CEEDATA energy analysis

Nuclear power

CO_2 emissions and energy balance

Firenze, 30 May 2010

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Nuclear power:
technically the most complex energy system ever

- opaque to decision makers
- culture of secrecy
- costs and safety practically uncontrollable
- politicians advised by interest groups, e.g.
  IAEA, NEA, WNA, NEI, Areva, EdF

This study

Life cycle assessment (LCA) + energy analysis

- physical
- global perspective
- long time horizon

Objectives:

- transparency
- independent scientific arguments

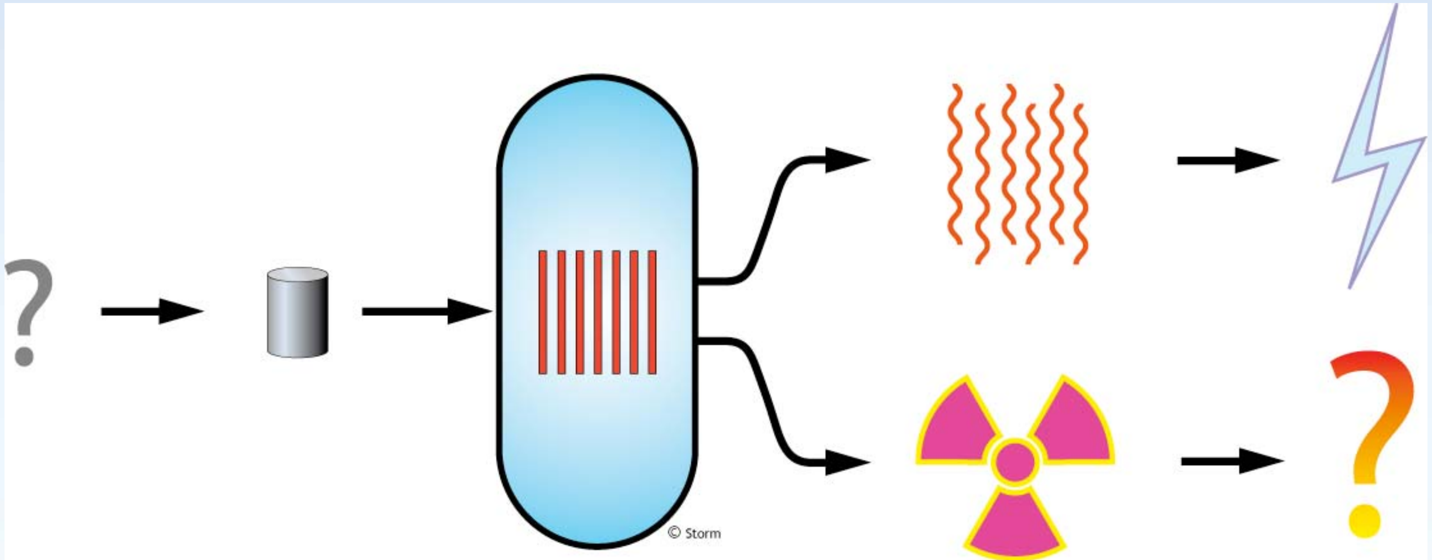
Outline

- nuclear chain
- nuclear CO_2 emissions
- head of the chain
  - energy cliff
  - coal equivalence
  - CO_2 trap
- tail of the chain
  - energy on credit
  - après nous le déluge
- conclusions

Nuclear power - CO_2 emissions and energy balance

What lies behind and ahead of this glossy image?

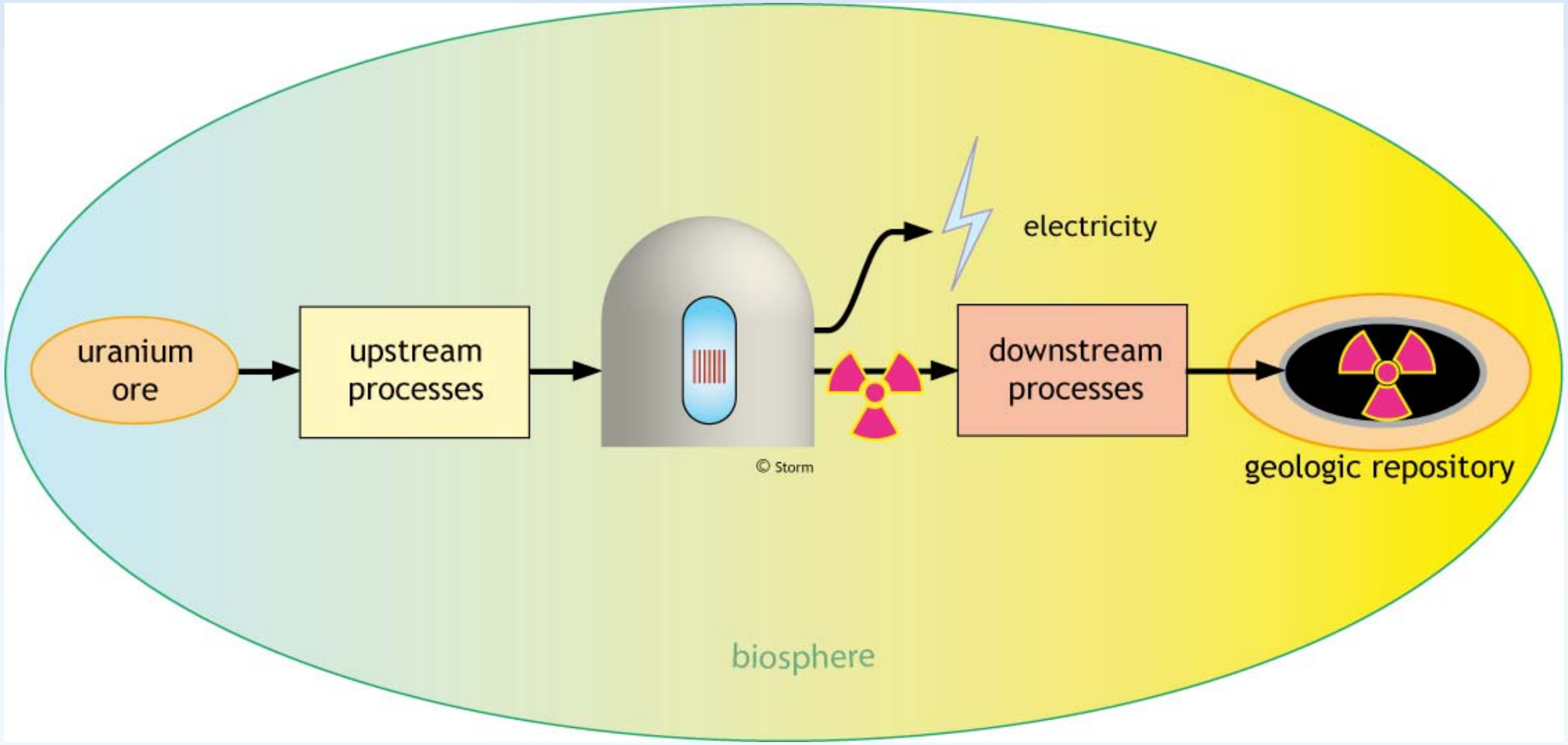
A nuclear reactor generates
heat and **radioactivity**
inextricable and irreversible



Where does the nuclear fuel come from?

What happens to the human-made radioactivity?

The nuclear chain:
nuclear power from cradle to grave



Life cycle assessment LCA-1

Upstream processes (head of the nuclear chain)

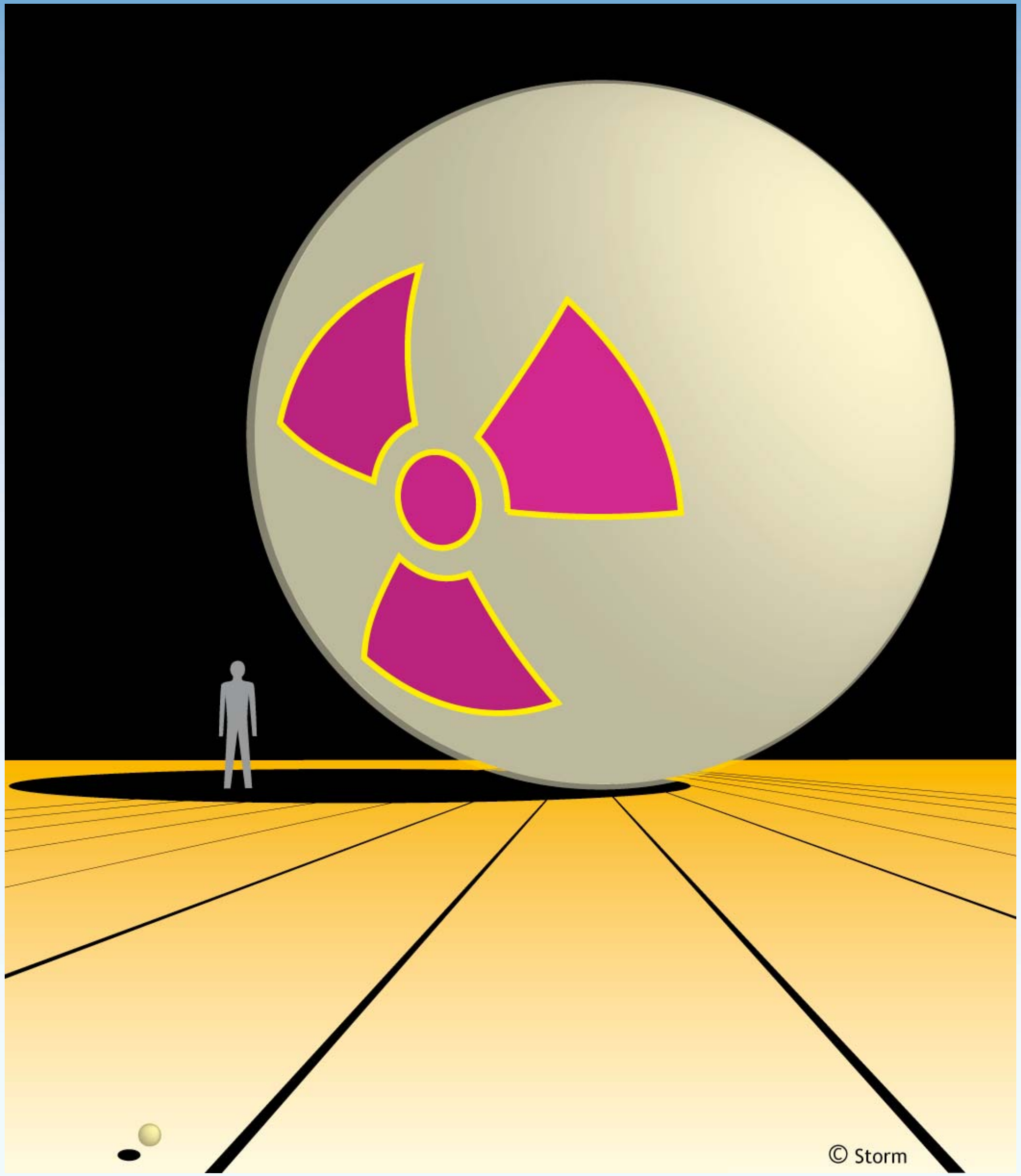
- uranium mining
- conversion
- enrichment
- fuel fabrication

+

- construction nuclear power plant
- operation + maintenance + refurbishments NPP

Human-made
radioactivity
by fission:

1 billion
x
natural



Life cycle assessment LCA-2

Downstream processes (tail of the chain)

- spent fuel interim storage
- spent fuel packaging
- other rad waste handling and packaging
- construction geologic repository
- definitive storage all rad wastes in geologic repository
- restoration uranium mine site to habitable condition

+

- cleanup + dismantling NPP
- definitive storage of dismantling debris in geologic repository

All processes of the nuclear chain, except the nuclear reactor itself, are conventional industrial processes, emitting CO_2.

Ergo: nuclear power produces CO_2.

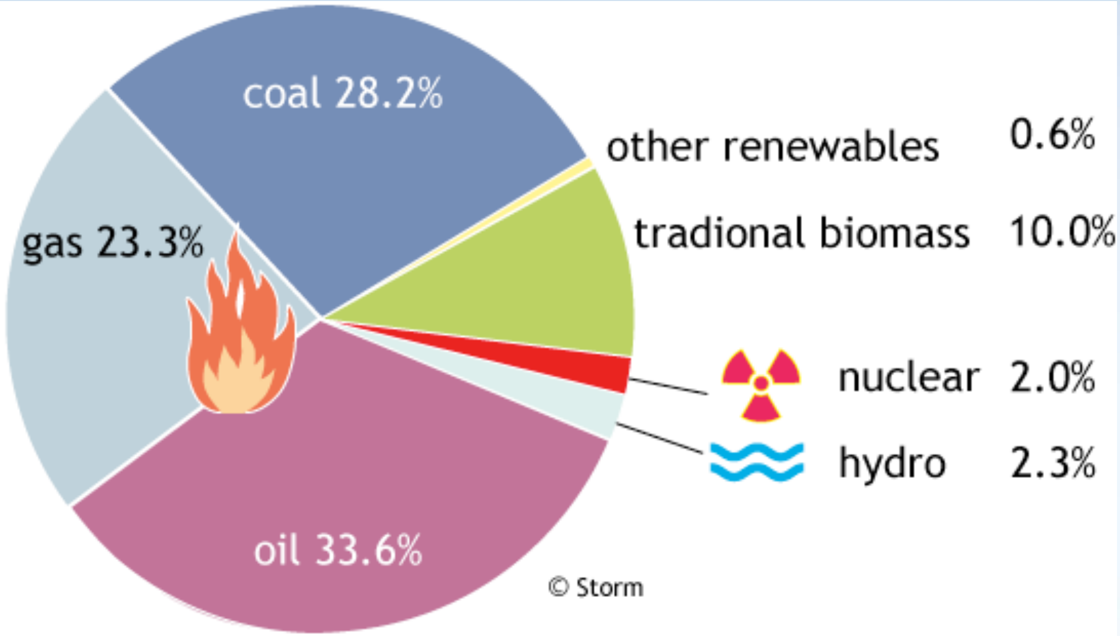
Nuclear power and greenhouse gases (GHGs)

- current lifetime emission 85-130 gCO_2/kWh
- increases over time
- emission other GHGs not known, but very likely
- ‘no data’ does not equal ‘no emission’

Enrichment in USA: ~5 gCO_2eq/kWh freon-114

Note difference gCO_2/kWh and gCO_2eq/kWh !

Nuclear contribution to the world energy in 2008



world energy consumption in 2008: ~491 EJ

traded energy: 439 EJ

Energy quality of uranium resources: the ignored factor

E quality =

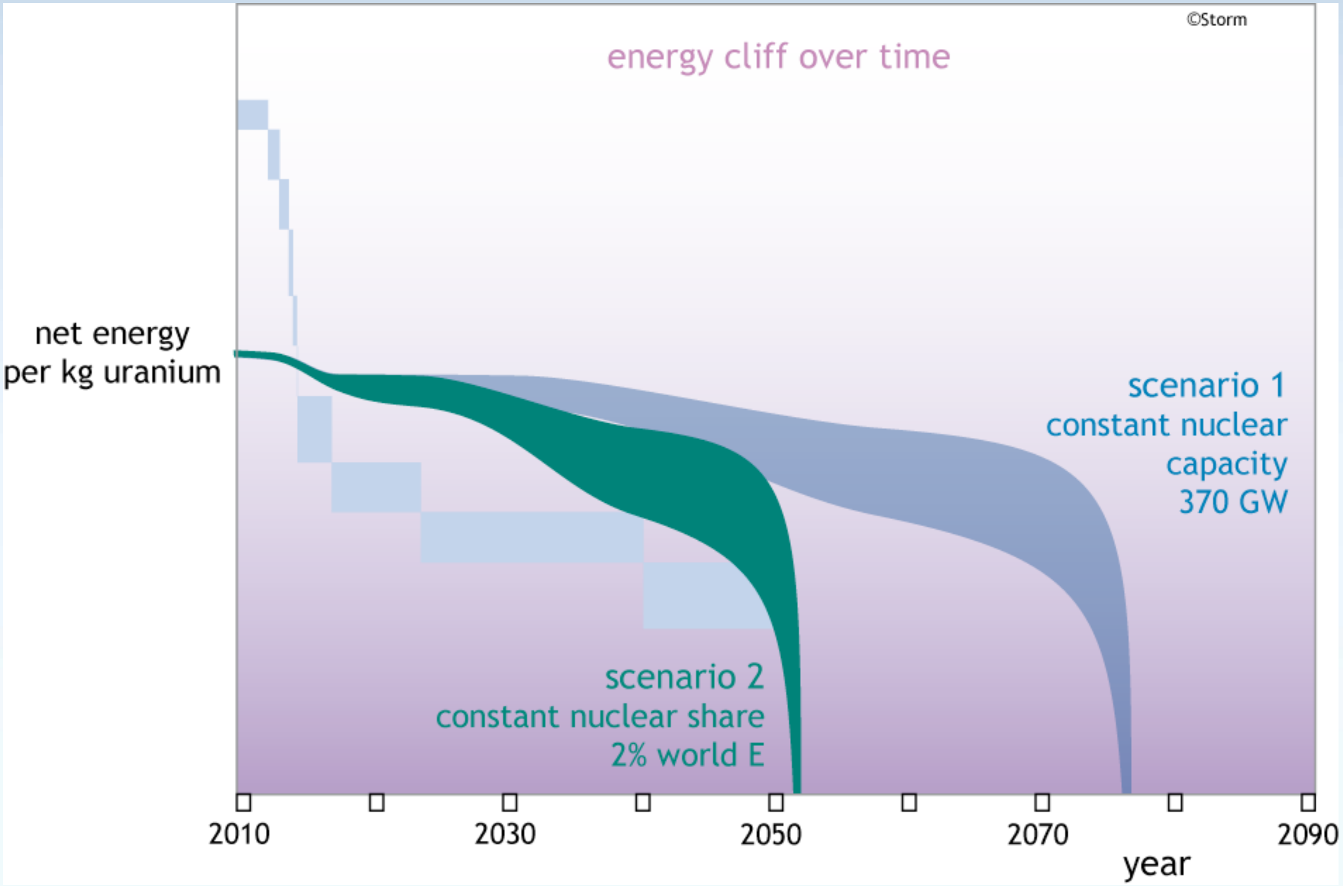
E output 1 kg U in reactor

minus

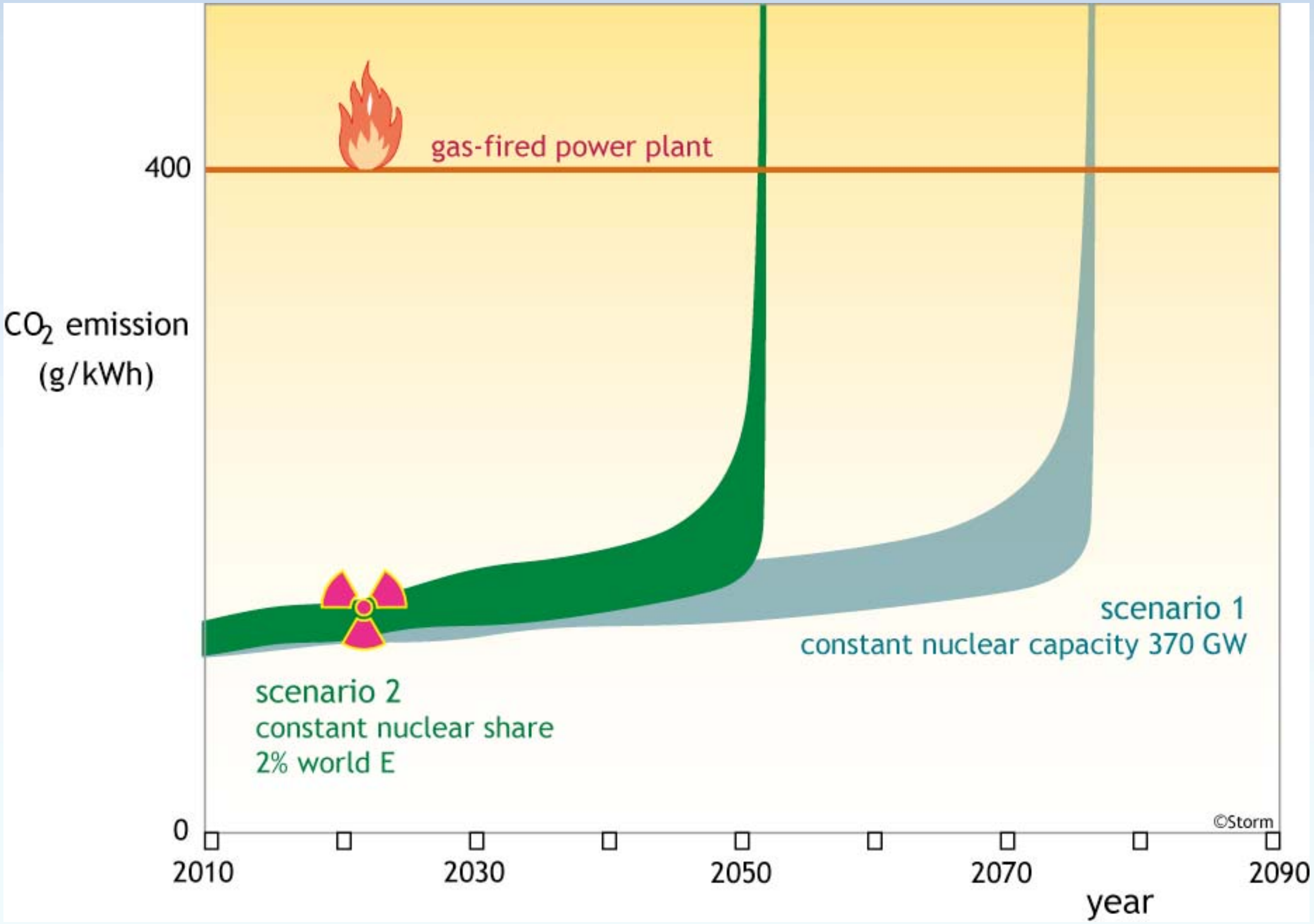
E input chain + extraction 1 kg U from ore

The *average E quality* of world uranium resources goes down over time

Energy cliff over time



The CO_2 trap:
nuclear CO_2 emission over time



Uranium resources: **economic** view

- criterion: price of U
- higher U price >
  - more exploration >
    - more discoveries >
      - larger U resources
- ergo: U resources practically inexhaustible

Uranium resources: **energy** view

- criterion: net energy
- not U price, but E quality decisive
- beyond energy cliff:
  nuclear power = energy sink
- ergo:
  net energy content world U resources limited

Coal equivalence

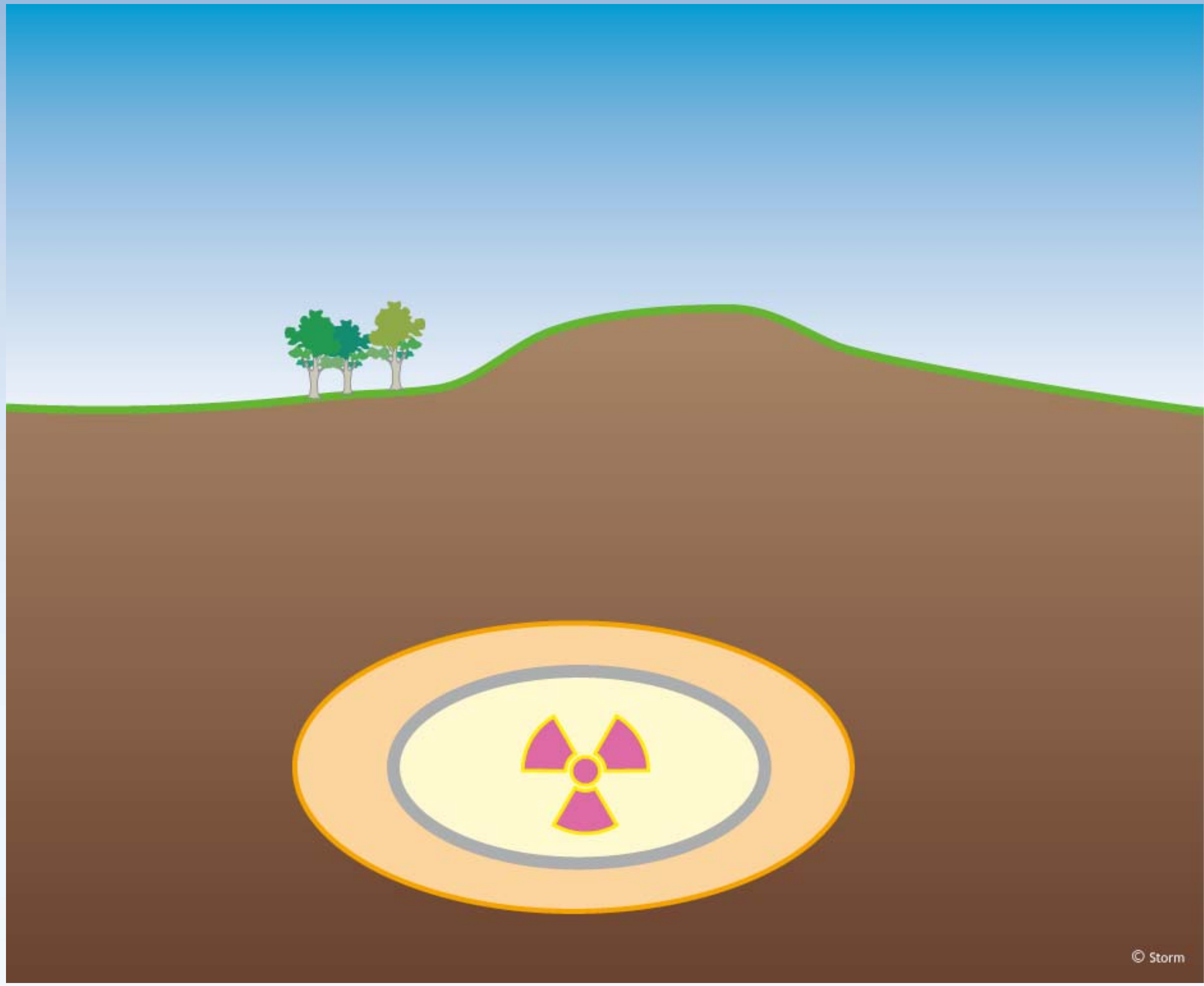
E content uranium ore = E content coal

At ore grade G = 0.1-0.2 kg U/tonne ore

Nuclear power - CO_2 emissions and energy balance

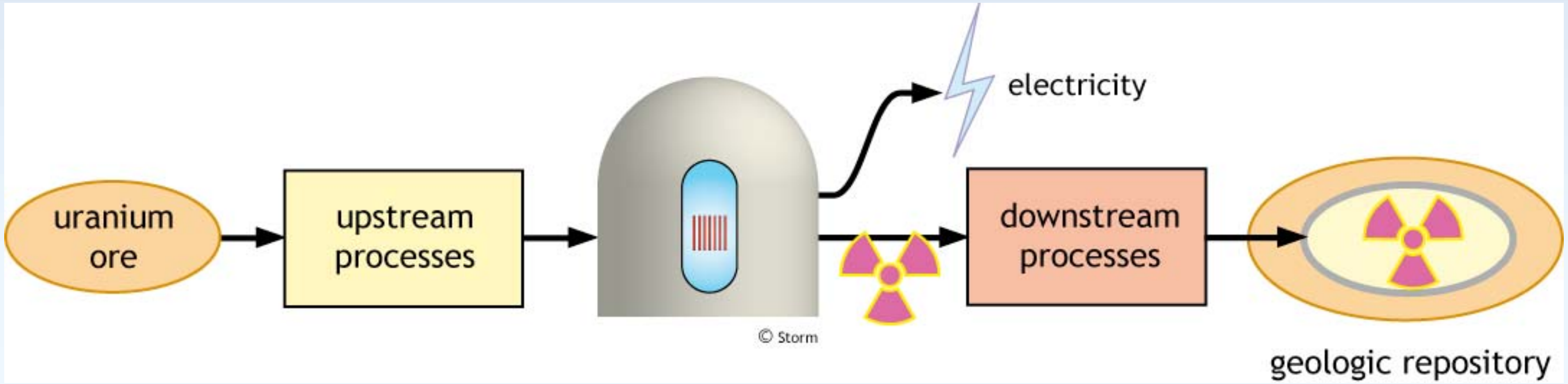
One reactor (1GWe) generates each year
1000 nuclear fission bomb equivalents (15 kt)
of radioactivity

Each year 370000 Hiroshima bomb equivalents
added to world radioactive inventory



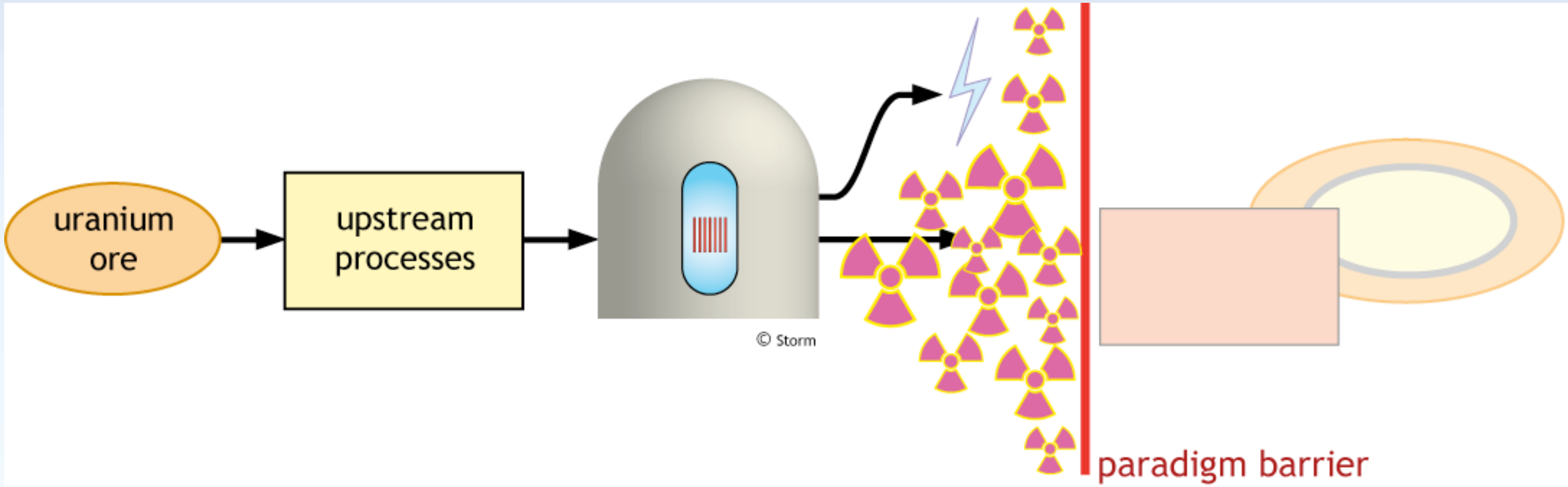
The least dangerous option: all human-made radioactivity in a geologically stable repository

The nuclear chain as it ought to be



cooking the meal consuming the meal washing the dishes

The nuclear chain as it happens to be



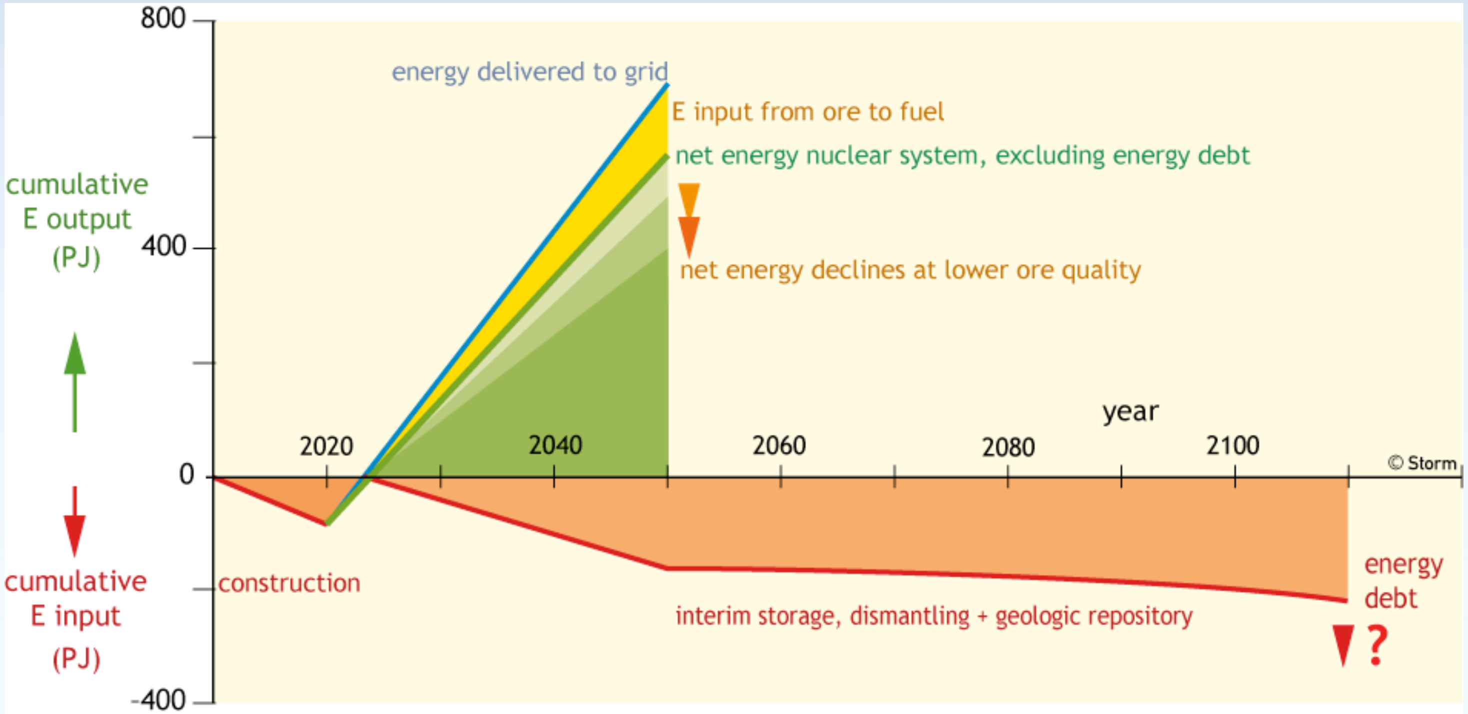
the dishes are piling up

Paradigm barrier

- short-term profit seeking
- habit of living on credit
- *après nous le déluge* attitude
- belief in unproved technical concepts

Après nous le déluge

Energy debt


800
400
0
-400
cumulative
E output
(PJ)
cumulative
E input
(PJ)
energy delivered to grid
E input from ore to fuel
net energy nuclear system, excluding energy debt
net energy declines at lower ore quality
year
2020
2040
2060
2080
2100
© Storm
construction
interim storage, dismantling + geologic repository
energy
debt
?

Energy payback time

	years	depends on
• nuclear	10 - 27	ore grade
• wind	< 0.5	
• photovoltaics	1-3	location

nuclear power = energy on credit

Economic concepts invalid

- energy = conserved quantity
- size unprecedented
- timescale (>100 years) unprecedented
- investments pure losses
- debt grows over time

Monetary debt, NDA first cost estimates:

- cleanup and decommissioning
  - Sellafield reprocessing plant €**60-120bn**
  - 1 nuclear power station €**5-10bn**/GWe

- geologic repository €**xbn**

Man on the moon (Apollo project)
final cost (€2008) < €100bn

Conclusion 1

Nuclear power does not comply with any sustainability criterion

- energy cliff
- CO_2 trap
- energy debt
- high & rising consumption of scarce materials (non-recyclable)

Conclusion 2

We do not need nuclear power:

there are by far better solutions

- cheaper
- faster
- safer
- constant flow (inexhaustible)
- constant quality
- capacity meets world demand
- without further deterioration of the biosphere
- geopolitical stability

Conclusion 3

We don't need new technology
We just need a new paradigm

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