Nuclear Power

What it is

Where it is now

Where is it going in future

The Global Energy Landscape

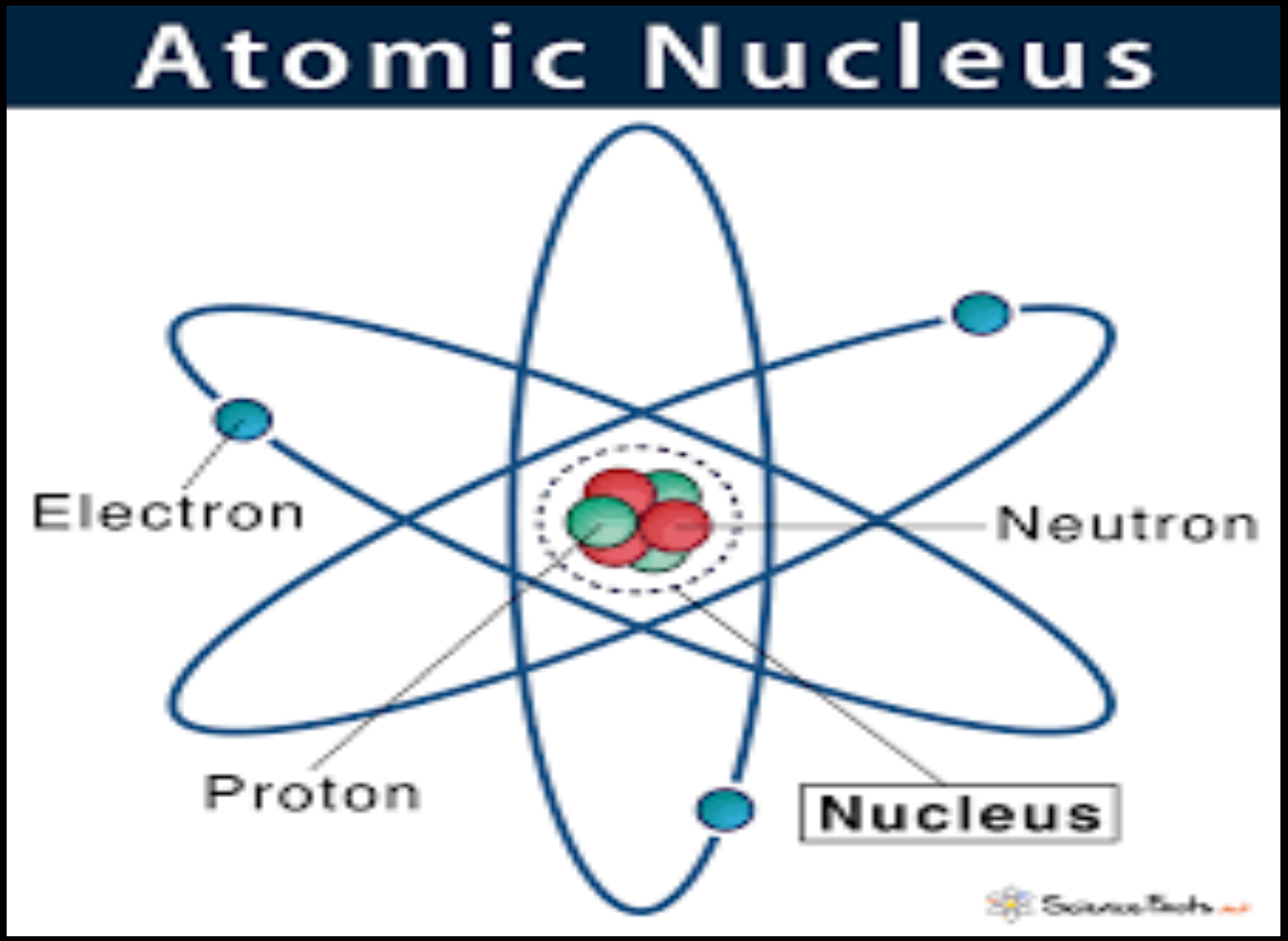
Ken Luongo

President - Partnership for Global Security

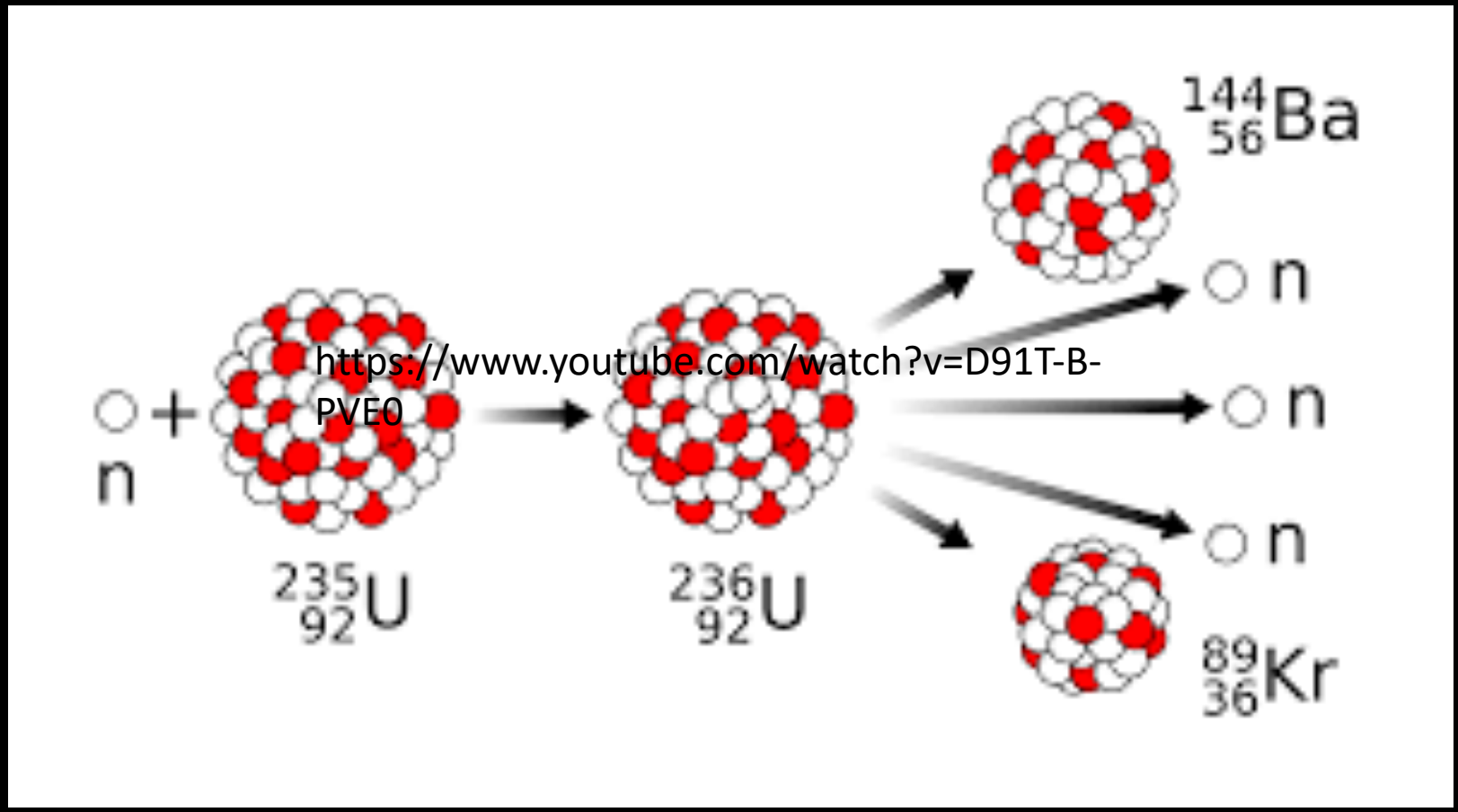
Nuclear Power

- Nuclear Fission and its use inproducing electrical power and its cost.
- Distribution of Nucler Power Stations
- Nuclear radiation and the myths around it
- Nuclear Waste and the myths around it
- The future for Nuclear Power
- Small Modular Reactors

The Atom



Nuclear Fission — Nuclear Power



Nuclear Fission radioactivity 4.23 mins

Nuclear Fission In a Reactor

The Energy of Nuclear Fission

with the help of Chat GBT

i**The bomb contained approximately 64 kilograms (**141 pounds) of enriched uranium, but only a small portion of this material actually underwent fission in the chain reaction.

Given the above how much Uranium actually underwent fission?

From your previous question, the energy released E is 63 terajoules. Using the mass-energy equivalence equation=mc^2

we can rearrange it to solve for the mass m of uranium-235 that underwent fission:

Substituting the given energy value and the speed of light 3x 10^8 m/s in Einstein equation E $m=c^2 / E$

we get: $m=63\times^{12} J/3\times 10^8 m/s^2 = 7\times10^{-5}$ kg or 70 milligrams

So, approximately 70 milligrams of uranium-235 underwent fission in the Hiroshima bomb.

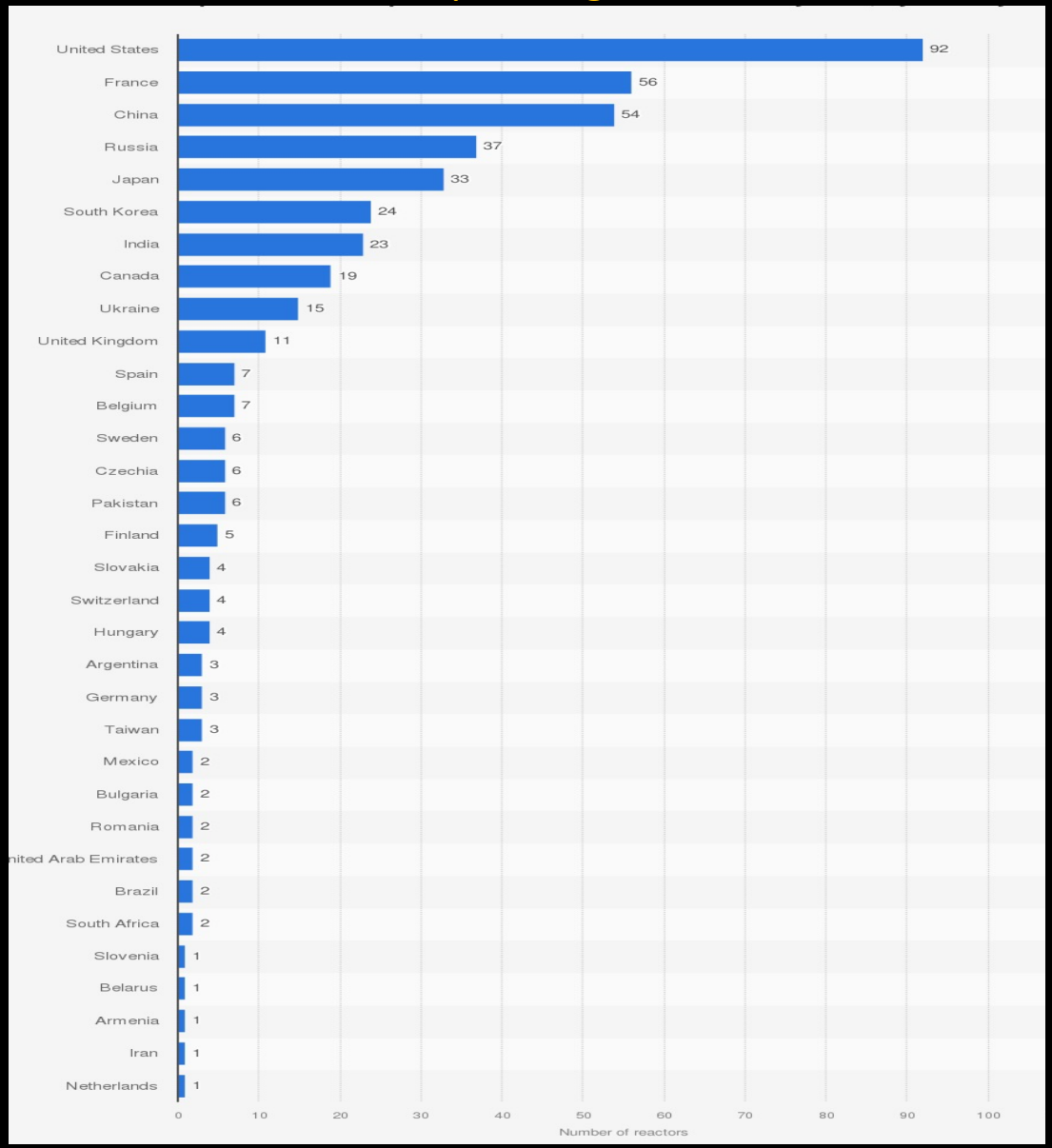
So To Nuclear Power Stations

Nuclear Plants World Wide

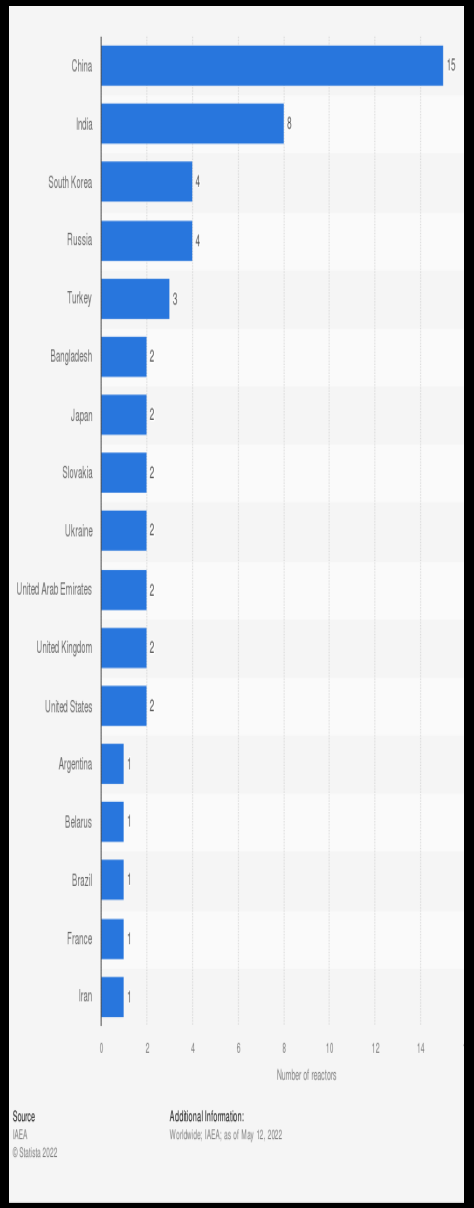
DB Operating reactors, building new reactors
LB Operating reactors, planning new build
DG No reactors, building new reactors
LG No reactors, planning new build
O Operating reactors, stable
R Operating reactors, considering **phase out**
BI Civil **nuclear power** is **illegal**
G No reactors

Nuclear Power Plants

Operating



Under Construction



Nuclear Power – Japan

- As of March 2020, of the 54 nuclear reactors, of the 42 operable reactors only 9 reactors are running
- A total of 24 reactors are scheduled for decommissioning
- Japan's 2030 energy goals posit that at least 30 will be reactivated

Nuclear Power –UK

- Hinkley C will be operating by June 2027 (3.2 Gw –very big)
- Sizewell C is now being given the go-ahead (3.2 Gw – also very big)
- Rolls Royce propose SMRs instead of $20bn mega station on existing site in Wales (Wylfa)

Nuclear Power – Sweden

- Sweden has six commercial nuclear power units in operation at three sites:, nuclear energy provided about 30% of the country's electricity generation in 2021.

- Vattenfall Energy will be starting work on a pilot study of at least two small modular reactor (SMR) units at the site of the Ringhals nuclear power station.

Nuclear Power –China

- Currently 54 nuclear plants account for 3 % of the country's electricity.

- Beijing aims to increase nuclear power generation by building more than 150 new reactors by 2035.

By **Genevieve Donnellon-May in "The Diplomat"** September 20, 2022

n 2021, more than half (55.5 percent) of Ukraine's electricity was produced with nuclear power, follow

Pivdennoukrainsk Nuclear Power - Ukraine

In 2021, more than half (55.5 percent) of Ukraine's electricity was produced with nuclear power, followed by coal (23.6 percent), hydropower (6.7 percent) and gas (6.6 percent). Ukraine has 16 nuclear reactors across four nuclear power plants (NPPs).4 Sept 2022

Fuqing, East China's Fujian province

China's second nuclear power unit using Hualong One, a domestically designed third-generation nuclear reactor, starts power generation in Fuqing, East China's Fujian province on Jan 1, 2022.

Barakah Nuclear Energy Plant UAE

The UAE's nuclear power plant marked a “major milestone” on Thursday as the third of its four units was switched on.
The plant is located in Al Dhufra, AbuDhabi. Itwas designed and built byS Koreans companies with construction starting in 2012. Its has an APR 1400 reactors and will provide 25% ofUAE’s electricity demand

Korean NPP Design

- After the Chernobyl disaster in 1986, most reactor builders had tacked on a slew of new safety features. KHNP followed suit but later realized that the astronomical cost of these features would make the APR1400 much too expensive to attract foreign clients.

Hinkley Point Somerset UK - 2022

Hinkley A

Hinkley B

Hinkley C

Outputs

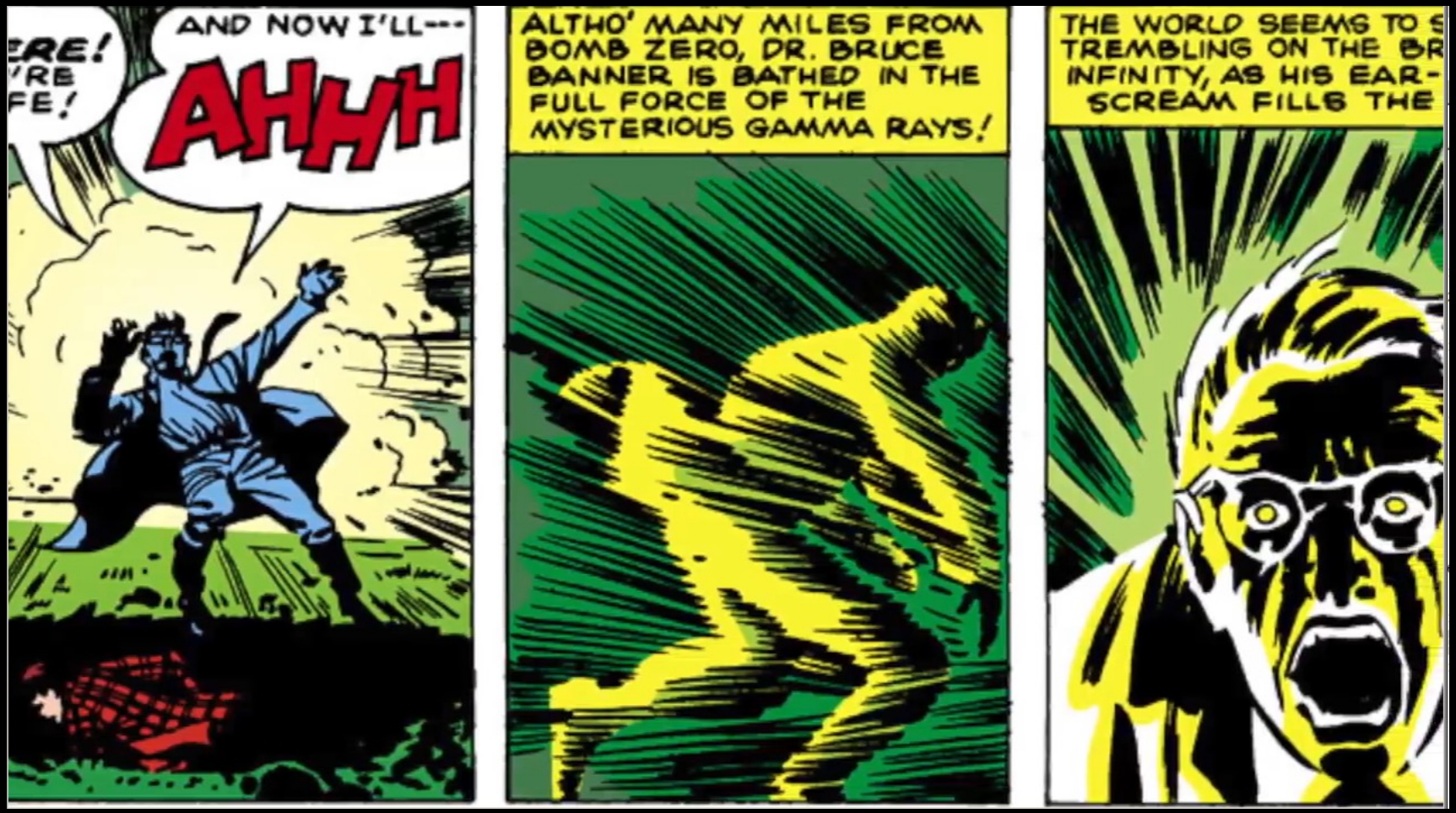
A 500Mw

B 1250 Mw

C 3260 Mw

Nuclear Radiation

A false image projected by the ill -informed



Nuclear Radiation
The Reality

Nuclear Radiation

The Minerals Council of Australia says Parliament House emits more radiation than a nuclear power plant. How so? All that granite is naturally radioactive.

Nuclear Radiation – the tank analogy

The tank contains radioactive material. A drain pipe is used to remove the radioactivity to absorption/dissipation

The larger the pipe the higher the radiation to be dissipated but the sooner the tank is emptied.

Elements that have low radiation rates (small diameter pipe) have long half lives. Low radiation for a long time

Calcium 41 103 000years (used in prostate imaging)

Uranium 238 Half-life : 4.468×10^{9} years

In the middle Americium 241 (in your smoke detector) has half life of 432 years

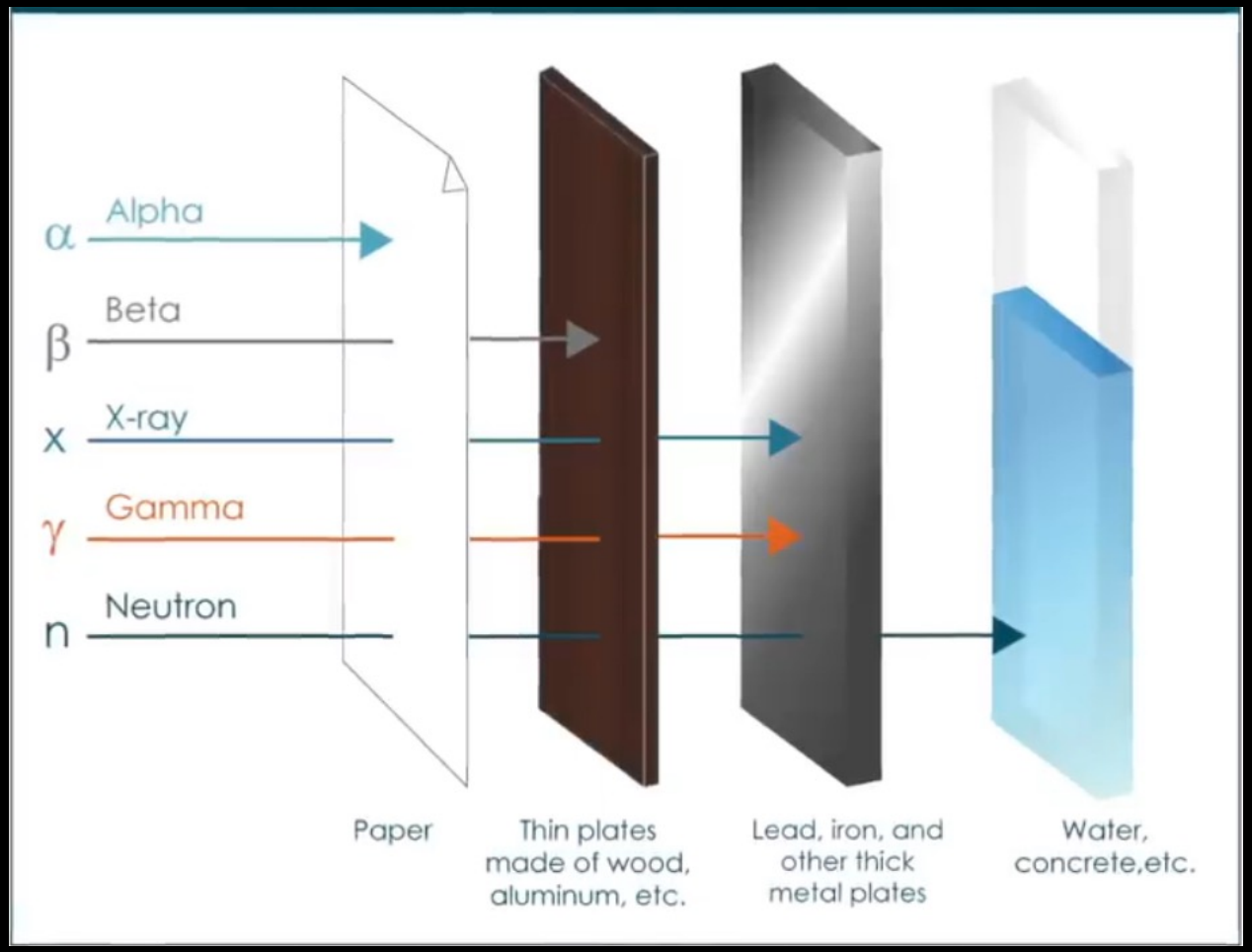
Elements that have high radiation levels have short half lives. High radiation for a short time.

Uranium 216 half-life of 10^{-3} seconds

Nuclear Radiation – the fire and embers analogy

Which gives out most heat? Which dies out first?

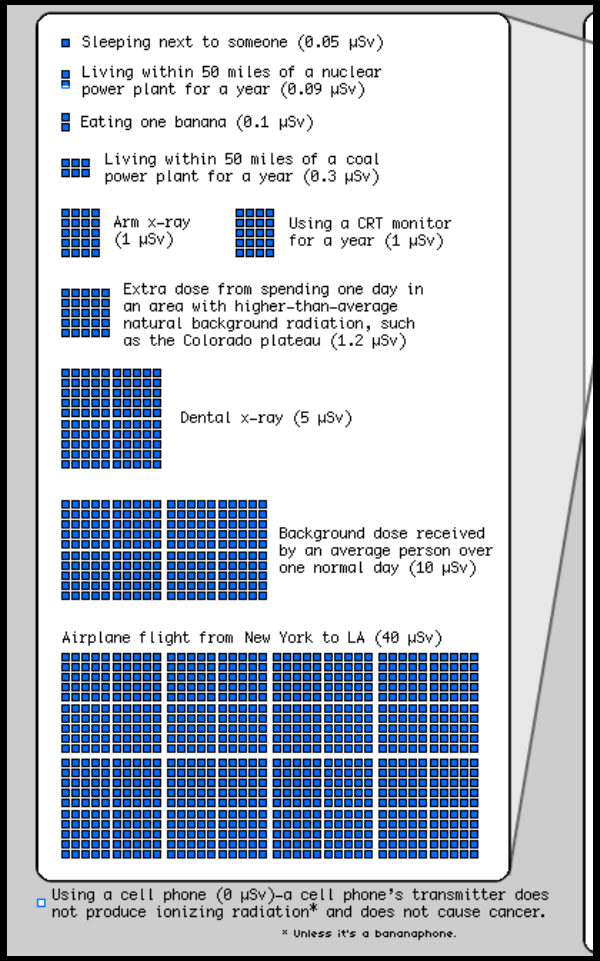
Types of Nuclear Radiation



Radiation Dose Rates - A

Sleeping next to someone

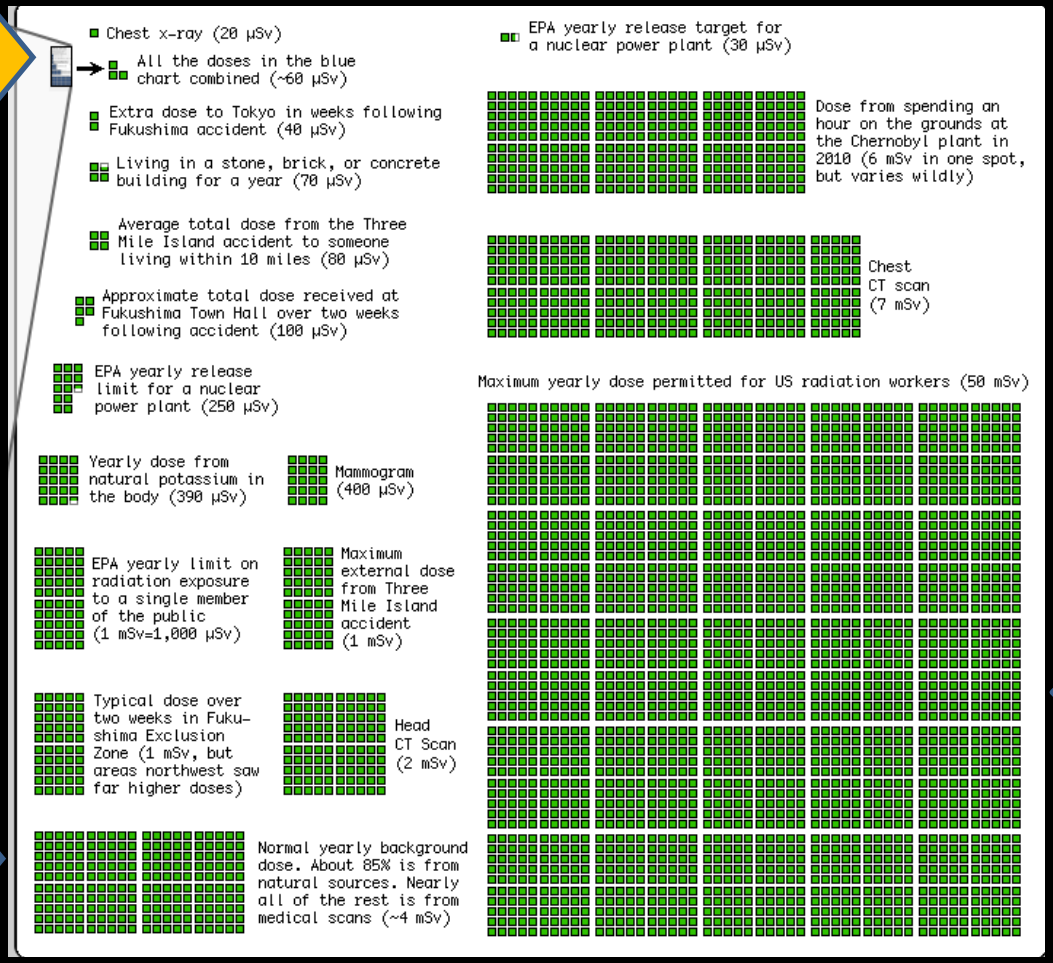
Background dose in a day for average person



Airplane flight New York to LA

Radiation Dose Rates

All doses from Chart A
0.000,06 Sv

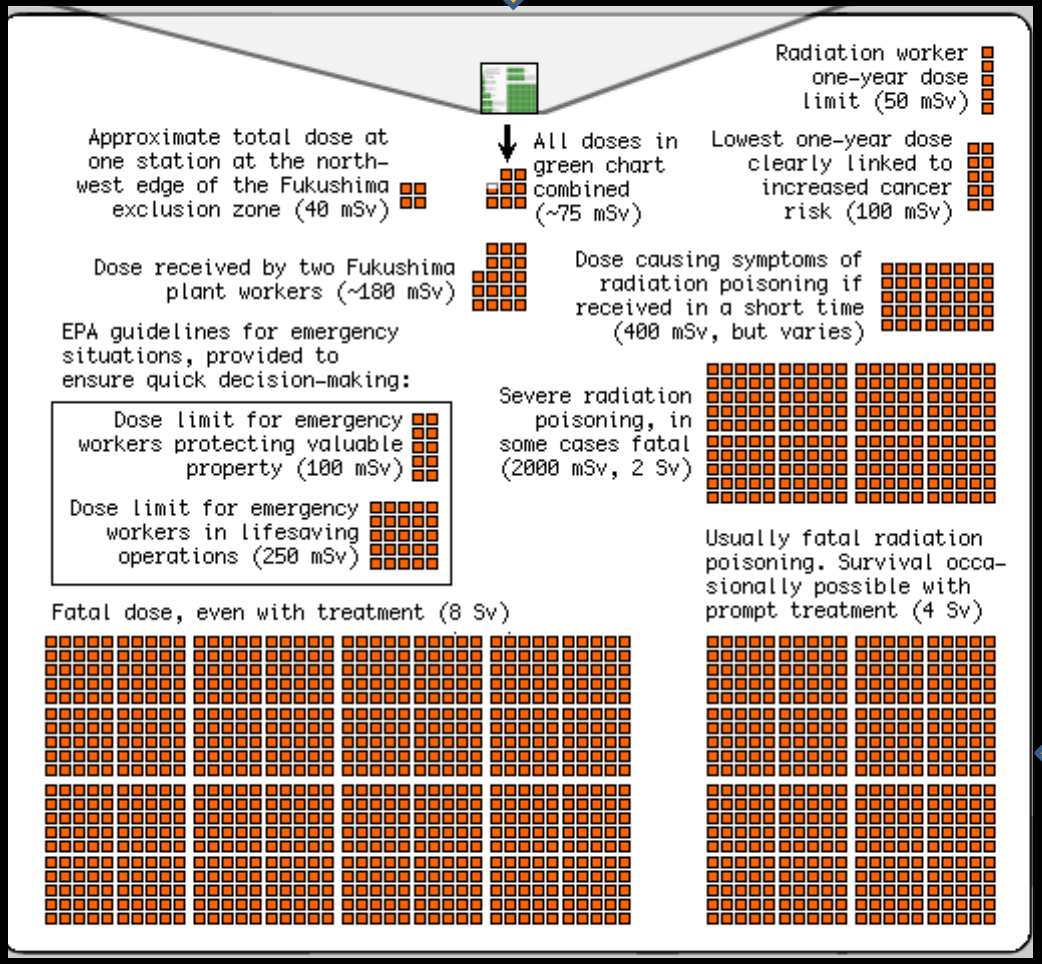


Normal yearly doses fromfrom background natural sources 0.004 Sv

Maximum yearly dose permitted for US radiation workers 0.050 Sv

Radiation Dose Rates

All Doses from Chart B combined - 0.075 Sv

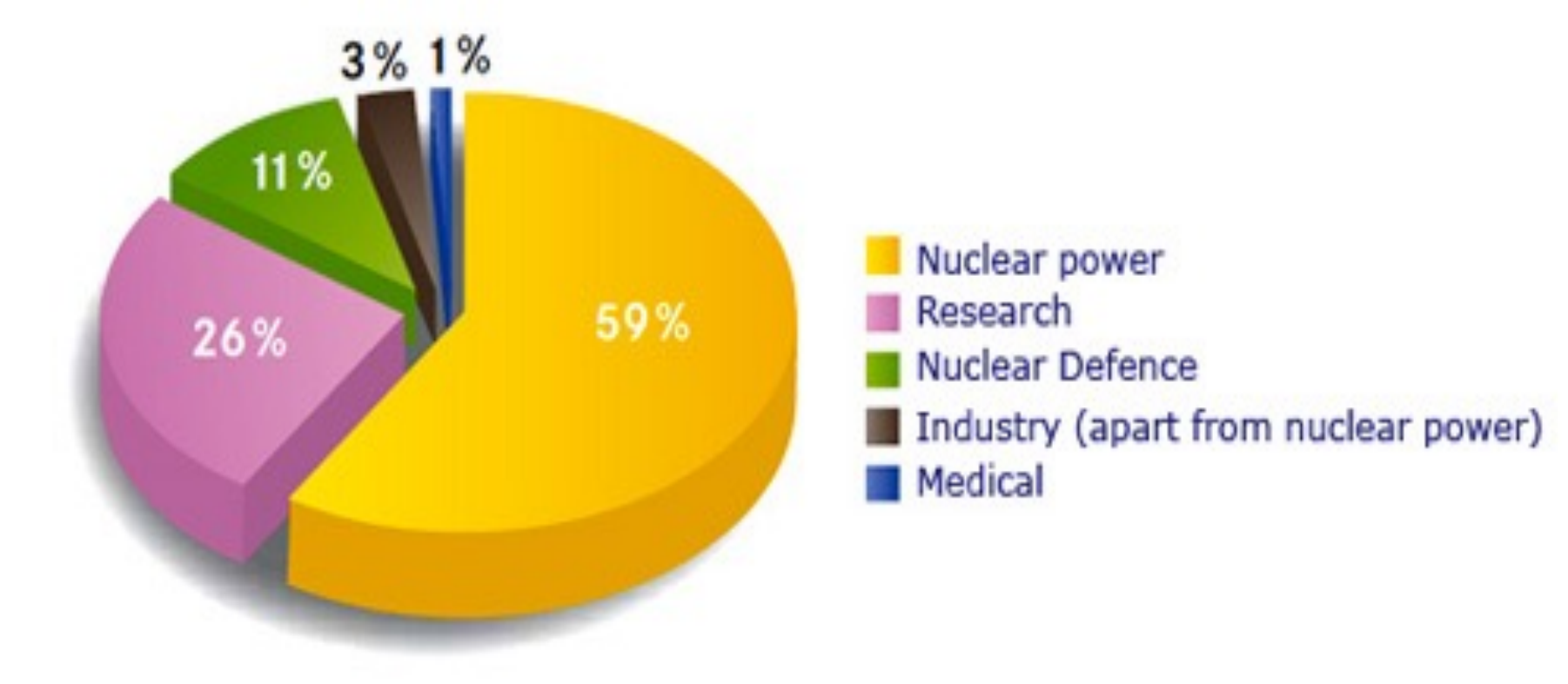


Fatal Dose 8 Sv even with treatment

Remember one X-ray dose is only 0.000,001 Sv

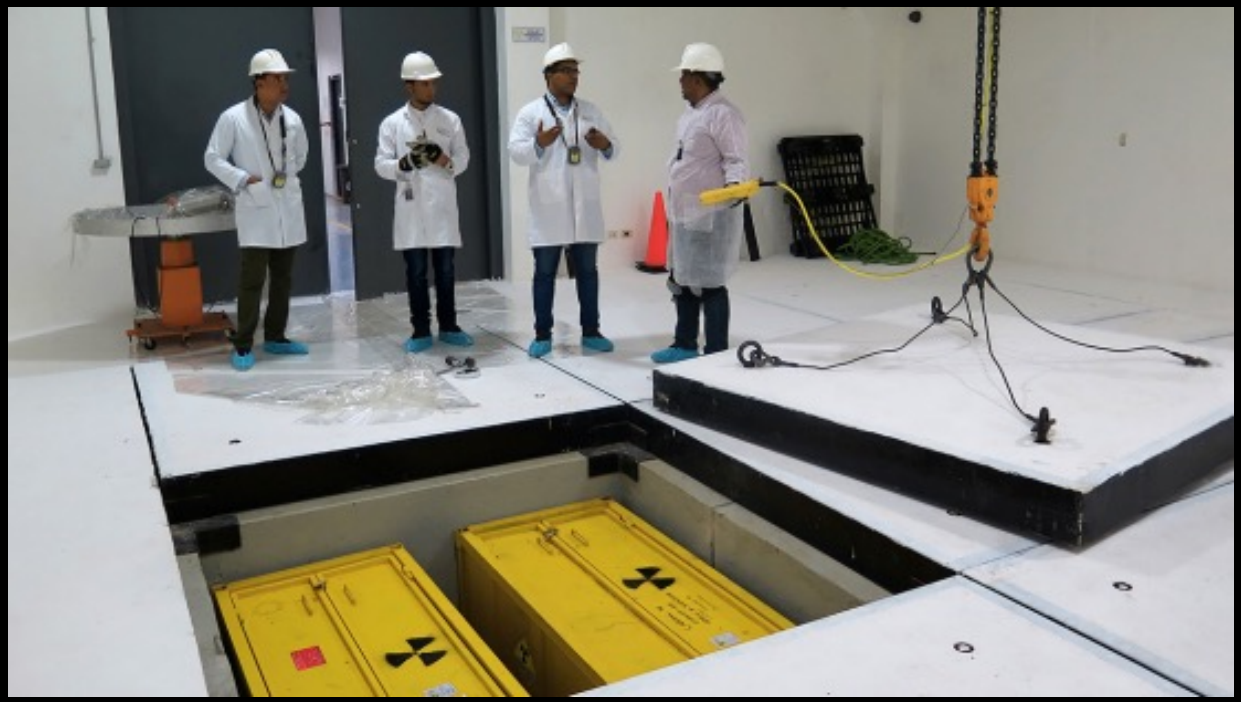
Usually fatal poisoning 4 Sv. Survival possible with prompt treatment

Nuclear Waste



Source cnrs Le Centre national de la recherche scientifique

Nuclear Waste



In terms of overall volume, around 95% of existing radioactive waste has very low level (VLLW) or low-level (LLW) radioactivity, while about 4% is intermediate level waste (ILW) and less than 1% is high-level waste (HLW).

For years, India, France, the UK, and other countries have carried out vitrification

Nuclear Waste

For years, India, France, the UK, and other countries have carried out vitrification of liquid waste from weapons production and fuel recycling—and still do. In the US, operators at Savannah River have been vitrifying weapons-related waste for about 20 years.

Tens of thousands of metric tons of highly radioactive spent nuclear fuel sit in large concrete-steel silos, or dry casks, in many countries, awaiting permanent disposal in a geological repository. These casks are at the Vermont Yankee Nuclear Power Station in Vernon.

Since the start of nuclear electricity production in 1954 to the end of 2016, some 390,000 tonnes of spent fuel were generated. About two-thirds is in storage while the other third was reprocessed: @ 15t/m3 = 26,000 m3

(US produced 5.000m3 since 1968)

Yallourn Brown Coal Fired Power Station

18 million Tonnes/annum

Australia's 2nd. largest coal mine

@ 0.9m3/tonne

= 16,000,000 m3/annum

Nuclear Waste in Perspective

- In one Year a single Australian brown coal fired power station digs a hole - of 16,000,000 m3 - big enough to hold ALL the waste - 26,000 m3 - produced To Date by all the nuclear power plants in the World and have room for a further (@55 t/annum)12,000 years production of spent fuel. (Reactors only refuel every 1 1/2 years)

Nuclear Power –The Future ?

Large High Output Reactors

Vogtle Unit 3

October 2022

Plant Vogtle Units 3 and 4 are the first nuclear plants to be built in the United States in 30 years.

Small Modular Reactors

Rolls-Royce has designed three generations of naval reactors since the 1950s and also operates a small test reactor. It led the design of a small integral reactor (SIR) of 330 MWe in the late 1980s.

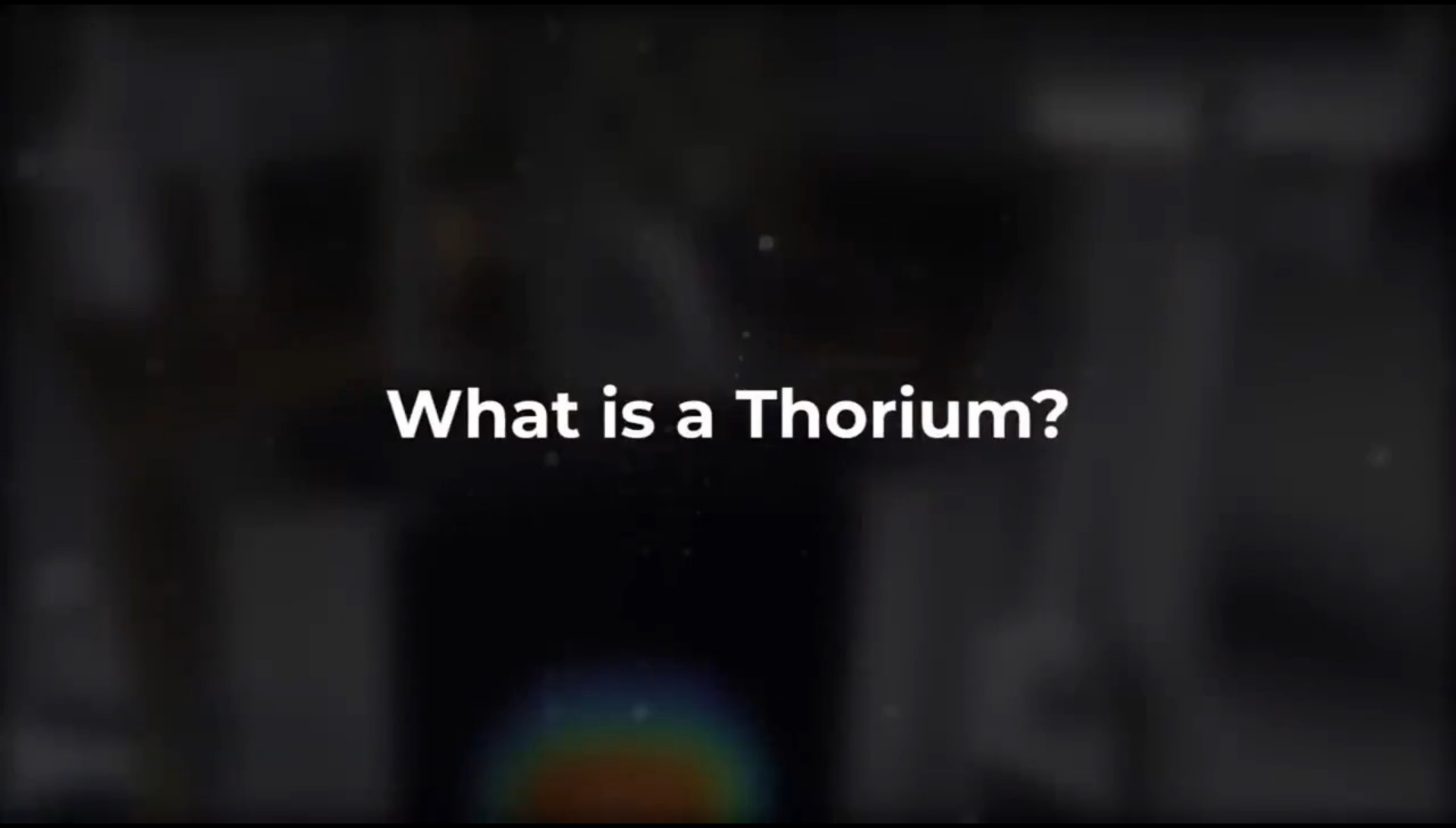
They are currently offering a set of SMRs instead of $20bn mega station on existing site in Wales (Wylfa)

Small Modular Reactors

Proposed next Generation of Russian floating Reactors

Thorium Reactors

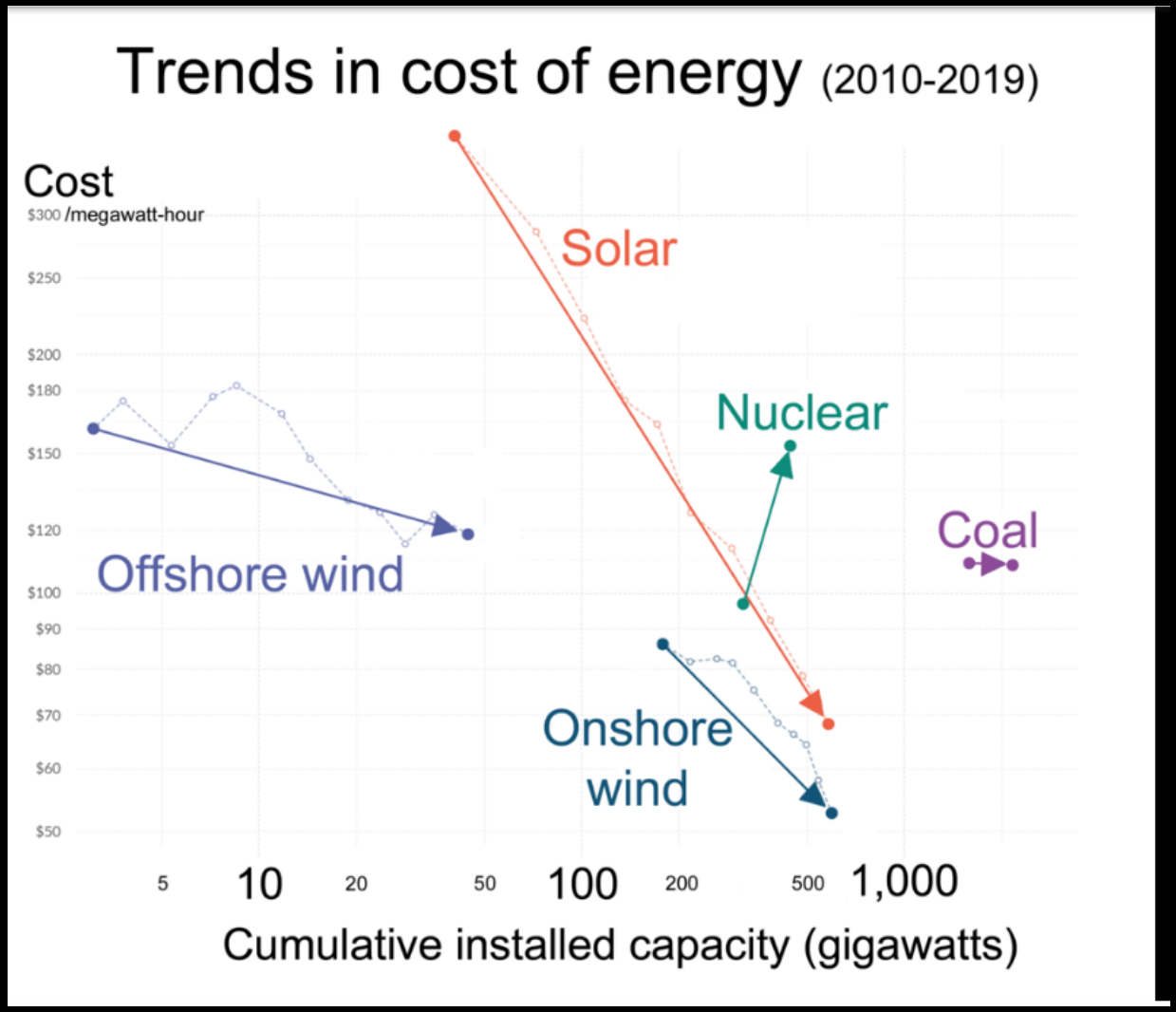
4 1/2 mins


What is a Thorium?

Generation IV reactor designs under development

	Neutron spectrum (fast/thermal)	Coolant	Temperature (°C)	Pressure*	Fuel	Fuel cycle	Size (MWe)	Use
Gas-cooled fast reactors	fast	helium	850	high	U-238 +	closed, on site	1200	electricity & hydrogen
Lead-cooled fast reactors	fast	lead or Pb-Bi	480-570	low	U-238 +	closed, regional	20-180** 300-1200 600-1000	electricity & hydrogen
Molten salt fast reactors	fast	fluoride salts	700-800	low	UF in salt	closed	1000	electricity & hydrogen
Molten salt reactor - **advanced high-temperature reactors**	thermal	fluoride salts	750-1000		UO_2 particles in prism	open	1000-1500	hydrogen
Sodium-cooled fast reactors	fast	sodium	500-550	low	U-238 & MOX	closed	50-150 600-1500	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-625	very high	UO_2	open (thermal) closed (fast)	300-700 1000-1500	electricity
Very high temperature gas reactors	thermal	helium	900-1000	high	UO_2 prism or pebbles	open	250-300	hydrogen & electricity

Major Power Sources and Trends



By Our World In Data - Max Roser - https://ourworldindata.org/cheap-renewables-growthArchive thereof:

Nuclear Power

- It is expensive
- It is safe
- It is clean
- It is very reliable
- It has a short and reliable supply chain
- It is likely to be indispensible for industrial countries with limited clean natural resources

Current as at Nov. 2023

ex World Nuclear News WNN

- Belarus Second unit enters commercial operation
- Together with the first unit the new nuclear power plant will provide about 40% of the country's electricity needs.

- Chinese SMR Containment shell in place
- The steel containment dome was successfully hoisted into place at the ACP100 small modular reactor demonstration project at the Changjiang site on China's island province of Hainan, China National Nuclear Corporation has announced.

- Sweden Planning permission sought for new reactors at Ringhals
- Vattenfall seeking approval for the construction of new reactors on the Värö Peninsula, to the west of the existing Ringhals nuclear power plant in Sweden. Doosan Enerbility to design used fuel storage system

- South Korean engineering firm Doosan Enerbility has signed a contract with Korea Hydro & Nuclear
- Power to carry out the overall design of a used nuclear fuel dry storage system.

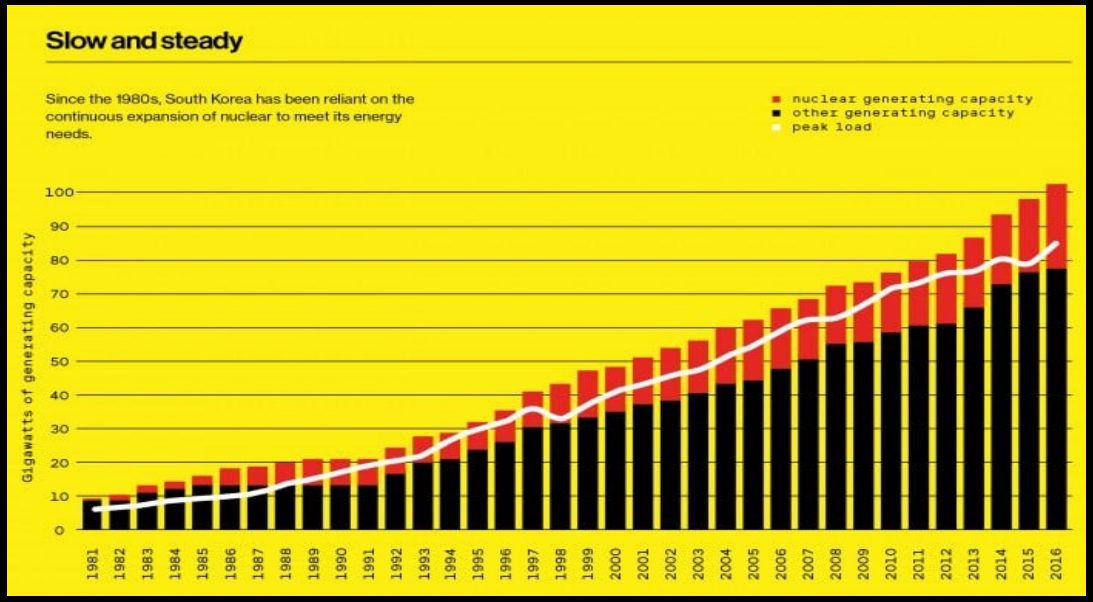
- Norway SMR power plant proposed based on multiple small modular reactors in the municipalities of Aure and Heim..

Current as at Nov. 2023

ex World Nuclear News WNN contd.

- France and Kazakhstan have pledged cooperation on minerals and the nuclear fuel cycle, while in Uzbekistan there was agreement to raise the level of bilateral relations, during official visits by President Emmanuel Macron this week. The French president was accompanied by a large delegation including representatives from French industry.
-
- China Cold testing completed at first Zhangzhou , the first of two Hualong One reactors under ;
-
- South Ukraine unit 1 gets 10-year extension
-
- Holland and Denmark Partners to study hydrogen production using Rolls-Royce SMR
-
- Japan's Nuclear Regulation Authority has approved the operation of units 1 and 2 at Kyushu Electric Power Company's Sendai nuclear power plant beyond 40 yearsTerraPower of the USA and the Japan Atomic Energy Agency, on the development of sodium-cooled fast reactors.
- Czech Republic Westinghouse, EDF and KHNP submit final bids for three more future reactors

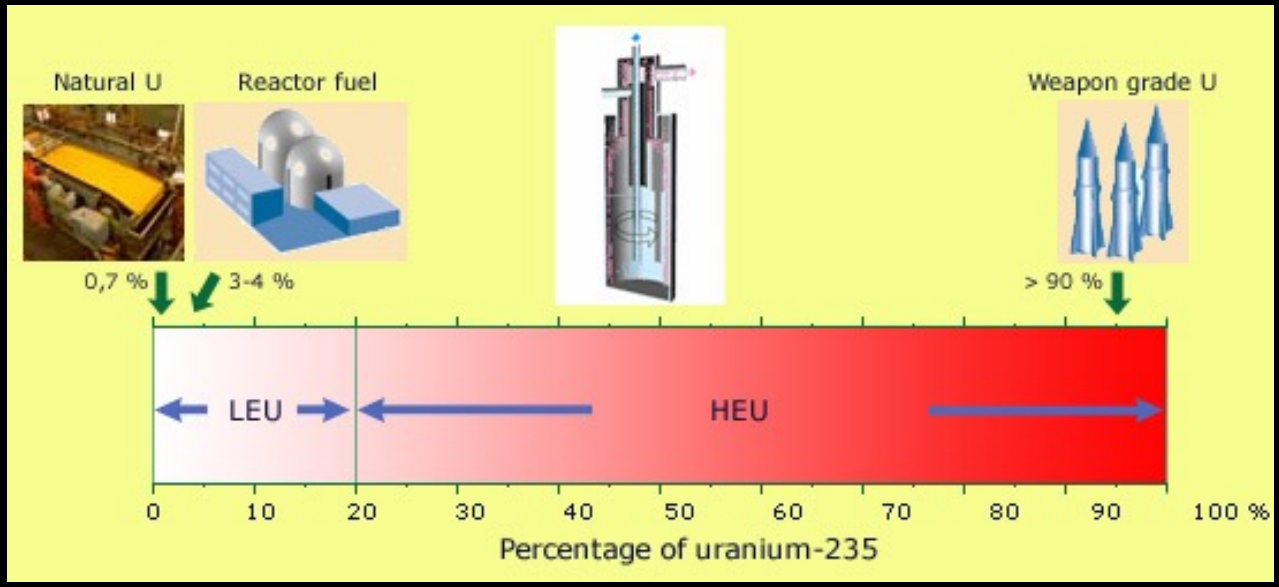
Korean NPP Design



Prosecutors discovered that thousands of counterfeit parts had made their way into nuclear reactors across the country, backed up with forged safety documents. KHNP insisted the reactors were still safe, but the question remained: was corner-cutting the real reason they were so cheap?

After the Chernobyl disaster in 1986, most reactor builders had tacked on a slew of new safety features. KHNP followed suit but later realized that the astronomical cost of these features would make the APR1400 much too expensive to attract foreign clients.

Uranium 238 and 235



- **Weapon-grade and civilian uranium**
  Natural uranium is poor in the fissile isotope, containing as it does only **0.70%** of uranium 235. It must be enriched before it can be used as a fuel in any commercial reactor. These reactors are powered by uranium which is enriched to have anywhere between **3 and 4%** of uranium 235. In order to have an atomic bomb, the uranium has to be enriched to above **90%**. The boundary between the uranium meant for civilian uses (LEU or low-enriched uranium) and that uranium meant for military use (HEU or highly-enriched uranium) is generally fixed at **20%**.
  IN2P3