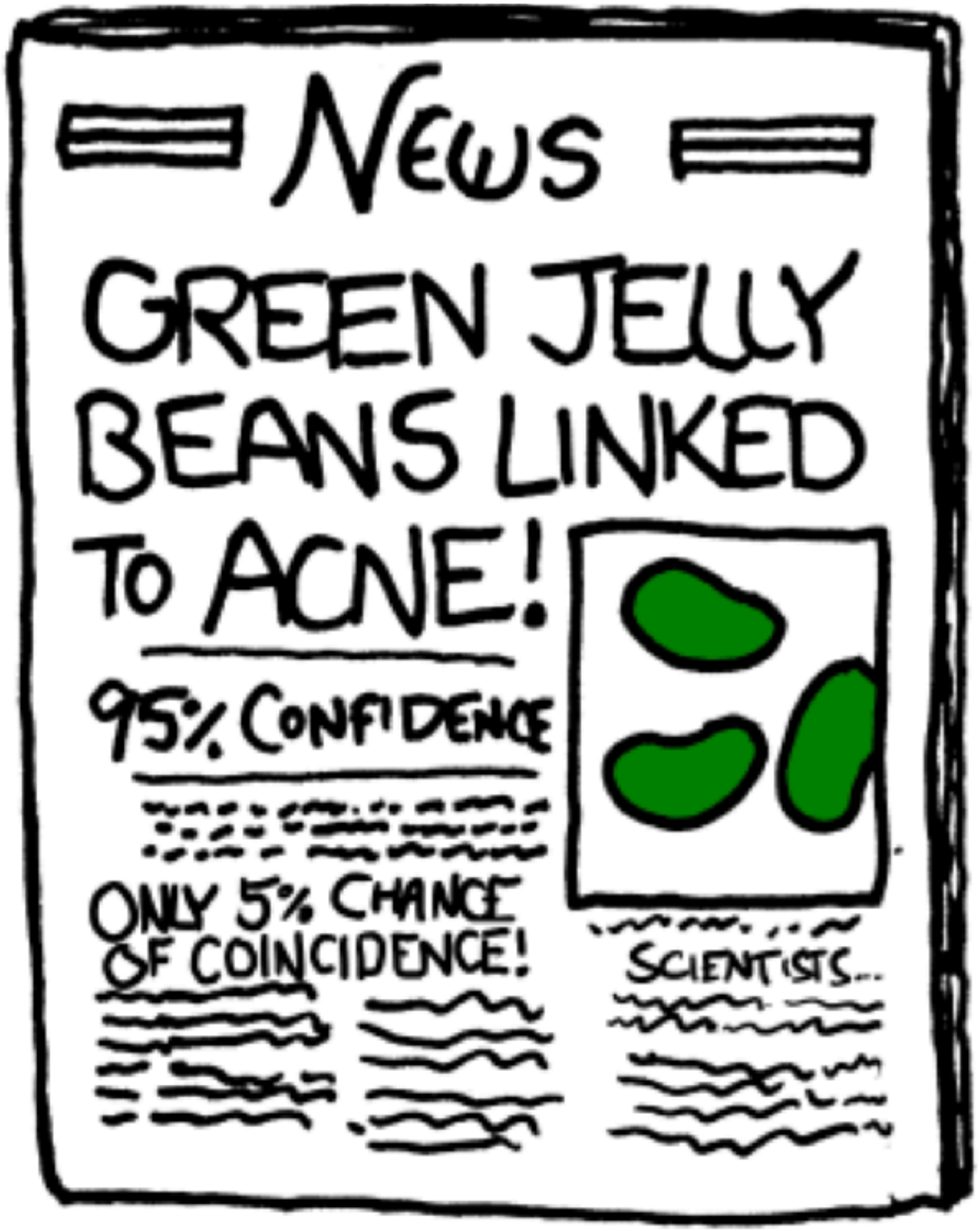

WE FOUND NO LINK BETWEEN PURPLE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BROWN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN PINK JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BLUE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TEAL JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN SALMON JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN RED JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TURQUOISE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN MAGENTA JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN YELLOW JELLY BEANS AND ACNE (P > 0.05).

xkcd.com/882


WE FOUND NO LINK BETWEEN GREY JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TAN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN CYAN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND A LINK BETWEEN GREEN JELLY BEANS AND ACNE (P < 0.05).
WHOA!
WE FOUND NO LINK BETWEEN MAUVE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BEIGE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN LILAC JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BLACK JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN PEACH JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN ORANGE JELLY BEANS AND ACNE (P > 0.05).

xkcd.com/882/


NEWS
GREEN JELLY BEANS LINKED TO ACNE!
95% CONFIDENCE
ONLY 5% CHANCE OF COINCIDENCE!
SCIENTISTS...

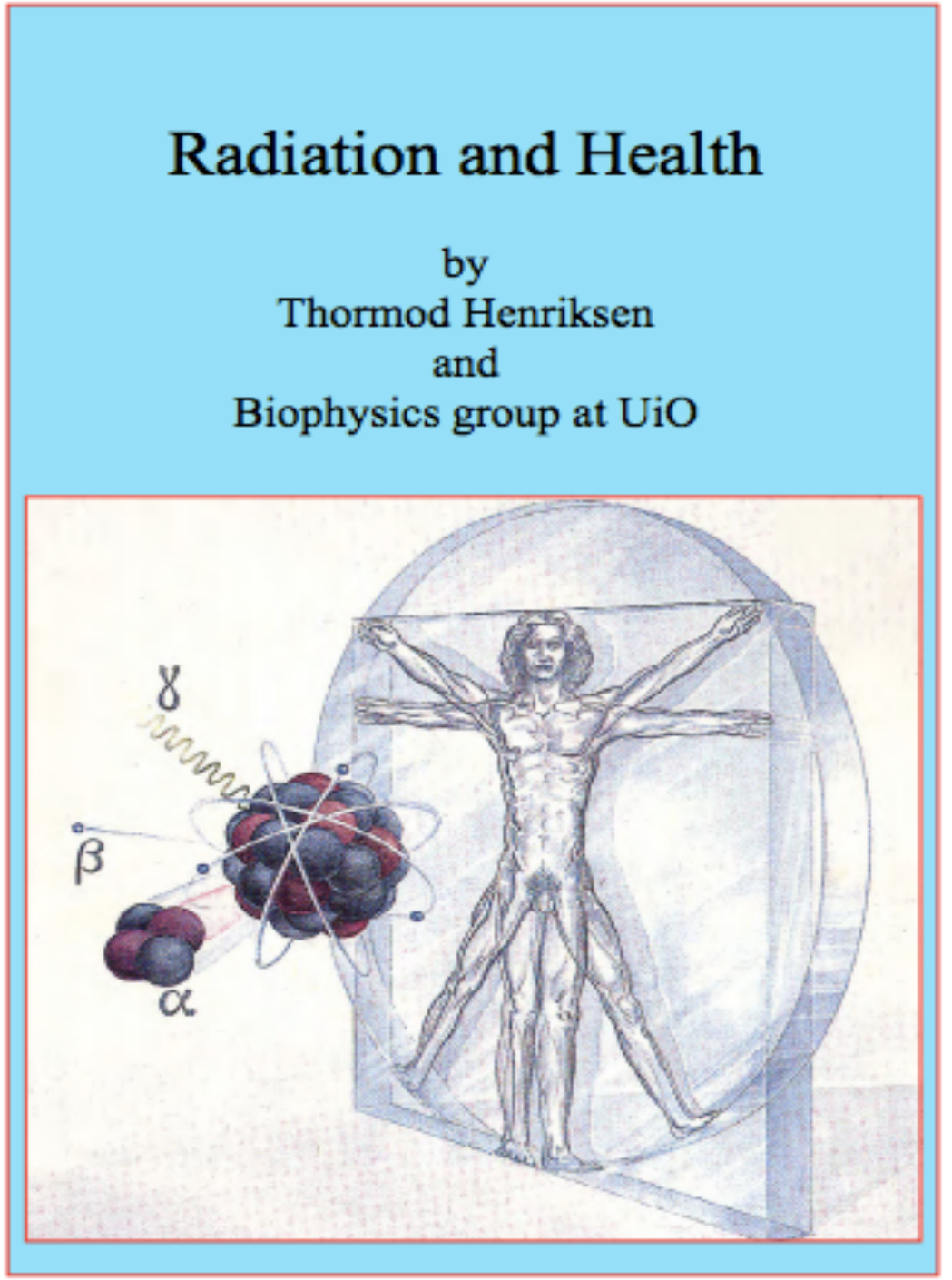

NEWS
GREEN JELLY BEANS LINKED TO ACNE!
95% CONFIDENCE
ONLY 5% CHANCE OF COINCIDENCE!
SCIENTISTS...

Dose of sanity and science:

Radiation and Health,
Thormod Henriksen

Free to download at
http://www.mn.uio.no/fysikk/tjenester/kunnskap/straling/radiation-and-health-2015.pdf

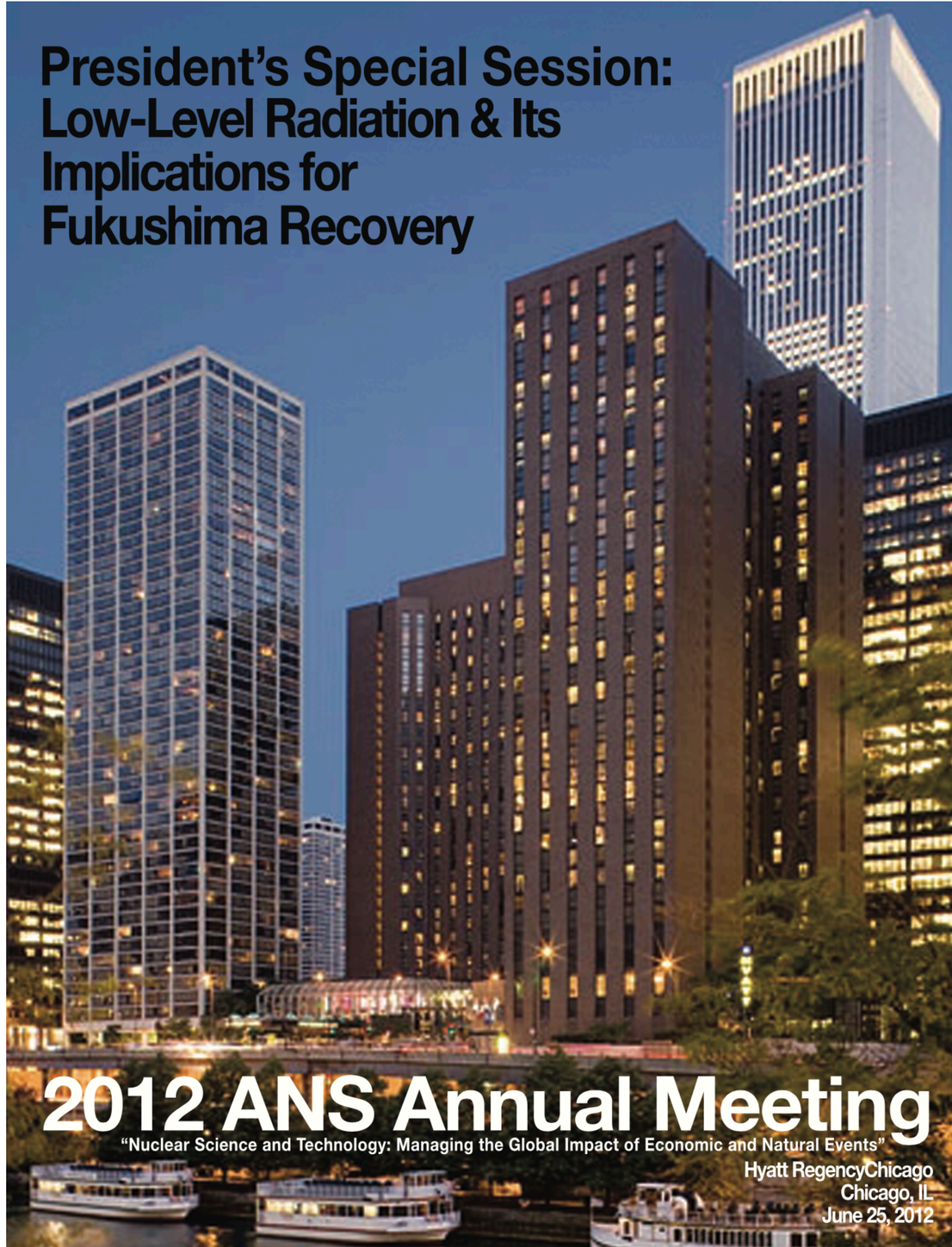
With his OK, I published paperback version on Amazon at cost.
https://www.amazon.com/dp/1499104073



American Nuclear Society

reprinted two dozen scientific studies showing low level radiation is benign.

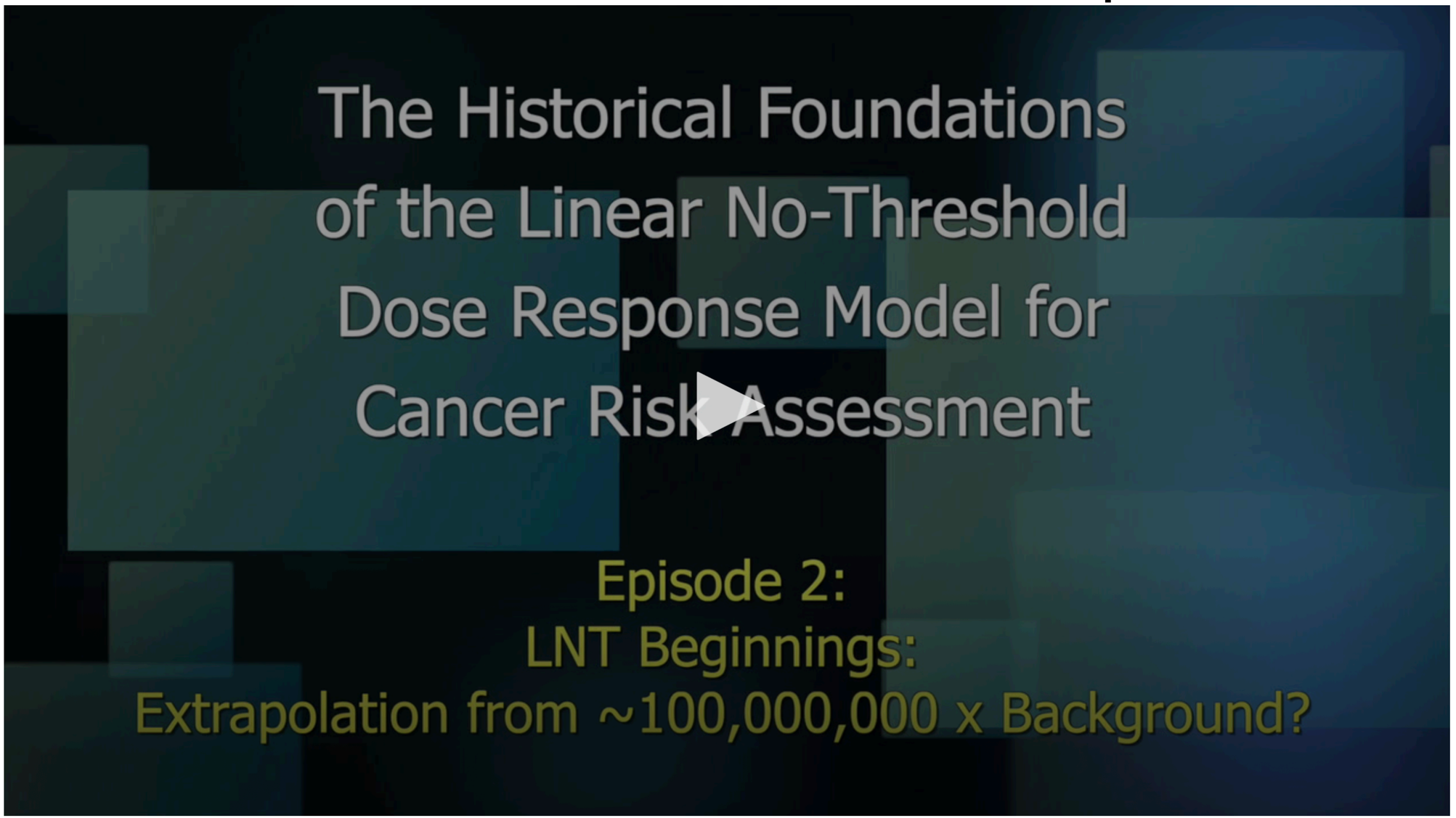
Free to download at:
https://www.ans.org/file/1336/special_session-low_level_radiation-fukushima-v1.4.pdf



https://www.ans.org/file/1336/special_session-low_level_radiation-fukushima-v1.4.pdf

Ed Calabrese uncovers LNT's scientic fraud.

22 episodes, 12 hours

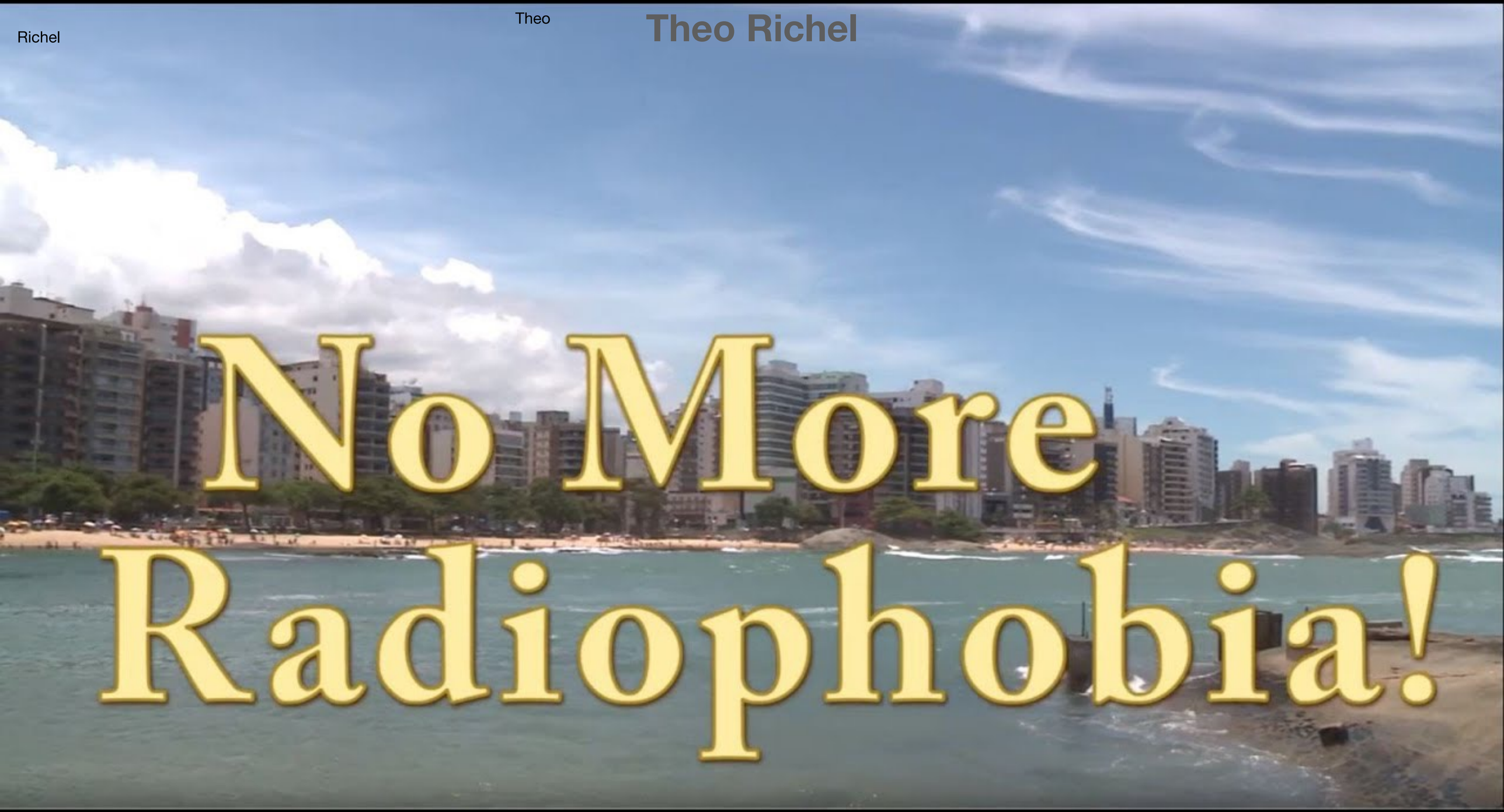


https://hps.org/hpspublications/historylnt/episodeguide.html

Richel

Theo

Theo Richel



What's a p-value?

Null hypothesis: Every day is equally lucky.
My Hypothesis: Friday-the-13ths are lucky days.
I observed 66 heads on Friday the 13th! I'm right!

p-value = 0.05 is the probability such an extreme result would be observed under the null hypothesis.

Toss a coin 100 times. Repeat.