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Working for a sustainable future...

NUCLEAR POWER?

WHY? WHY NOT?

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For the Energy Management Task Force
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Suggested reasons to favour nuclear power

- Cheap
- Clean, safe
- No greenhouse gases
- No other options for meeting energy needs

Nuclear power,

the basics

Atoms and Isotopes

- The core (nucleus) of each atom contains protons (positively charged). Most also contain neutrons (neutral charge)
- Elements are defined by the number of protons in the nucleus of their atoms e.g. hydrogen has 1, uranium has 92.
- But each element can exist in different isotopic forms, i.e. with a different number of neutrons in its nucleus

- Different isotopes of the same element are indicated by the superscript number beside their symbol that shows the total of the number of protons and neutrons.

- e.g H^3 is an isotope of hydrogen with one proton and 2 neutrons.

- Different isotopes of a given element behave the same way chemically but have different radioactive properties.

Radioactivity

- Some isotopes are unstable and decay naturally, throwing off part of their core or energy en route to a more stable structure.
- Some emit alpha particles, composed of 2 protons and 2 neutrons;
- Others emit beta particles, which are electrons;
- Some emit gamma radiation, which is just energy.

Alpha radiation

- The emitting nucleus loses 2 protons, so it changes into a different chemical element.
- Alpha radiation cannot penetrate far. It is stopped by a sheet of paper.
- However it produces ionization and can be very harmful if it gets inside your body.

Beta radiation

- The emitting nucleus loses an electron by converting a neutron into a proton, so a different chemical element is formed.

- Beta radiation is more penetrating than alpha. It requires a thin sheet of aluminum to stop it.

Gamma radiation

- No particles are emitted, so there is no change in the identity of the element.
- Gamma radiation is very penetrating (similar to X-rays). It requires lead shielding to protect operators.

Half-life

- Radioactive decay processes take place at different rates.
- The half-life is the time it takes for half of any given quantity of nuclei to decay.
- Half-lives range from a fraction of a second to many thousands of years.

Decay chains

- Many heavy isotopes go through a series of radioactive decay steps, each with its own half-life, before reaching a stable form.

U^{238} decay

- U^{238} alpha, 4.5×10^9 yrs → Th^{234}
- Th^{234} beta, 24.5 days → Pa^{234}
- Pa^{234} beta, 1.14 min → U^{234}
- U^{234} alpha, 2.33×10^5 yrs → Th^{230}

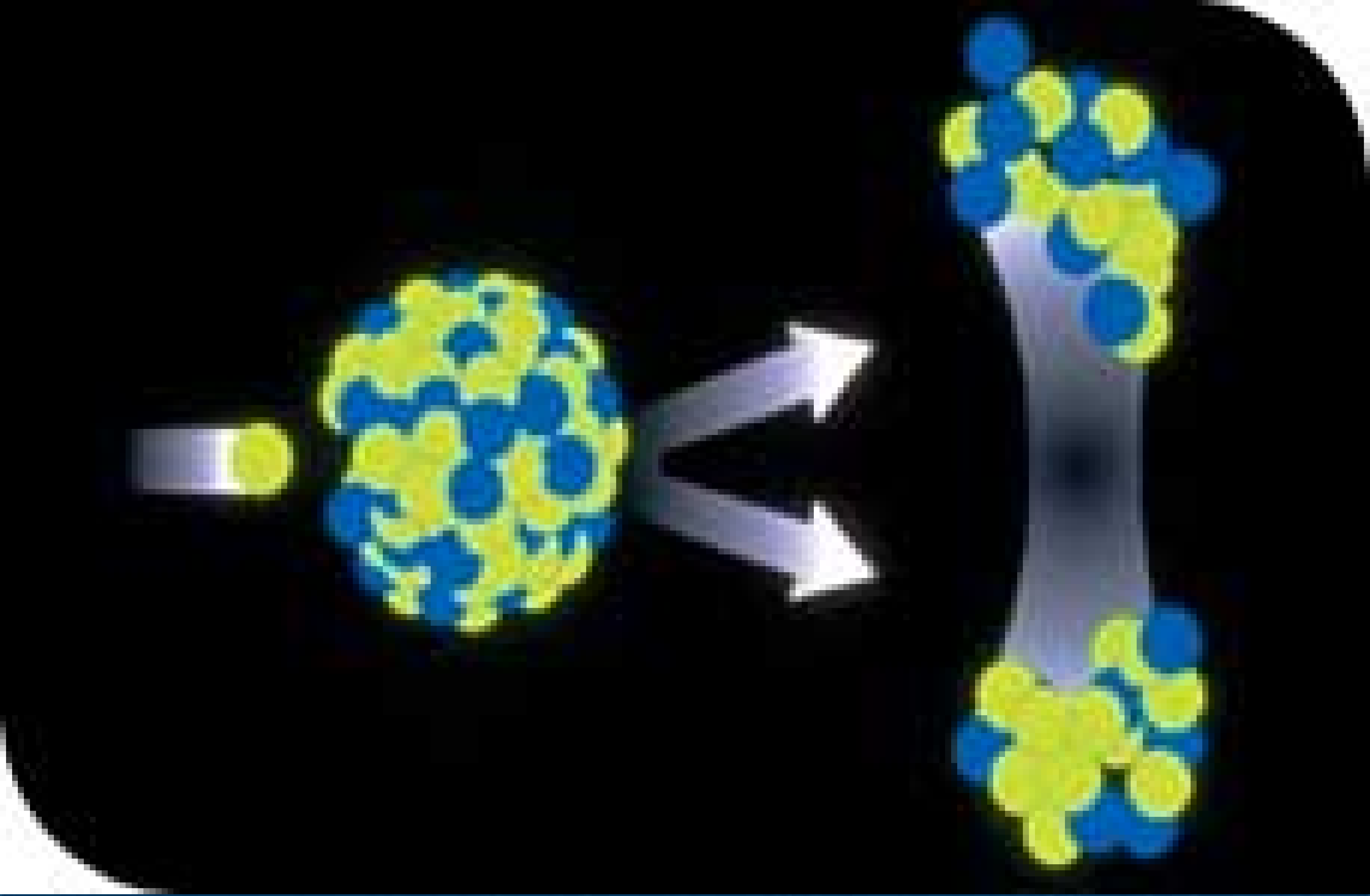
URANIUM 238 (U238) RADIOACTIVE DECAY

type of radiation	nuclide	half-life
	uranium—238	4.5×10^{9} years
α	thorium—234	24.5 days
β	protactinium—234	1.14 minutes
β	uranium—234	2.33×10^{5} years
α	thorium—230	8.3×10^{4} years
α	radium—226	1590 years
α	radon—222	3.825 days
α	polonium—218	3.05 minutes
α	lead—214	26.8 minutes
β	bismuth—214	19.7 minutes
β	polonium—214	1.5×10^{-4} seconds
α	lead—210	22 years
β	bismuth—210	5 days
β	polonium—210	140 days
α	lead—206	stable

How to get energy from a uranium atom

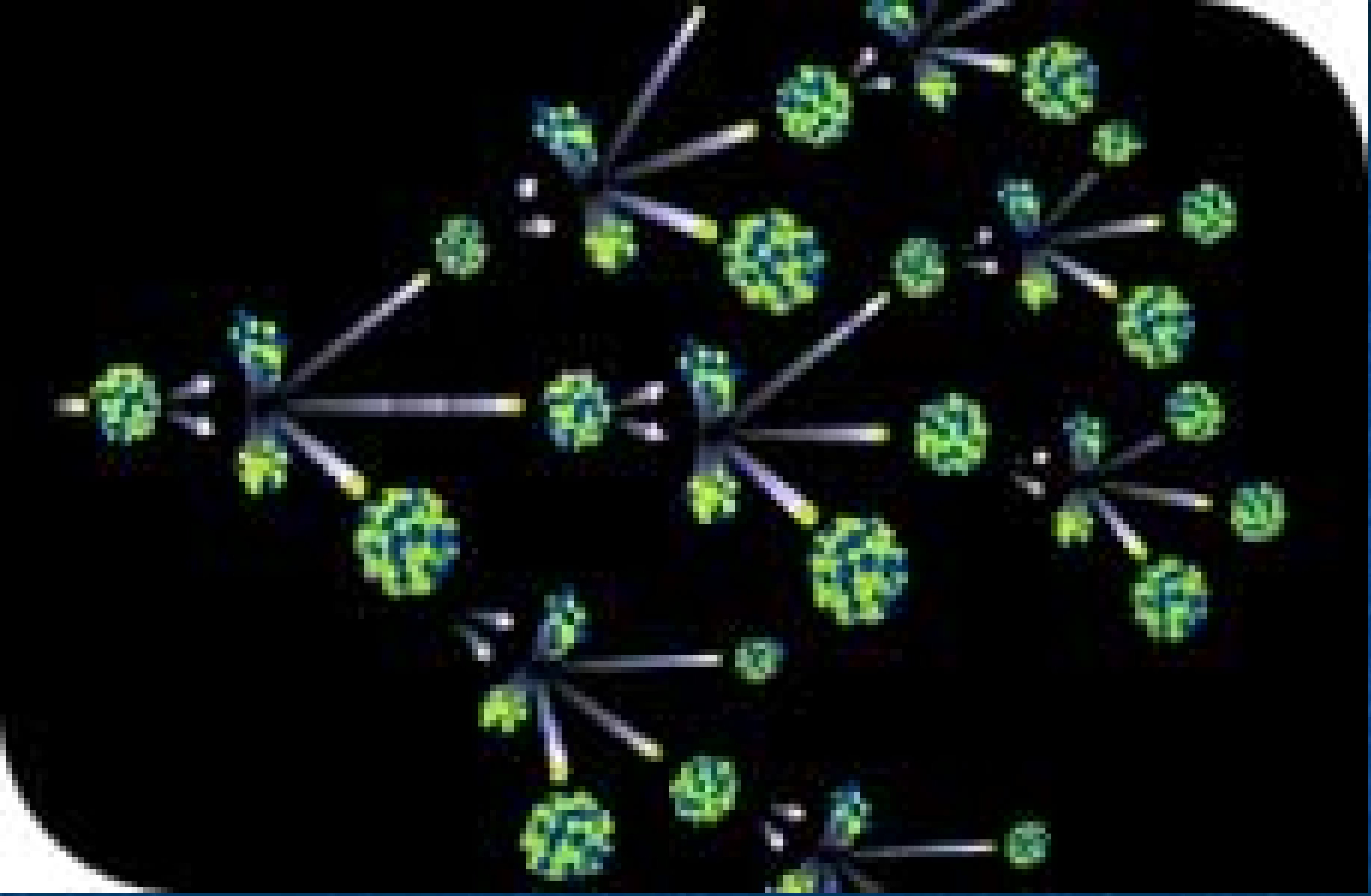
- A few heavy isotopes are fissile – they can be made to split into pieces by hitting them with neutrons, releasing a lot of energy in the process.

- U^{235}, which constitutes 0.7% of natural uranium, is fissile.



Fission products

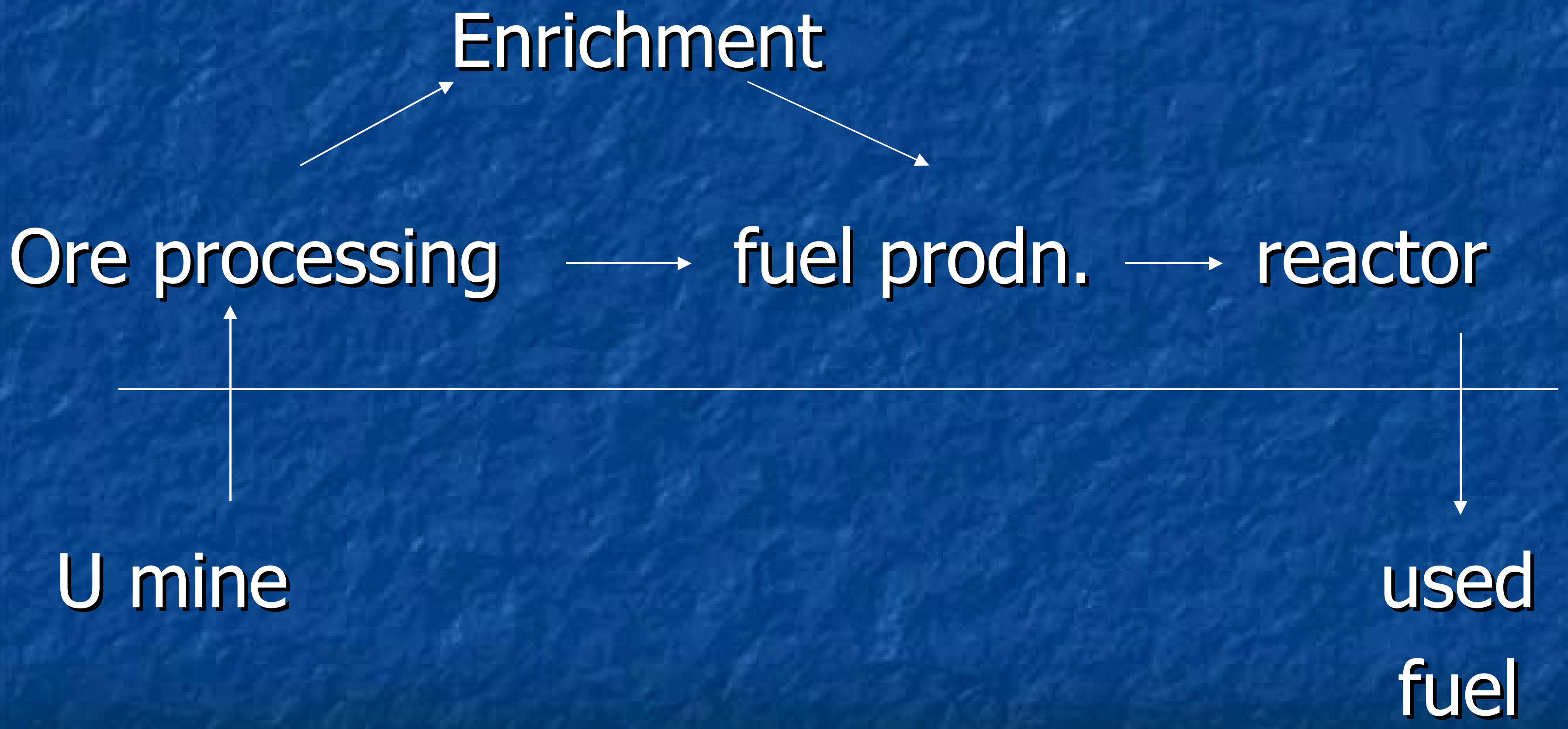
- Fission products are the pieces formed when the uranium atom splits. They are nuclei of smaller atoms, mostly in the form of highly unstable, radioactive isotopes.
- Additional neutrons are also produced in the fission process. These go on to split other uranium atoms, leading to a chain reaction



Chain reaction

- In each fission process some mass is converted into energy
- If number of neutrons is not controlled you may get a runaway chain reaction (explosion)
- To tame the chain reaction, absorb some of the neutrons to get controlled release of energy

- Simple nuclear fuel chain


Enrichment
Ore processing
fuel prodn.
reactor
U mine
used
fuel

What's missing from this picture?

- It's not a "cycle"
- Uranium mine tailings
- Mill effluent
- Production of plutonium
- Depleted uranium
- Tritium emissions
- On-going management of used fuel

Mine wastes

- Material from underground contains a mix of uranium and its decay products and various toxic chemicals
- Tailings placed in conical pits under water
- Mill effluent is cleaned to "acceptable level" (?) and released into surface waters

Plutonium

- Natural uranium contains 99.3% U^{238} and 0.7% U^{235}
- In the reactor U^{238} absorbs neutrons to form U^{239}, which beta decays to Np^{239}, then to Pu^{239}

- So used fuel contains a mixture of uranium, fission products and plutonium
- Plutonium can be separated out to use as fuel or for weapons

Depleted uranium

- Many reactors require enriched uranium (higher percentage of U^{235})
- Remnant after enrichment is "depleted uranium" (DU)
- Canadian U sold to US is enriched and DU goes into a stockpile
- Used for cladding of shells, bullets etc.

Tritium

- Operating CANDU reactors emit tritium, a radioactive isotope of hydrogen, formed by exposure of heavy water to radiation.
- Tritium is a beta-emitter with a 12 yr. half-life.
- CANDUs are emitting 100 times higher levels than Europe allows.

- "Tritiated water" behaves just like ordinary water and quickly spreads throughout the body.
- Studies suggest link to central nervous system birth defects and child leukemia.

Management of used fuel

- Contains mix of uranium, fission products, plutonium
- Initially, very brief exposure is fatal
- For first several years most of radioactivity comes from short-lived fission products

- Handled remotely & stored in “swimming pools”
- Later moved into “dry storage” on site.
- Long-lived materials must be kept out of ecosystem for 100,000 years.
- Potential for extraction of plutonium.

Biological effects of radiation

- Some fission products mimic body components, e.g. strontium
- Radiation can randomly break molecular bonds & damage genetic information of cell

Types of damage

- Carcinogenic - Damaged cell may reproduce abnormally
- Teratogenic – An irradiated foetus may develop abnormally
- Mutagenic – If sperm cells are irradiated, genetic damage may be passed on to children, grandchildren, great-grandchildren

What is the risk?

- Risks are generally proportional to radiation dose – there is no “safe” dose.
- Alpha radiation is about 20 times more damaging per unit dose than gamma.
- Alpha emitters have to be ingested into the body to cause harm.
- We can ingest them by breathing, drinking, eating or through skin lesions.

Potential sources of radioactive releases

- Uranium mining wastes, decay products
- Tritium from reactor operations
- Used fuel leakage from long-term storage
- Accident, sabotage or war damage to reactors or storage facilities
- Diversion of nuclear materials for nuclear weapons or “dirty” bombs

Can we manage the wastes safely?

- Mining wastes?

- Used fuel? – Canada has a plan!

Nuclear Waste Management Organization

- "Adaptive Phased Management" approach
- Continue to store at reactor sites
- Transfer to a central site (Ontario, Quebec, New Brunswick or Sask.?)
- Possibly temporarily store in shallow underground burial location
- Transfer to long-term storage deep underground

- Currently working on how to decide where disposal site should be
- Seeking a “willing community”
- Estimated date permanent disposal site ready to receive wastes is 2070.
- Decision about whether/when to seal up vault postponed to future generations.

Suggested reasons to favour nuclear power

- Cheap ?
- Clean, safe ?
- No greenhouse gases ?
- No other options for meeting energy needs ?

Is it cheap?

- Ontario's Hydro's experience – a multi-billion dollar debt
- Uncertain costs for waste management
- End-use efficiency, distributed co-generation and many renewables are cheaper than nuclear
- Cost of renewables falling dramatically

Is it clean, safe?

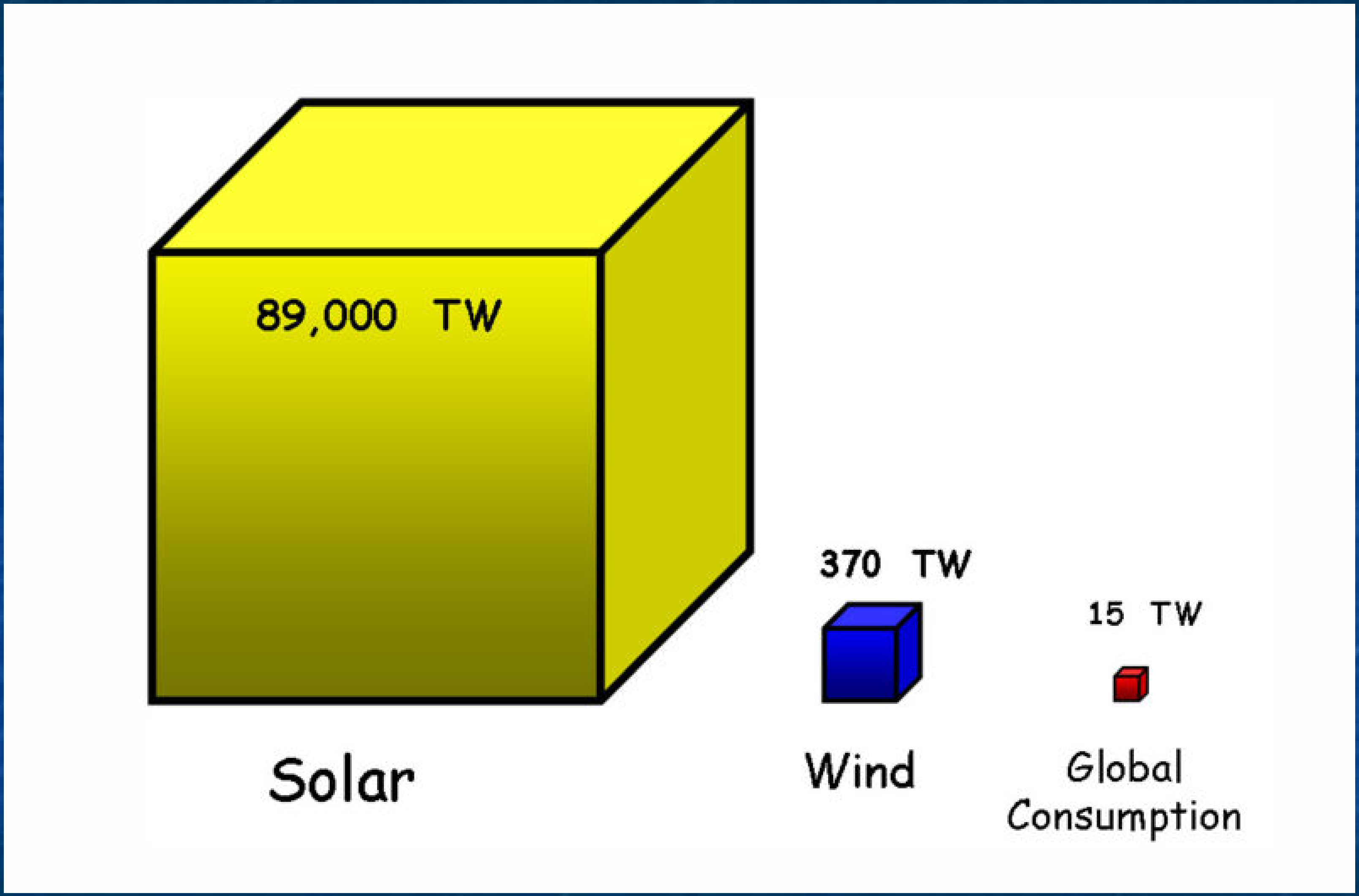
- Mine tailings
- Mill effluent
- Tritium emissions
- Used fuel management
- Security, Weapons potential

Is it free of greenhouse gas emissions?

- All energy sources have some associated GHG emissions
- Fossil fuels used in exploration, mining, milling, refining, enrichment, transportation, construction, decommissioning, waste management
- Emissions certainly much lower than from traditional coal plants, but not zero.

Are there better options?

- Manage demand through improved efficiency
- Distributed co-generation
- Renewables: One option - "Photovoltaics on its own has the potential to replace nuclear power on the required timescale, even in the UK"
- Problem of intermittency is being solved


89,000 TW
Solar
370 TW
Wind
15 TW
Global
Consumption

What do you think?

- Where should our priorities for energy development lie?

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