CEEDATA energy analysis

The inconvenient practice of nuclear power

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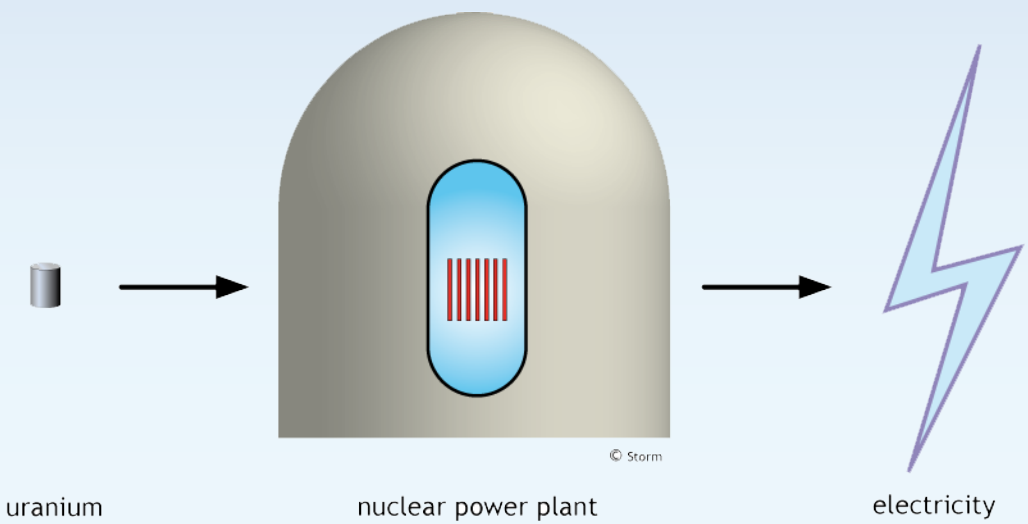
nuclear power as advertised

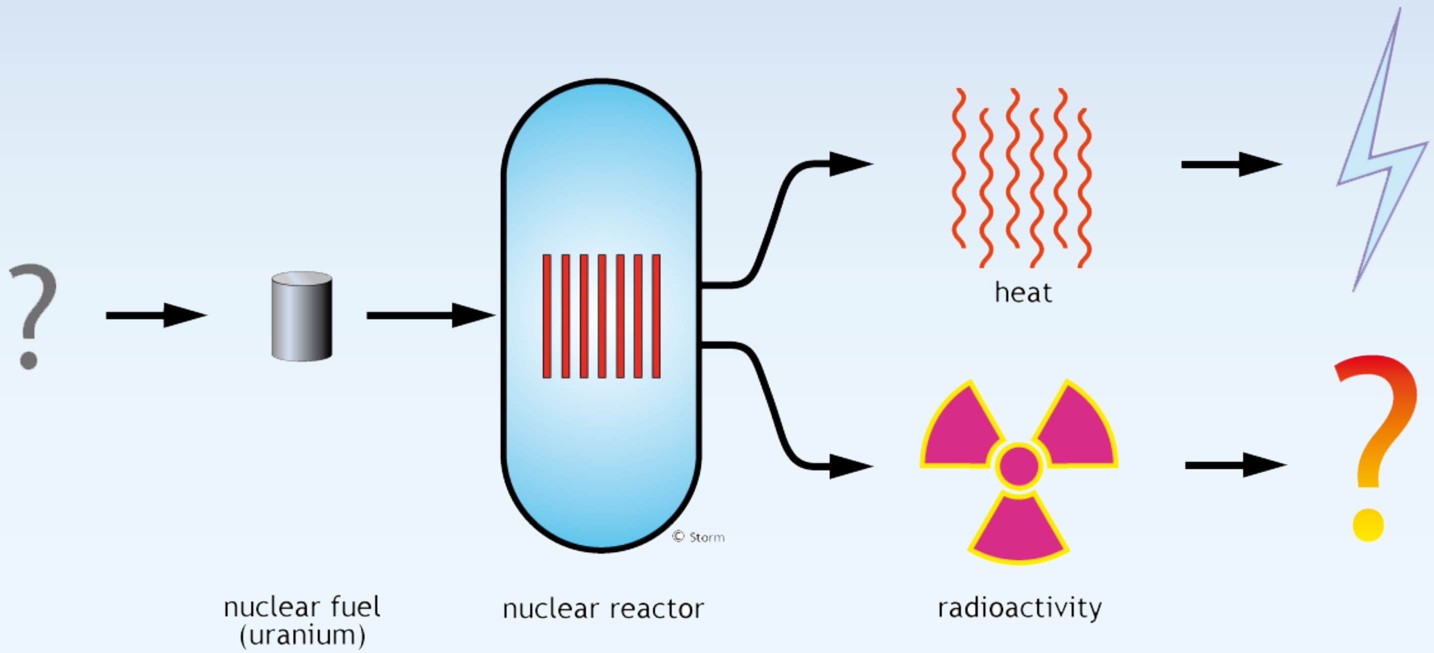
"clean, safe, sustainable"



Practice is not that simple

A nuclear reactor generates

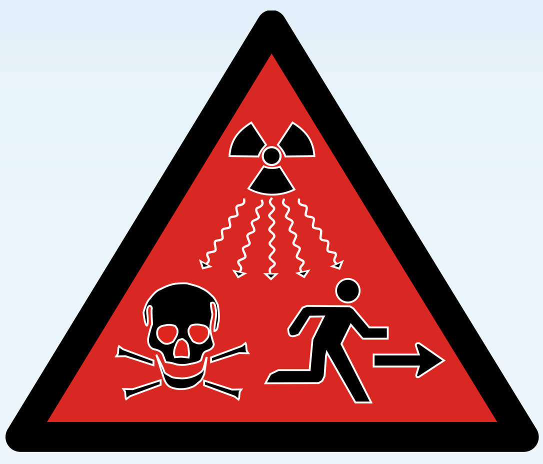
heat + **radioactivity** inextricably and irreversibly



The inconvenient practice of nuclear power

- From where comes the nuclear fuel?
- What happens to the human-made radioactivity?

Assessment by means of physical life cycle analysis (LCA)
+ energy analysis



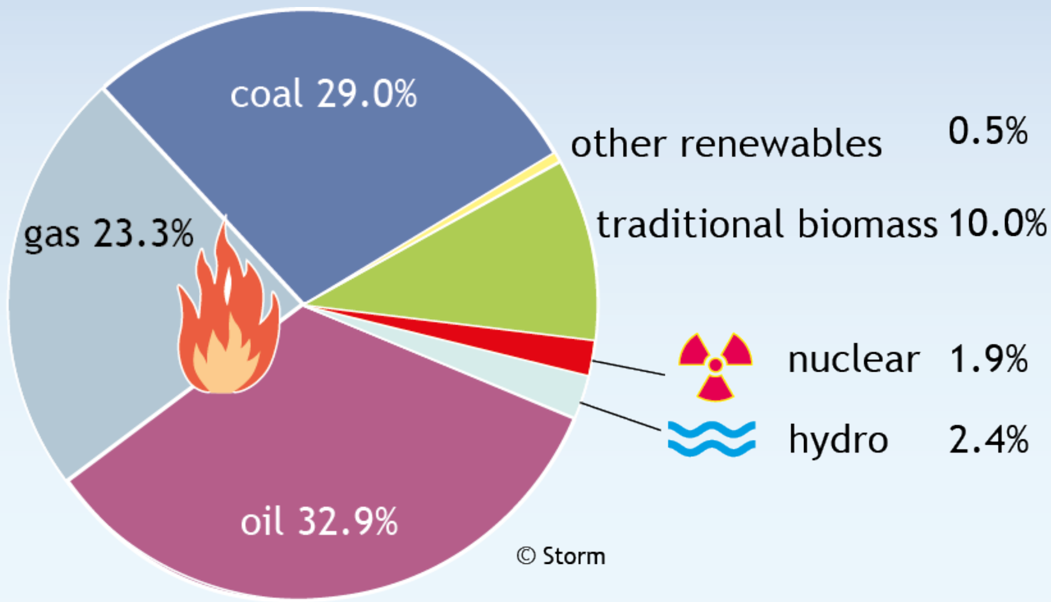
Outline

1

Global potential of nuclear power

- nuclear share world energy supply
- nuclear process chain
- principle of energy analysis
- energy costs energy: EROEI
- energy quality of uranium resources
- coal equivalence
- energy cliff
- CO_2 trap

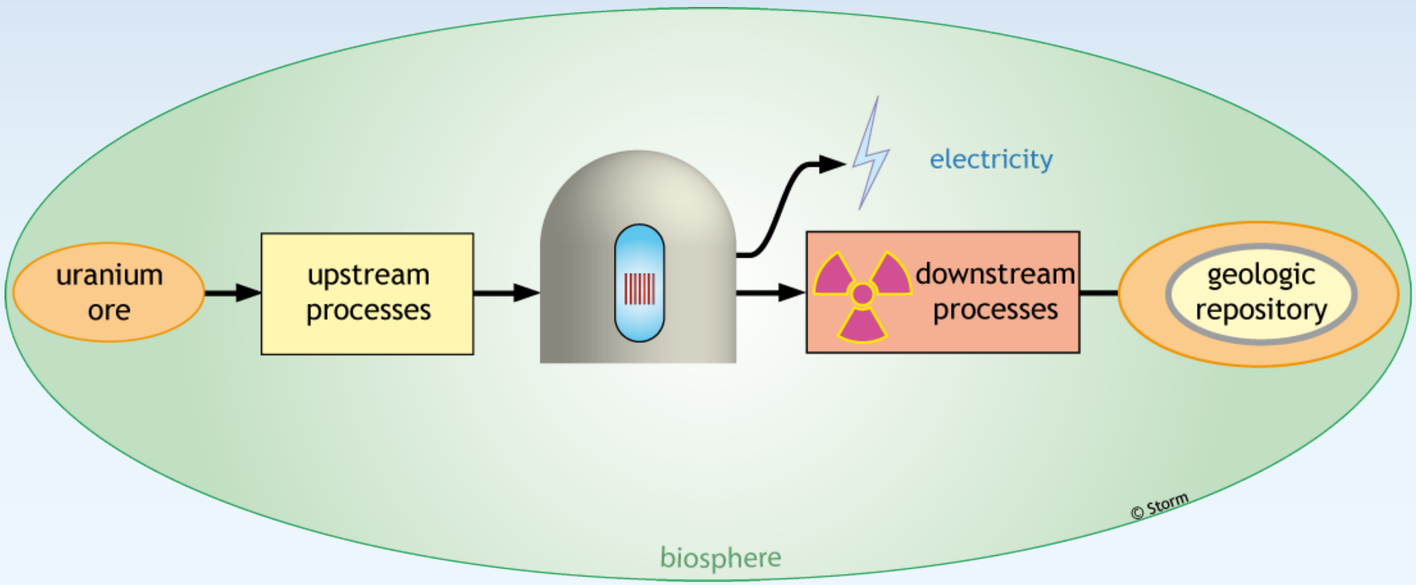
Nuclear share world energy in 2010



world energy consumption in 2010: ~515 EJ

traded energy: 463 EJ

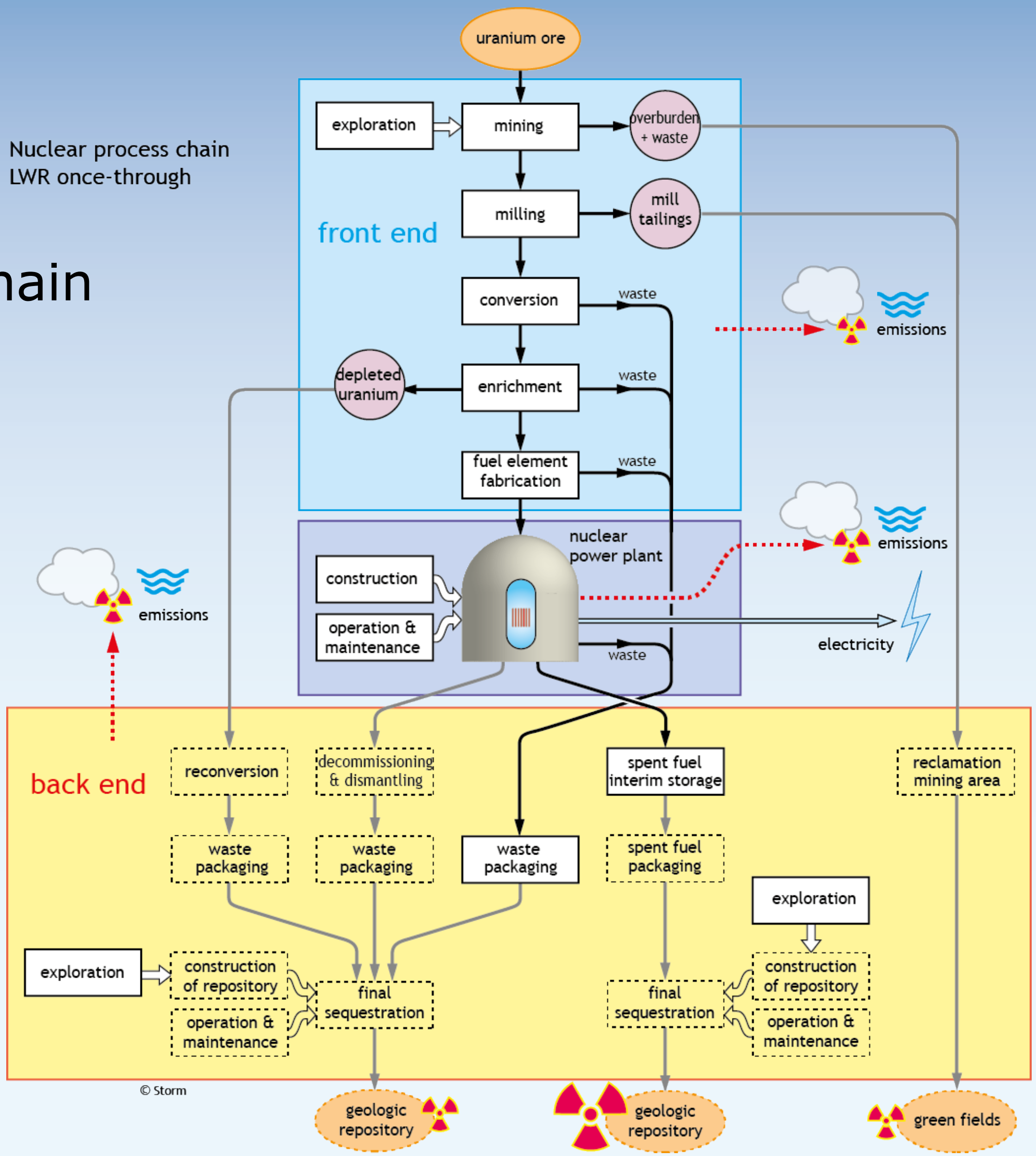
A nuclear reactor is part of the nuclear chain, all processes from cradle to grave occur within biosphere



The inconvenient practice of nuclear power

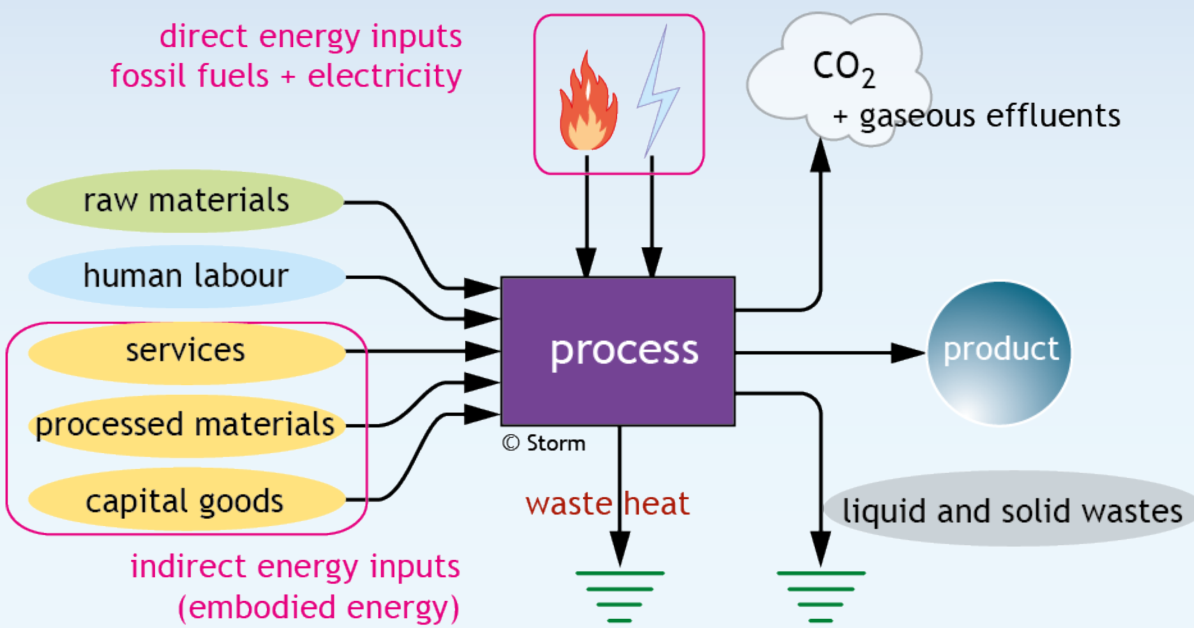
Nuclear process chain

Nuclear process chain
LWR once-through

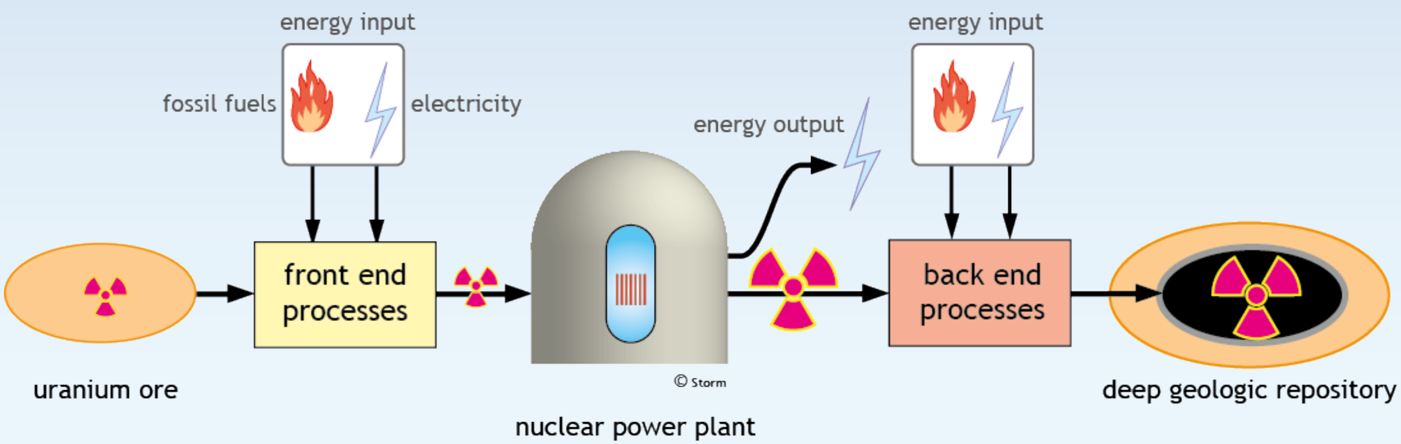


Method

Analysis and quantification of all material and energy inputs and outputs
of each process of the nuclear chain from cradle to grave



Energy inputs and output of the nuclear chain as it ought to be. from cradle to grave

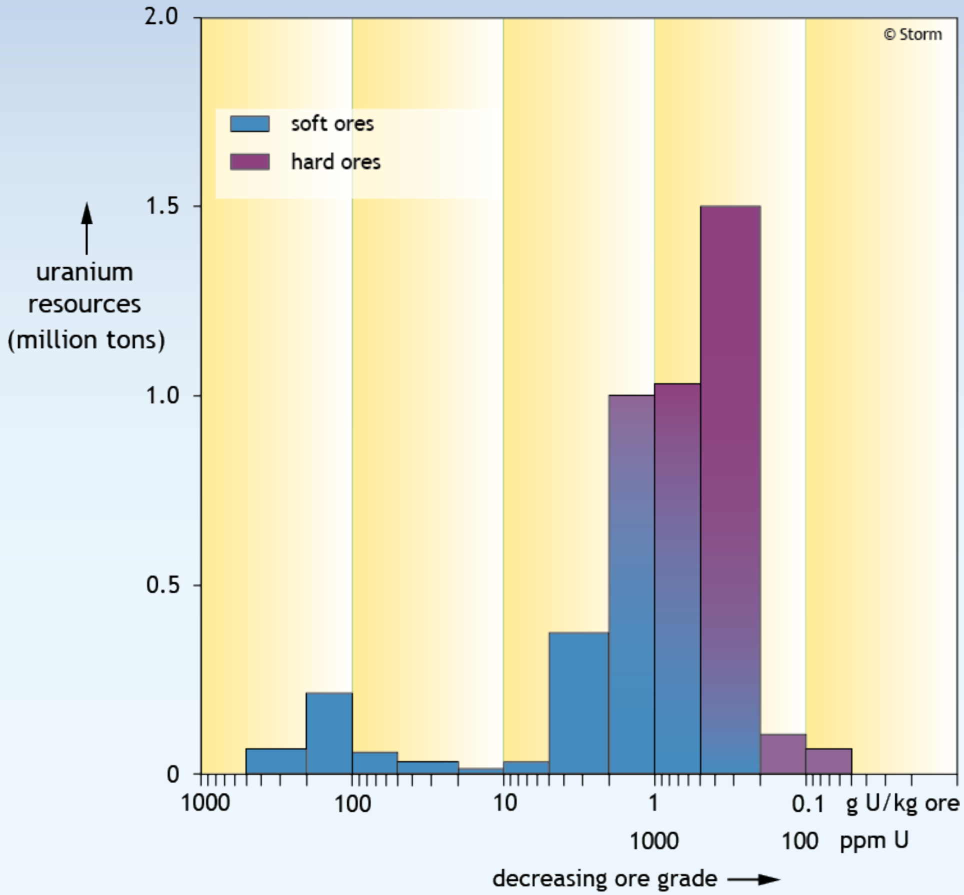


cooking the meal → enjoying the meal → washing the dishes + clearing the mess

Energy Return On Energy Investments

$$\text{EROEI} = \frac{\text{total energy output}}{\text{sum energy inputs}}$$

Known uranium resources of the world



Uranium resources and E quality

Energy quality =
net energy potential per kg U as present in the crust

Energy quality lower as: lower uranium grade
deeper deposits
harder ore minerals

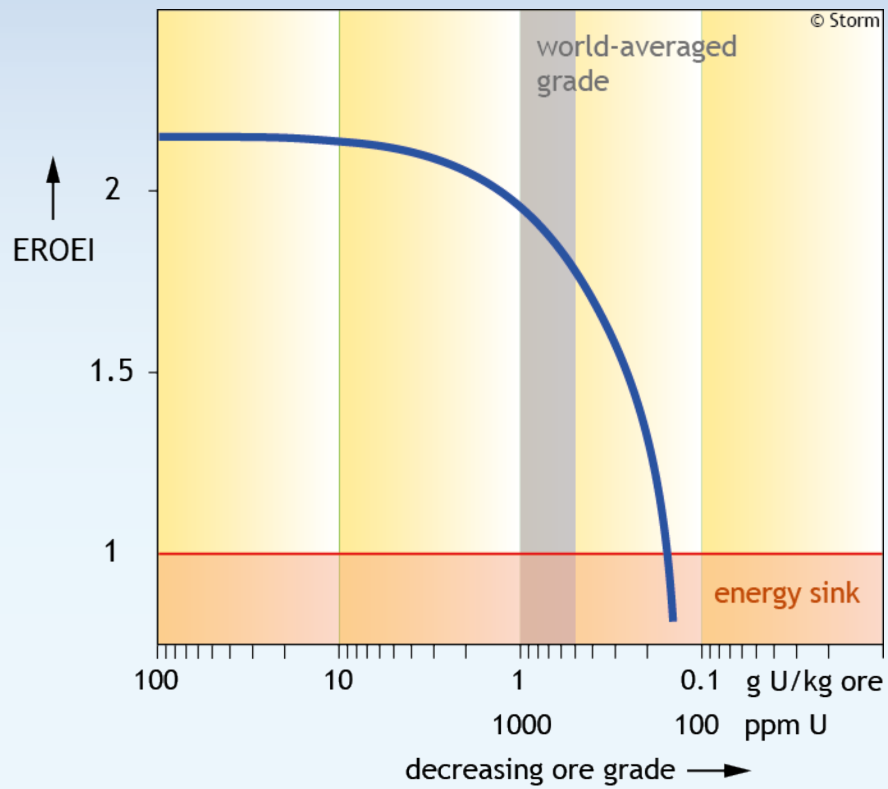
More energy consumed per recovered kg U =>
less net energy per kg U generated by nuclear chain

Coal equivalence

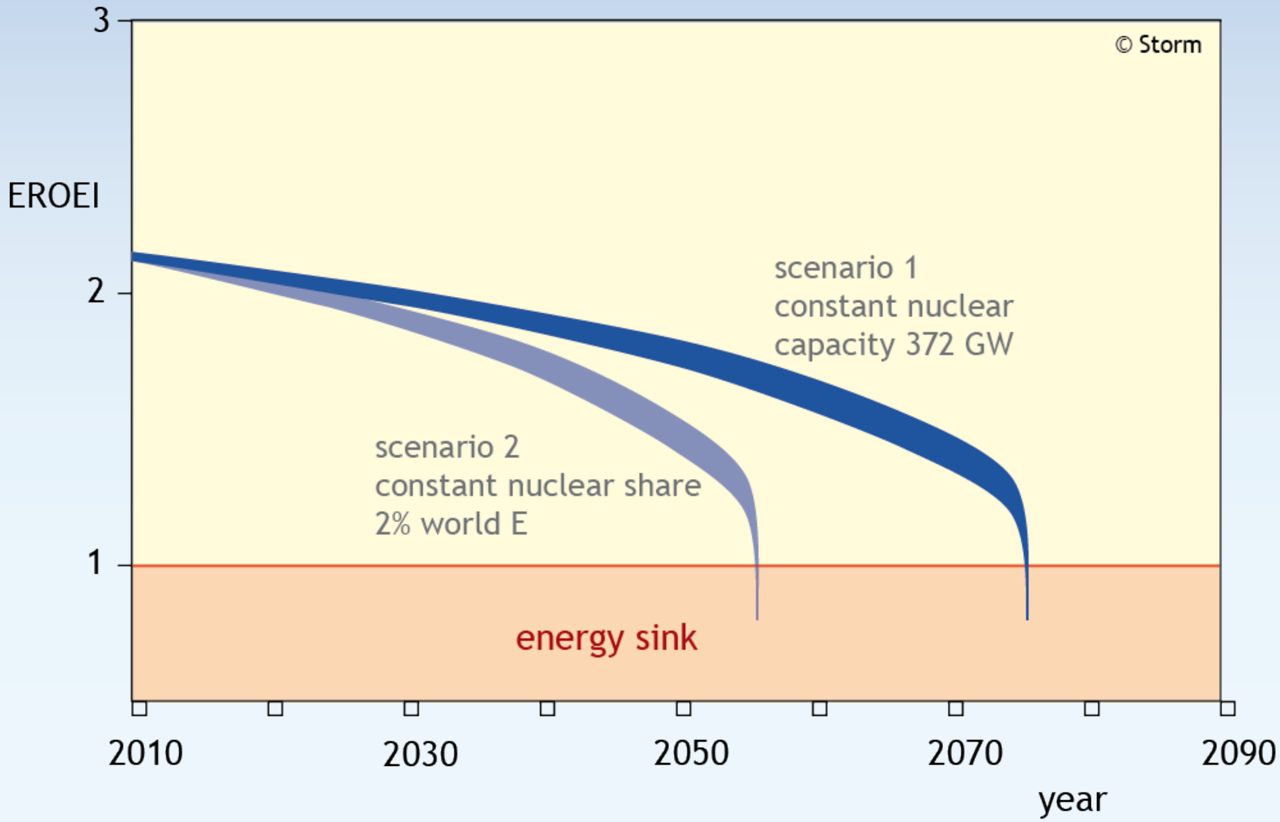
At 200 grams U per ton rock (200 ppm):
mass of uranium ore mined and processed
= mass of coal mined and burned
to produce same amount of electricity.

Energy cliff

energy return on energy investments EROEI vs ore grade

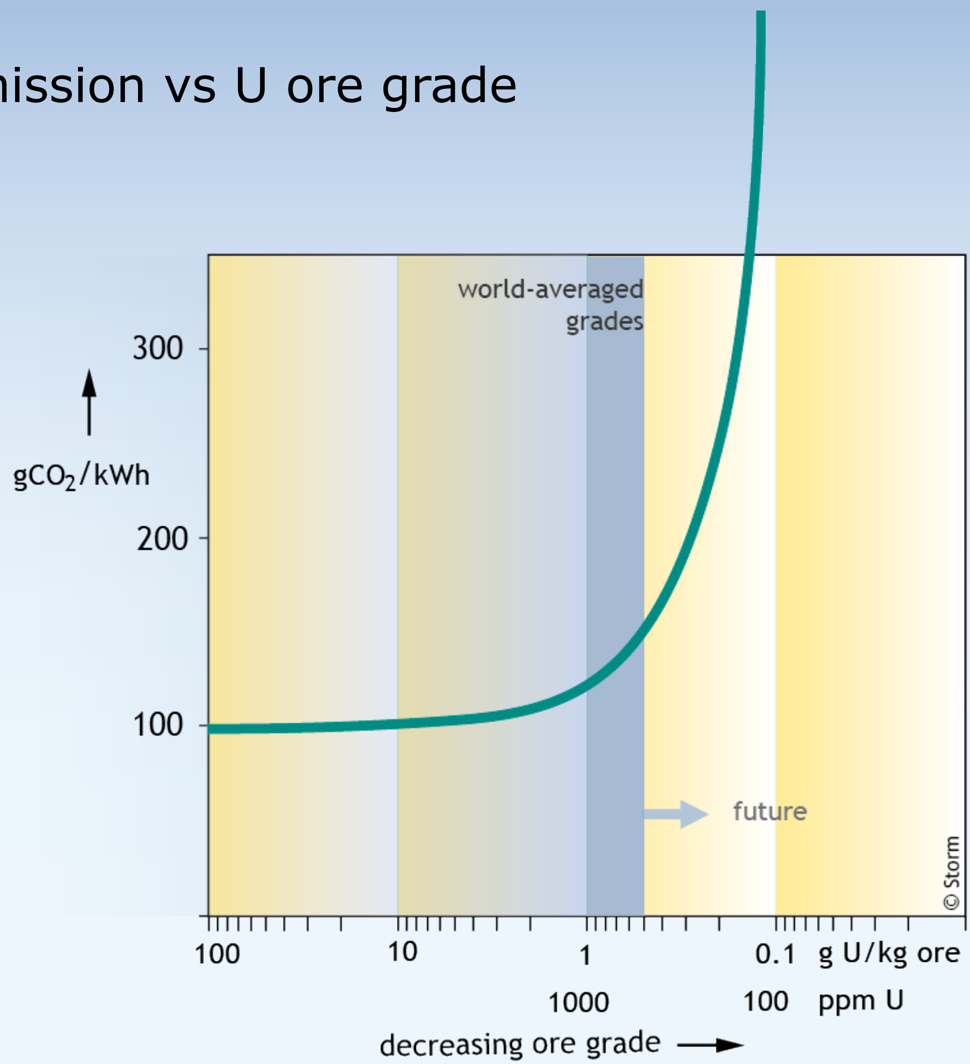


Energy cliff over time



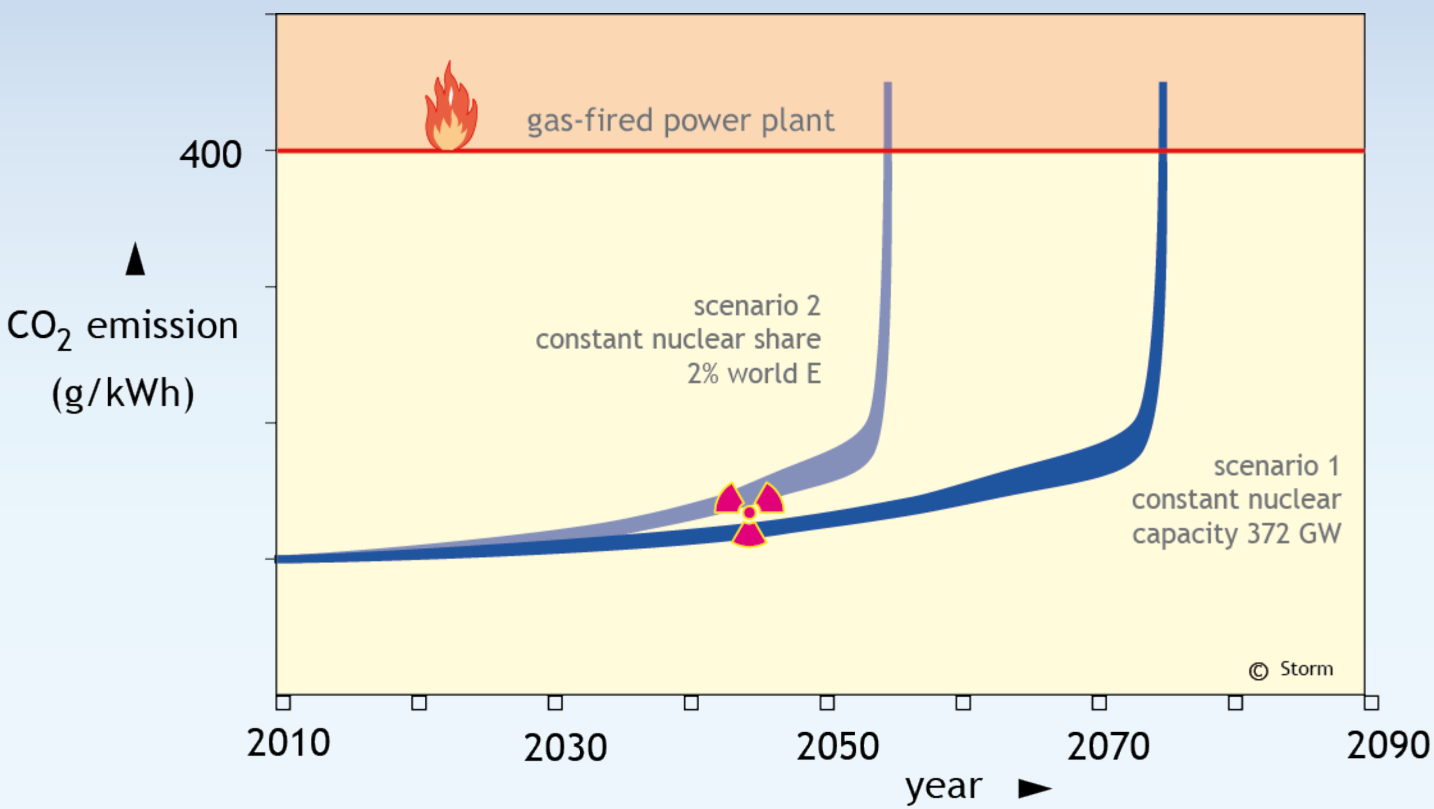
CO_2 trap

nuclear CO_2 emission vs U ore grade



CO_2 trap

nuclear CO_2 emission over time



Outlook uranium resources: view of nuclear industry

- criterion: price of uranium, unit: $/kg U
- higher U price
  > more exploration
  > more discoveries
  > larger U resources
- ergo: U resources practically inexhaustible

Outlook uranium resources: physical view

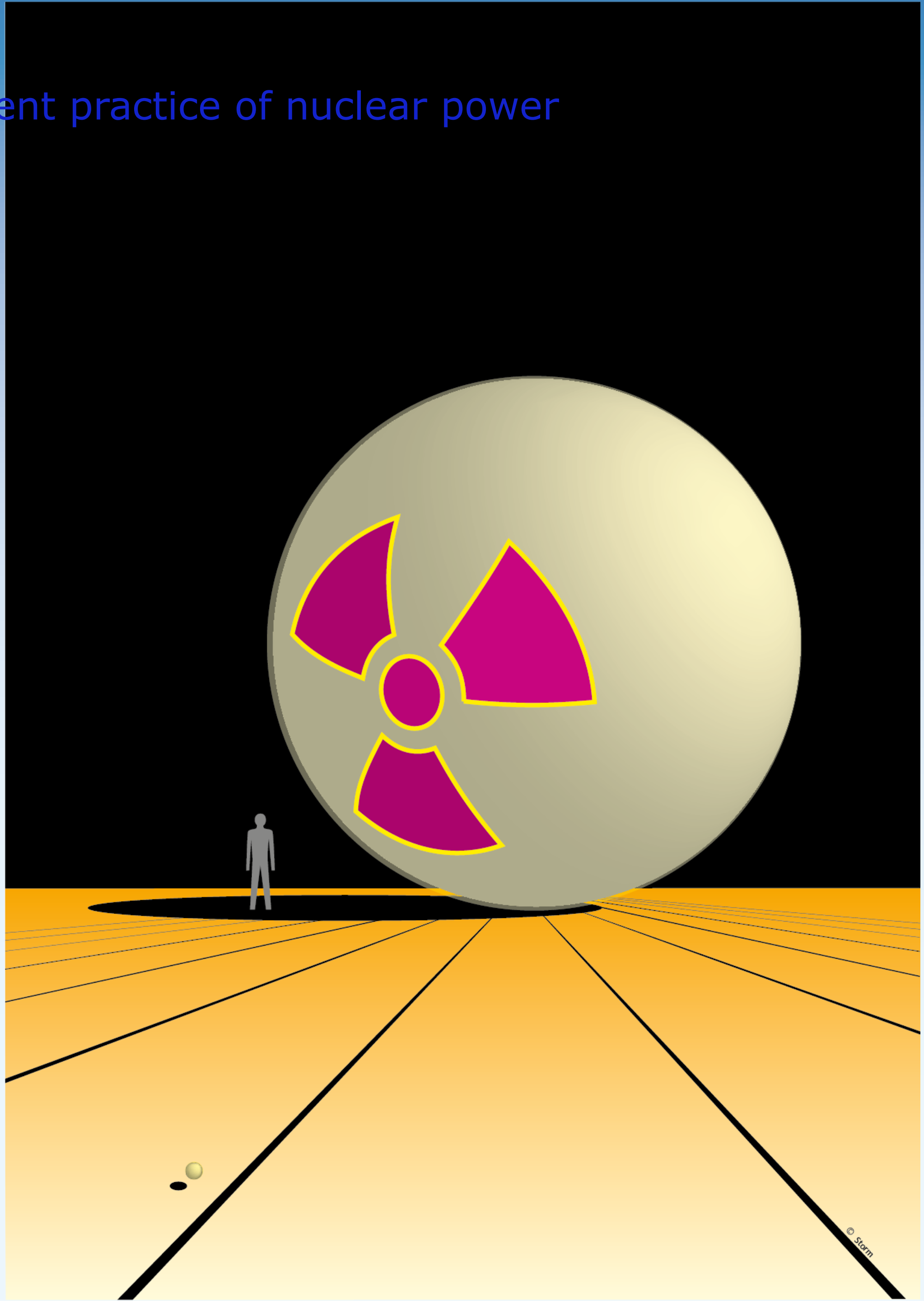
- criterion: extraction energy, unit: joule/kg U
- not U price, but energy quality counts
- beyond energy cliff: nuclear power = energy sink
- ergo: *net energy* content world U resources limited

2

Human-made radioactivity

Human-made
radioactivity

1 billion
X
natural input



Radioactivity

Each reactor (1GWe) generates each year
1000 nuclear bomb equivalents
(15 kiloton, Hiroshima)

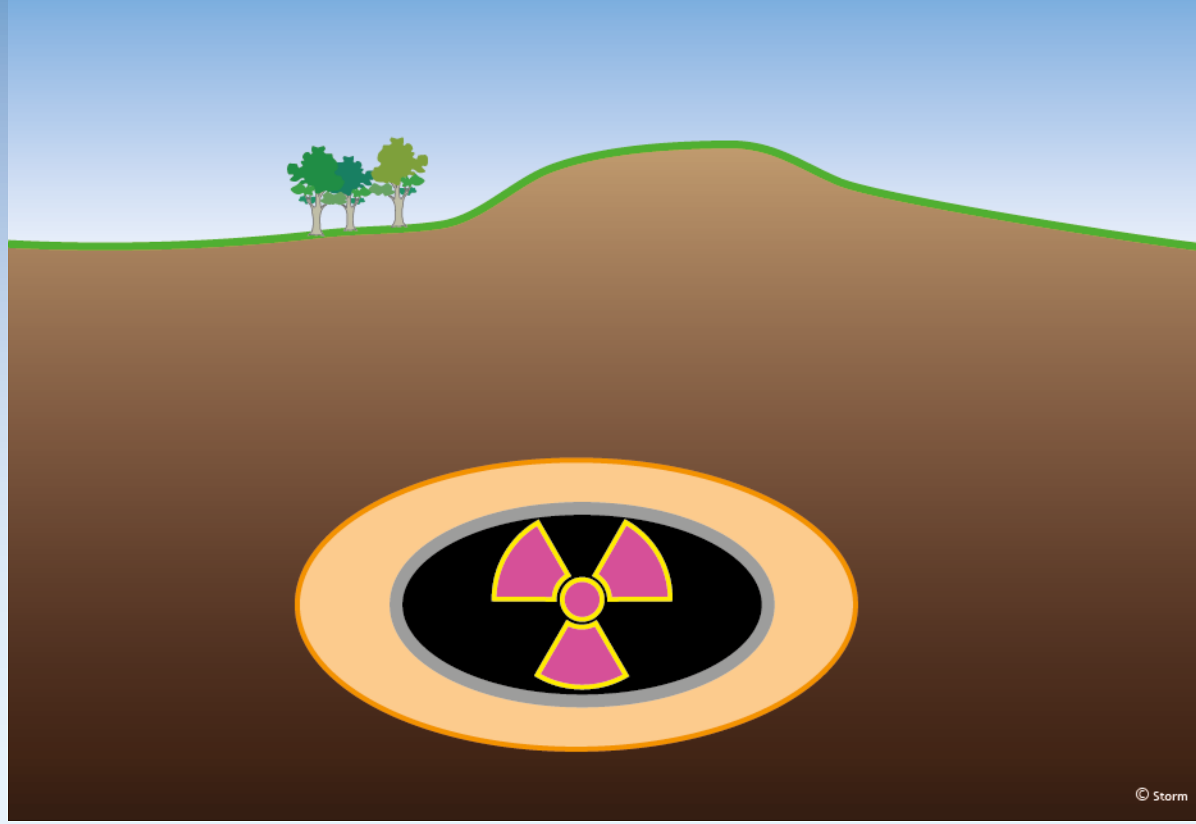
Radioactivity

World human-made radioactive inventory ever generated
10 million bomb equivalents
still in mobile form in human environment

Radioactivity

- cannot be made harmless to living organisms
- cannot be destroyed
- decay cannot be accelerated

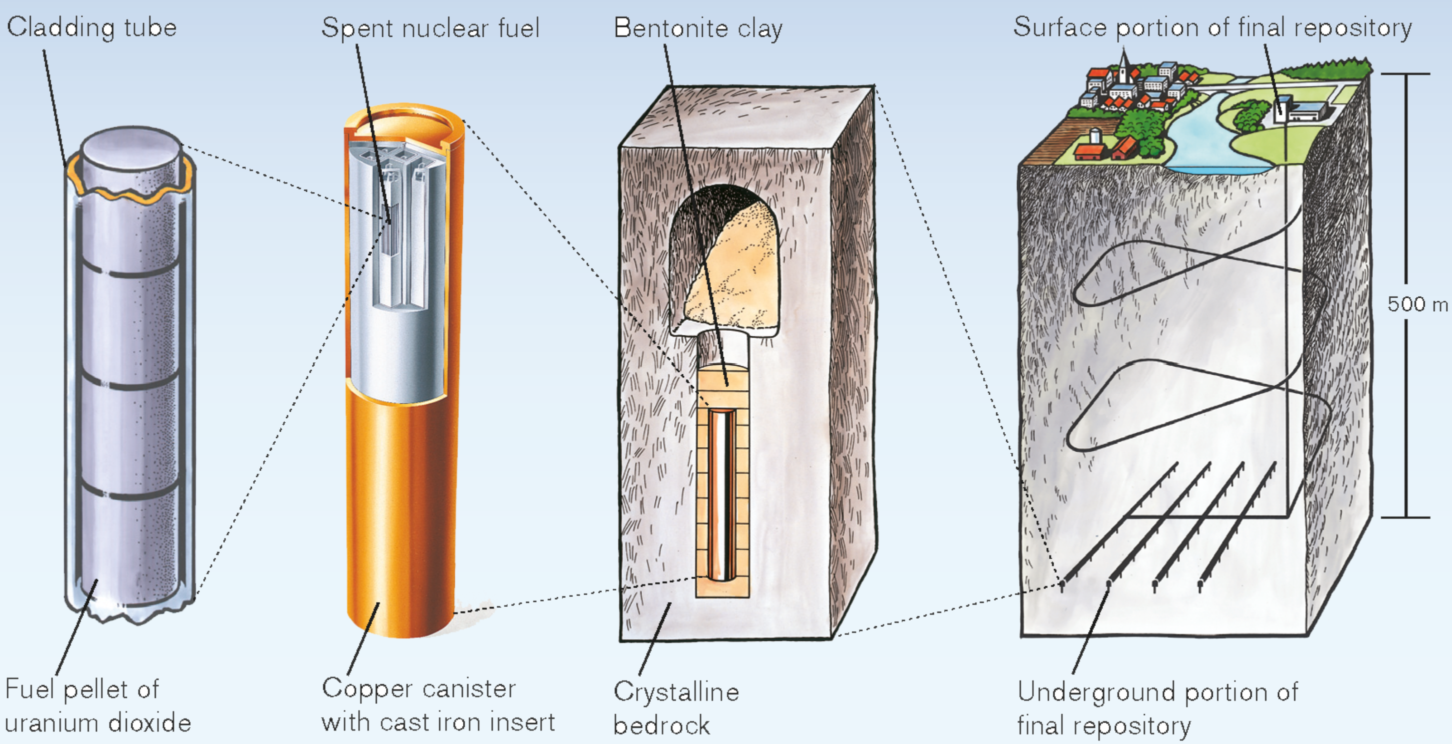
The inconvenient practice of nuclear power



Just one option

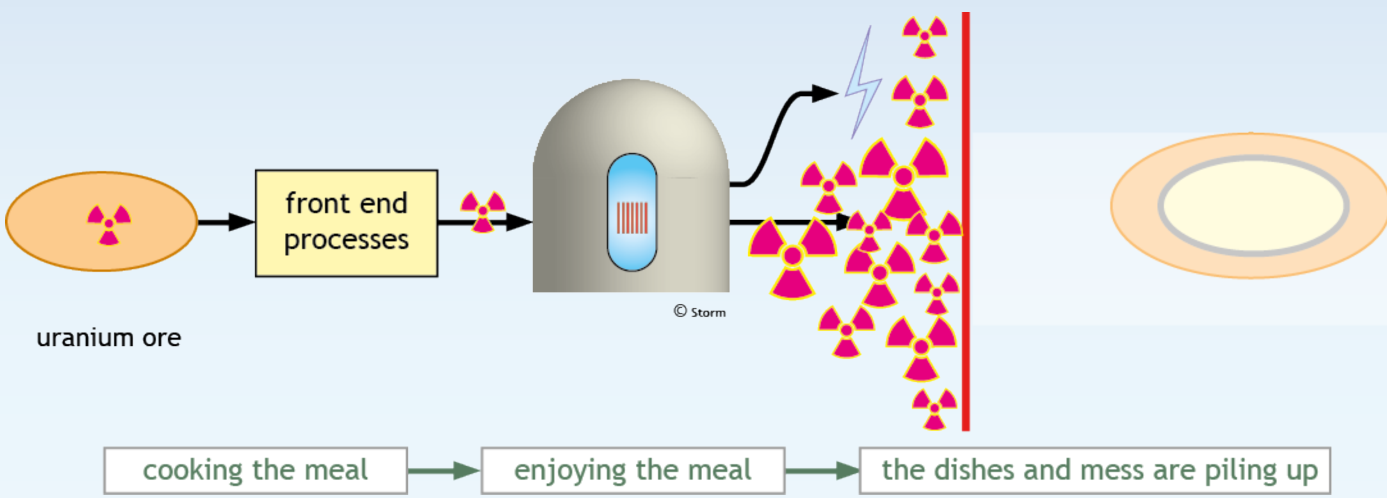
Isolation of radioactivity from the biosphere in a geologic repository

Concept of deep geologic repository



The KBS-3 concept for disposal of spent nuclear fuel.

Nuclear chain: current practice



Paradigm barrier

- short-term profit seeking
- habit of living on credit
- believing in virtual technology
- privatisation of profits, socialisation of costs

- *Après nous le déluge*

Après nous le déluge

This happens spontaneously

Prevention requires
dedicated effort
energy
materials

3

Hazards of nuclear power

- health effects of radioactivity
- dispersion of radioactivity
- nuclear disasters
- rising risks
- role of IAEA and WHO
- downplaying health hazards

Health effects of radioactivity (‘low’ doses)

- cancers (usually lethal)
- non-cancer chronic diseases (lethal and non-lethal)
- premature aging
- stillbirths
- genetic malformations
- inheritable diseases

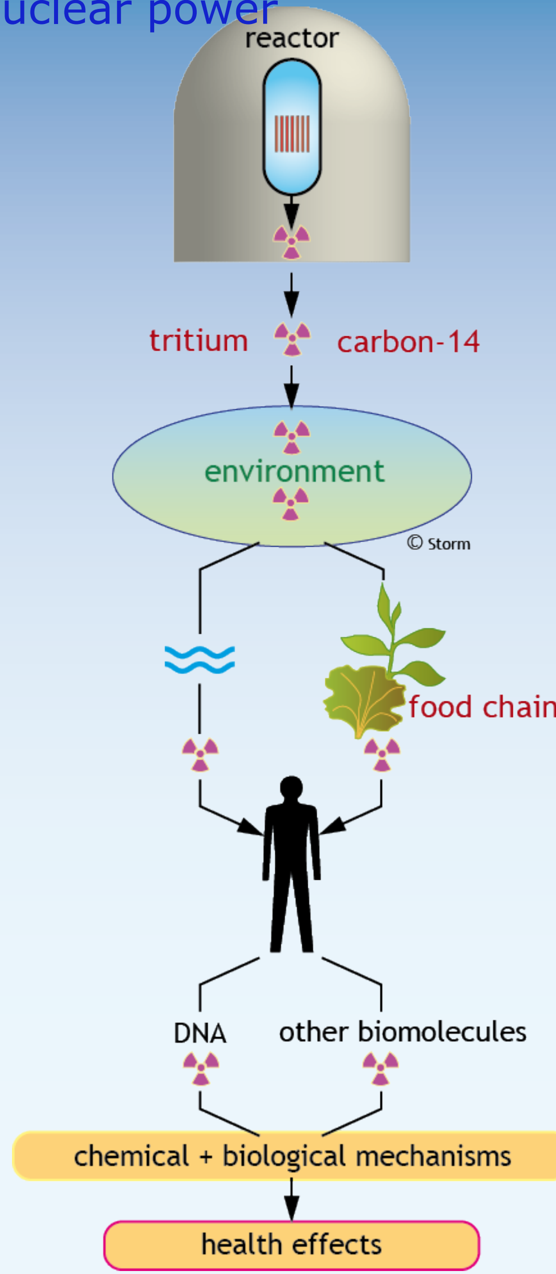
Long latency periods (years to decades)

Pathways of radioactivity

Chronic exposure to tritium and carbon-14 via air, food and water

Chemical and biological mechanisms in human body poorly understood

Health effects epidemiologically proved



Detection of radioactive contamination

Only strong gamma emitters detectable by common radiation counters

Not alpha & beta radiation

=> many dangerous radionuclides not detectable

Among other: Tritium
Carbon-14
Iodine-129

Official dose-effect models

based on:

- hardly understandable models from 1940s and 1950s
- radiation (X-ray + γ) from external sources
- arbitrary assumptions

not included:

- empirical evidence past decades
- biochemical behavior radionuclides inside body
- chronic exposure to number of different radionuclides
- cumulation of radionuclides in specific organs

Standards allowed exposure to radioactivity

Can easily be adapted to economic and political needs

Not based on unambiguous scientific medical evidence

Radioactive discharges

- intentional (authorized) routine discharges
  - flexible standards
- unintentional leaks and accidents,
  - often unnoticed, often concealed
- disasters (Chernobyl, Fukushima)

Risk enhancing factors

- narrow safety margins, large consequences
- extremely long cradle-to-grave periods (>100 years)
- human factor
- ageing of materials and equipment
- secrecy and entanglements of interests
- inadequate measurements and computer models
- economic pressure
- transport nuclear materials
- political instability
- proliferation
- terrorism, armed conflicts

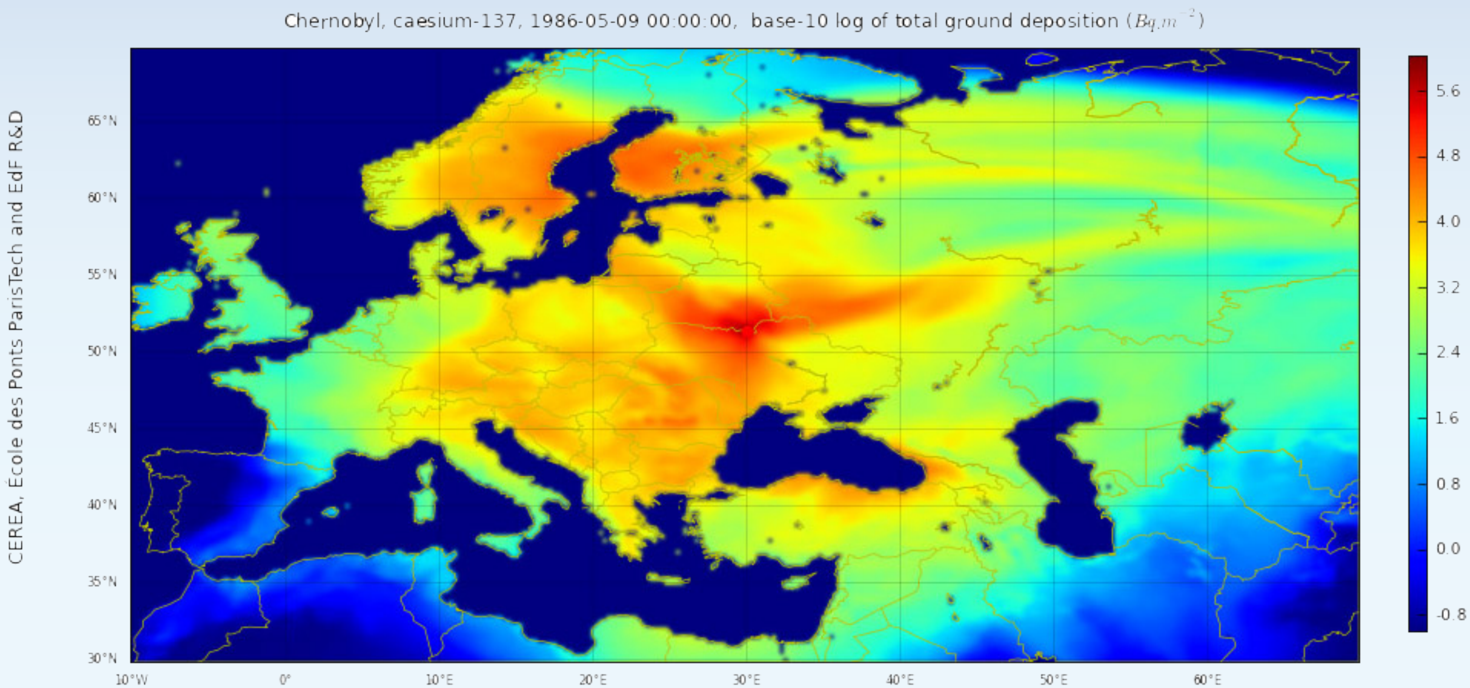
Nuclear disasters

If cooling fails, spent fuel melts, followed by steam- and hydrogen explosions and recriticality

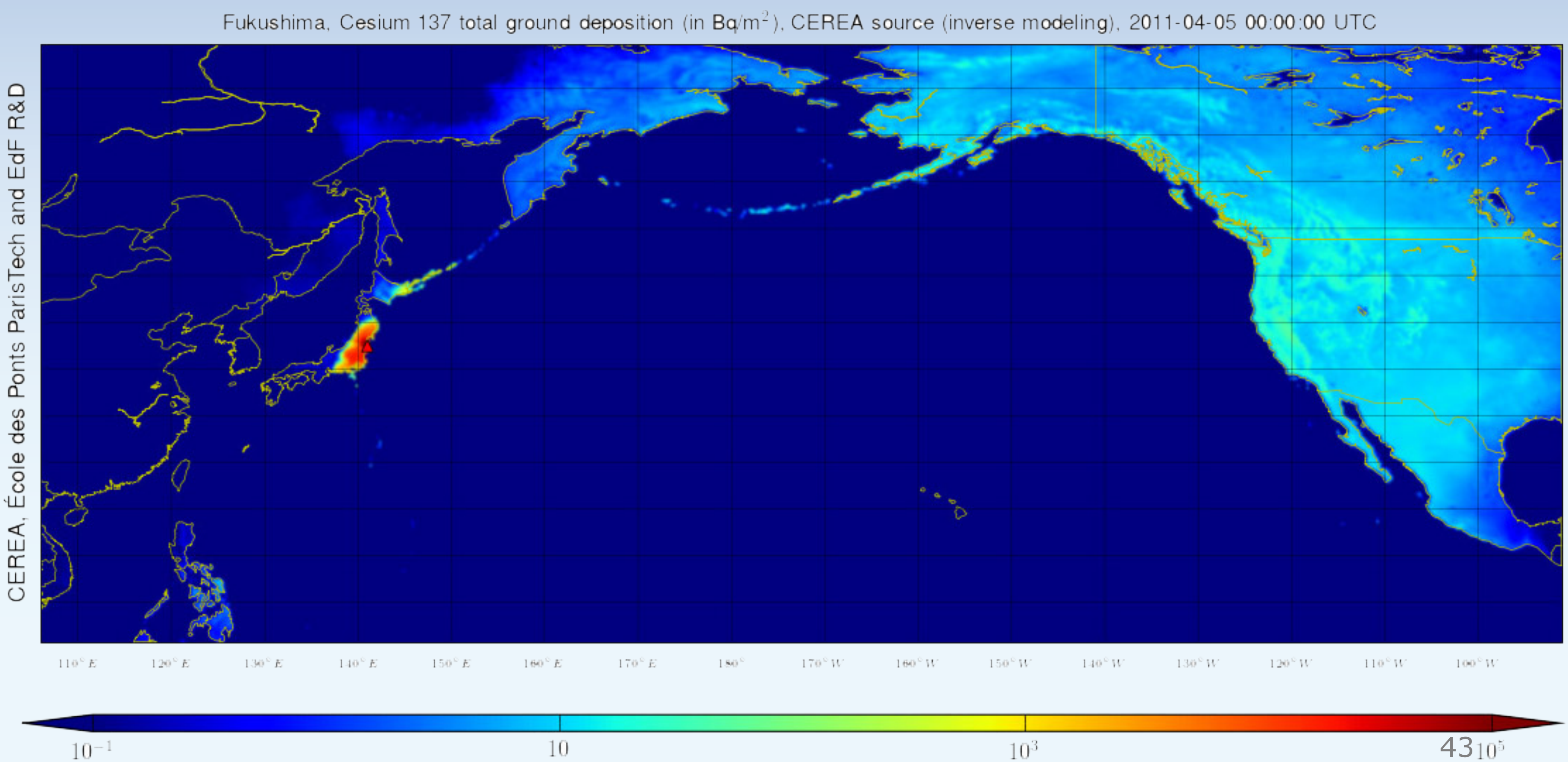
possible in: nuclear reactors
spent fuel pools
reprocessing plants

Explosion cooling pool Fukushima reactor 3 (14 March 2011)

Dispersion of radioactivity (Cs-137) from Chernobyl

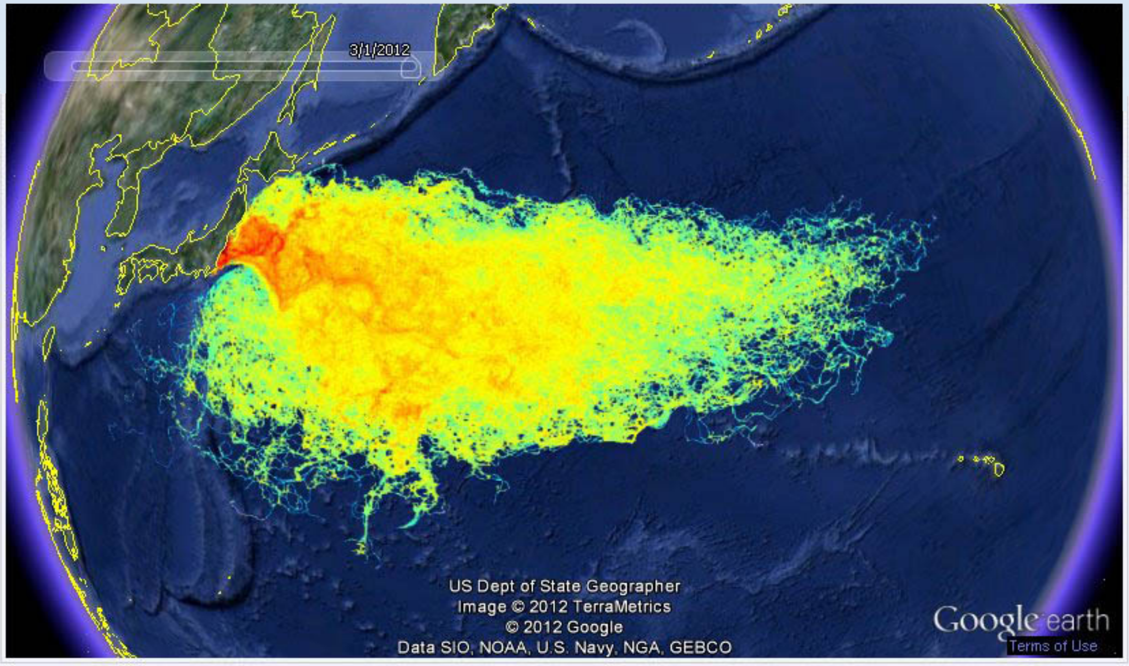


Dispersion of cesium-137 from Fukushima



Dispersion of radioactivity from Fukushima

Radioactive Seawater Impact Map (update: March 2012)



Rising risks nuclear disasters

- increasing amounts human-made radioactivity
- increasing number of temporary storage facilities
- increasing economic pressure
- increasing shortages skilled personnel

Added to:
Increasing irrevocable degradation of materials and structures
(Second Law of thermodynamics)

Economic pressure

Relaxation allowable discharges into enviroment

Decreasing inspections

Choices for ‘economically viable’ solutions

Declining economic means

Postponing adequate but costly activities

Role of the IAEA (International Atomic Energy Agency)

Dominant in communication nuclear world –>
policy makers and public

IAEA is not an independent scientific institute:

- promotion nuclear energy in mission statement
- promotes interests of member states
- reports need approval by member states

WHO-IAEA connection

In its reports on nuclear matters the World Health Organization (WHO) is not allowed to deviate from IAEA viewpoint

Downplay of health effects of radioactivity

IAEA (International Atomic Energy Agency)
and WHO (World Health Organization) *do not* recognise health effects attributable to exposure to ‘low’ doses

Biggest danger: radiophobia

IAEA view: models more trustworthy than empirical evidence

IAEA/WHO assessment Chernobyl disaster

"Unscientific and untrustworthy" (IPPNW)

4

Summary

1

Dim outlook nuclear power

- coal equivalence
- energy cliff
- CO_2 trap
- energy debt

2

Nuclear energy is energy on credit,
the bill comes later

Nuclear energy does not comply with *any*
sustainability criterion

3

Health hazards and societal risks of nuclear power are greatly underrated

Hazards increasing with time

Risks of large nuclear disasters are increasing

4

Nuclear world (first IAEA) severely downplays
health hazards of radioactivity

WHO dependent on IAEA on nuclear matters