GEN IV deployment: Long term perspective

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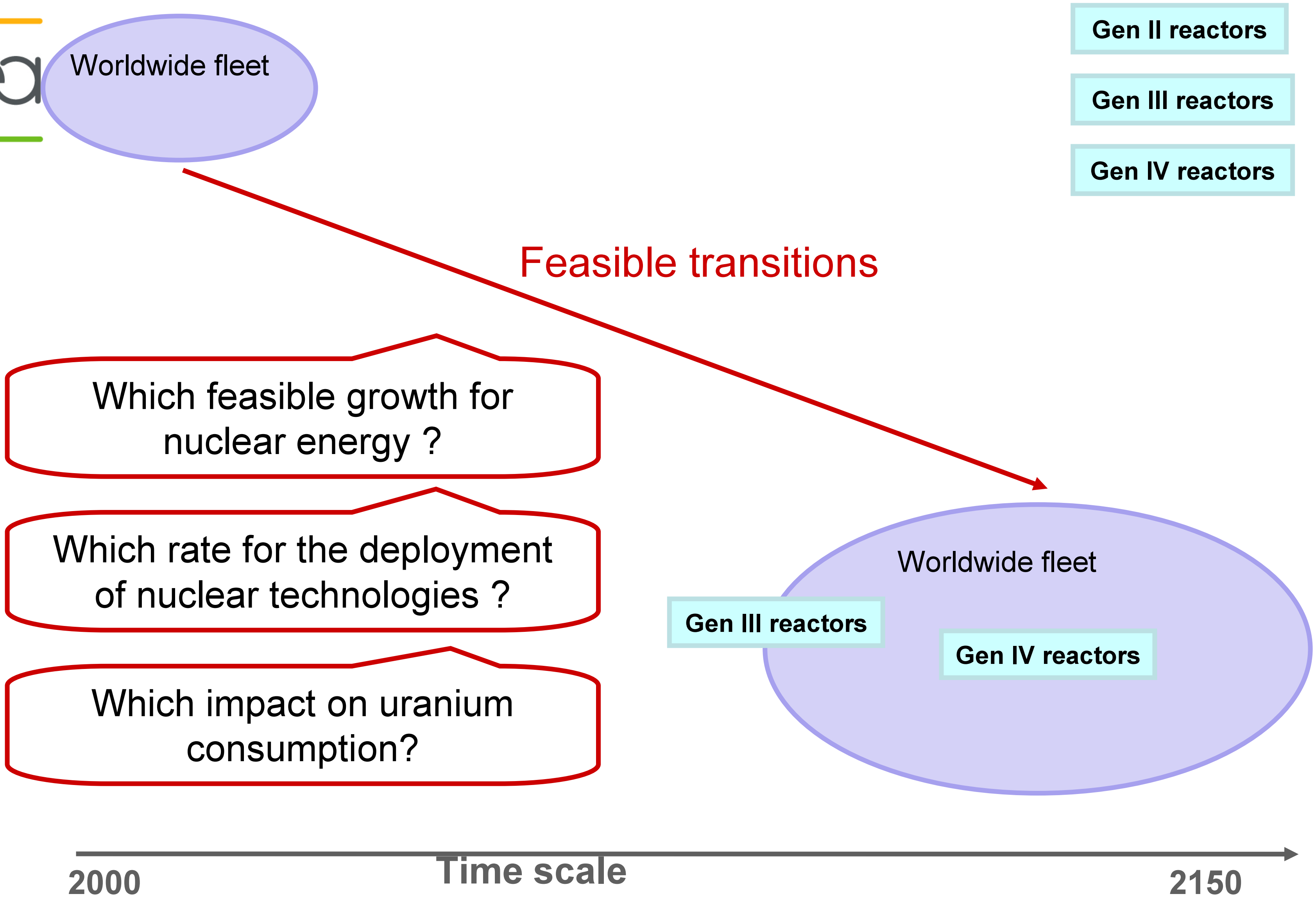
Transition scenarios studies



Plan

1. The GRUS model

2. Prospective scenarios and hypotheses

3. LWRs for all the period:
Uranium consumption and cost

4. Deployment of FRs:
Plutonium availability, Uranium consumption and sensitivity studies

5. Conclusion

GRUS

Gestion des Ressources en Uranium avec Stella

Uranium resource management using
STELLA software

How is the simulation performed?

We define:

- The initial conditions of stocks (material stocks, number of each kind of reactors, capacities of factories).
- The key parameters of the model (process costs, of the resources, the investment and operating costs of a reactor, technical characteristics of reactors).
- The electricity demand versus time

Every year we calculate the need in new capacity

The simulation will determine the nuclear fleet which will meet the demand in electricity according to the availability of the resources and diverse costs.

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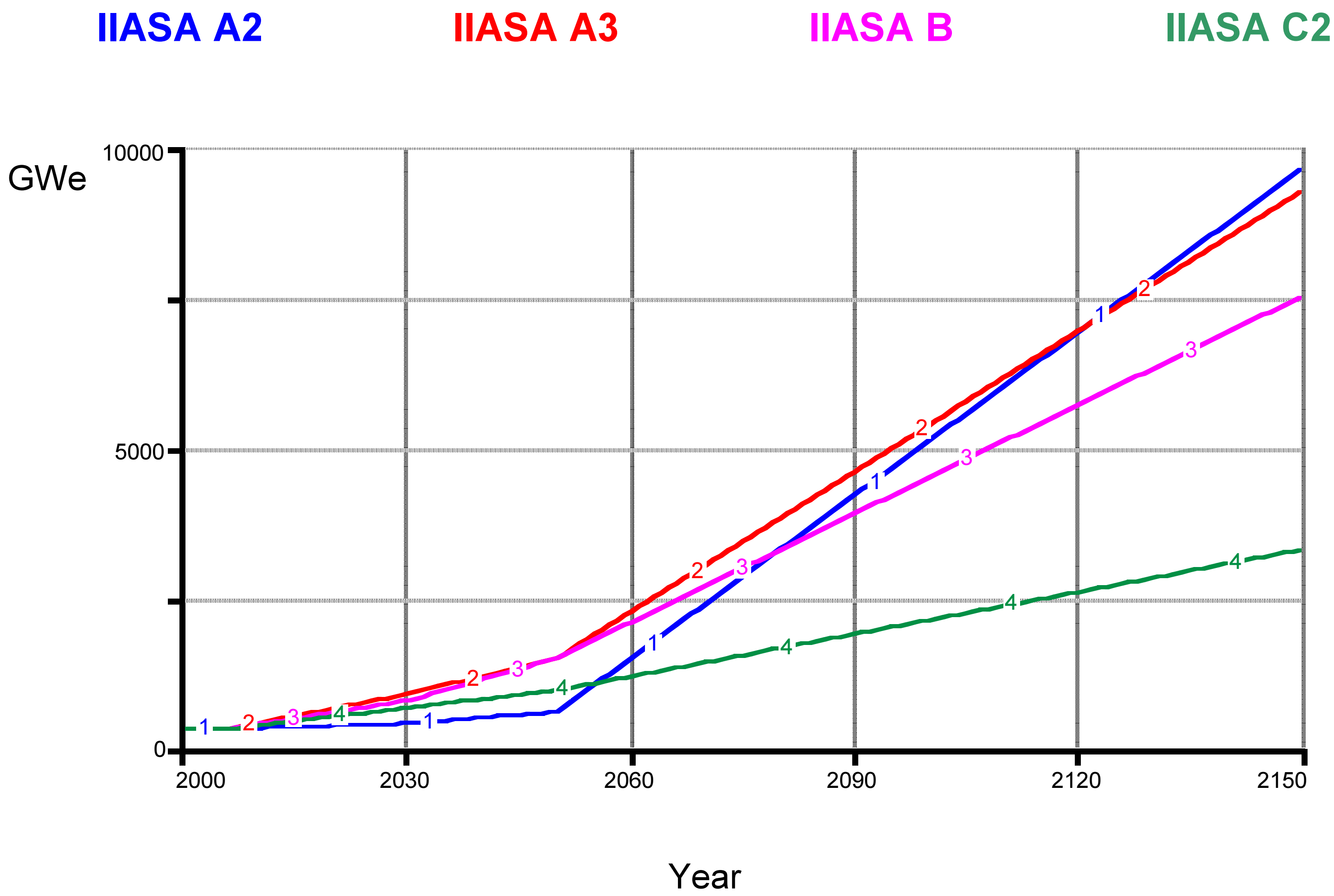
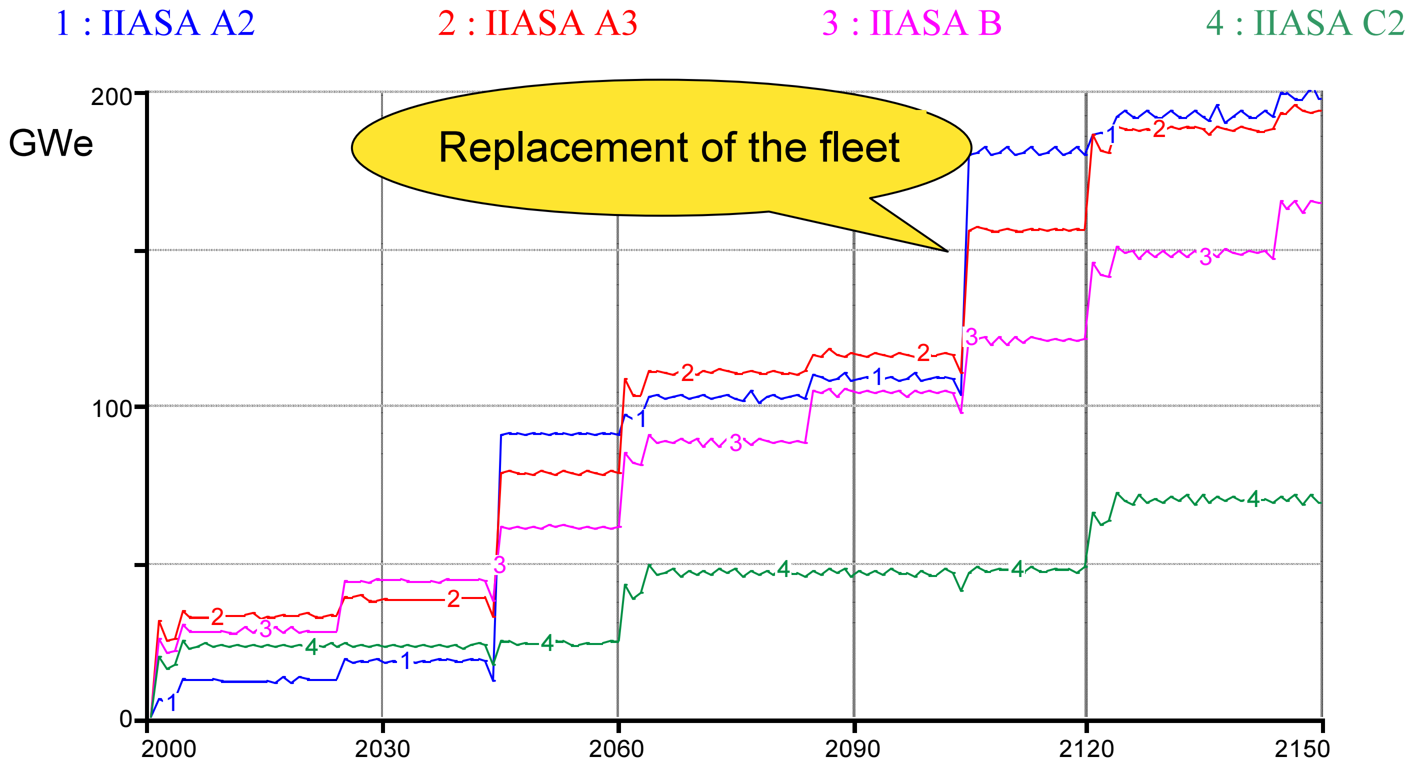
Assumptions: Energy need and nuclear capacity



Nuclear power to be installed

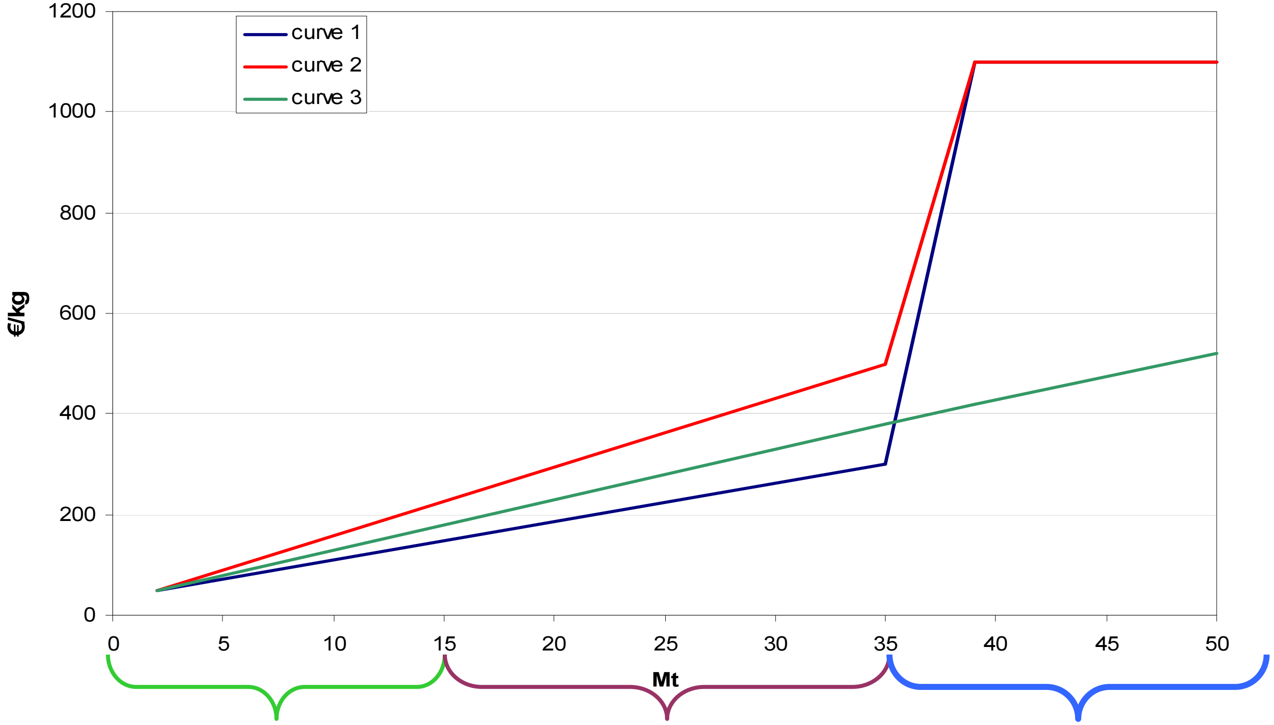


Net power to be installed every year

Uranium resources and costs

OECD/NEA-IAEA Data. Uranium 2007: Resources, production and demand

- Conventional uranium resources ⇨ 16 Mt
- Unconventional resources (phosphate…) ⇨ 22 Mt
- “Deposits” of low grade (sea water…) ⇨ 4000 Mt



Conventional resources **Phosphates** **« Deposit » of low grade (sea water…)**

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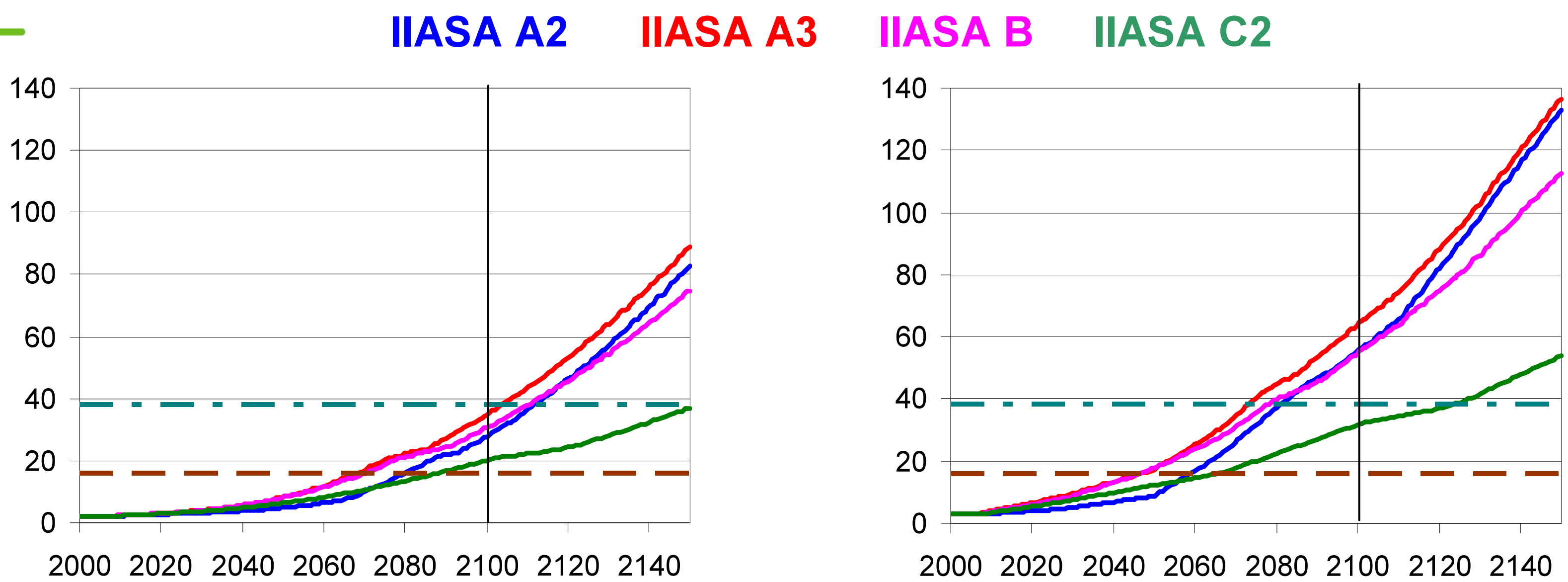
LWRs only, once-through

Consumed Uranium | *Consumed and engaged Uranium*



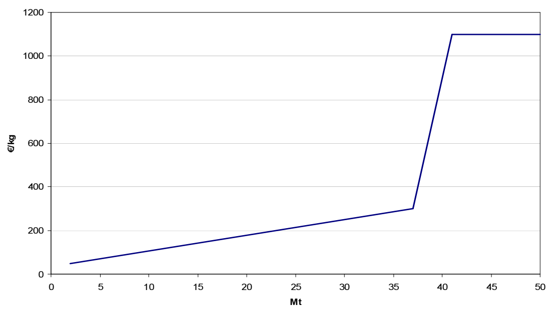
16 Mt Conventional resources

38 Mt (+ 22 Mt unconventional resources)

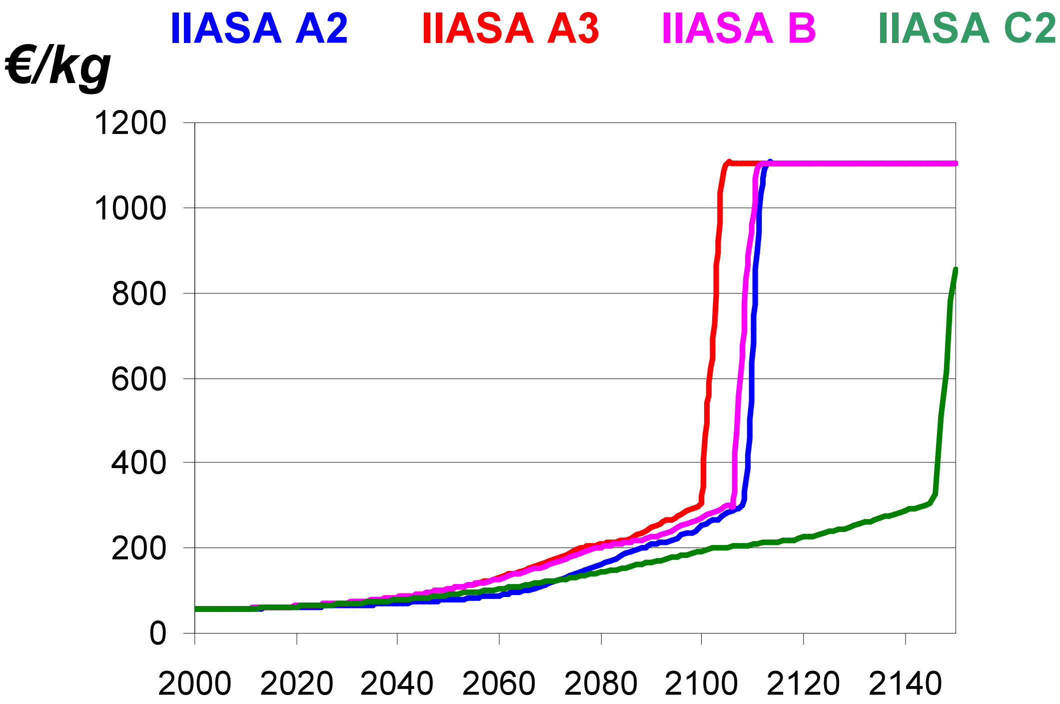
Engaged Uranium: future uranium consumption for the already installed reactors for their remaining life time

➢ **The deployment of fast reactors appears essential for nuclear sustainability.**

LWRs only: Uranium cost versus time



Hypothesis of uranium cost as a function of the already consumed uranium



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Hypotheses for introduction of fast reactors

Up to 2040, only LWR (EPR) are deployed.

Then, FR (SFR) are installed:

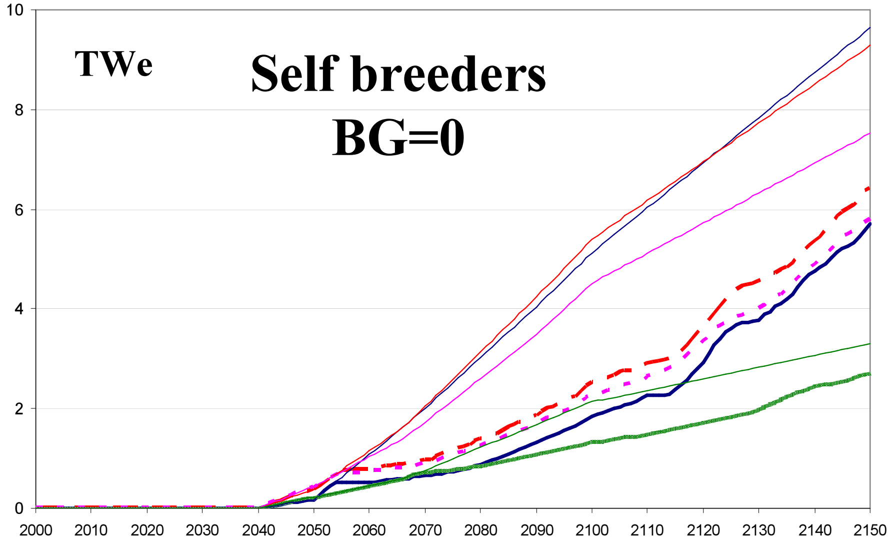
- Either as a small fraction (20%) of new installed capacity
- Or as much as possible depending on Pu availability

If Pu is not available LWR will be installed instead.

The reprocessing capacities will be adapted to need.

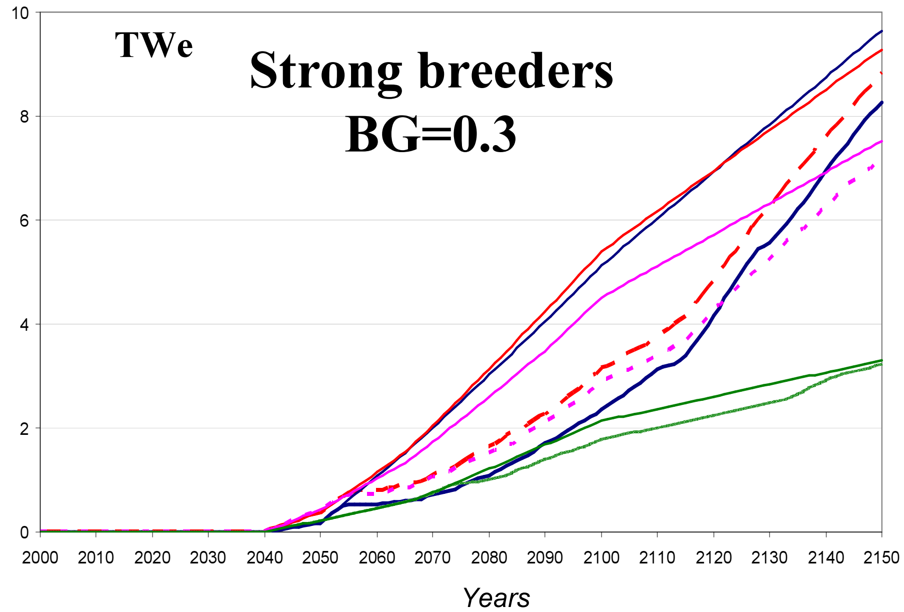
We suppose quite an optimistic cooling time.

FR installed capacity taking into account Pu availability



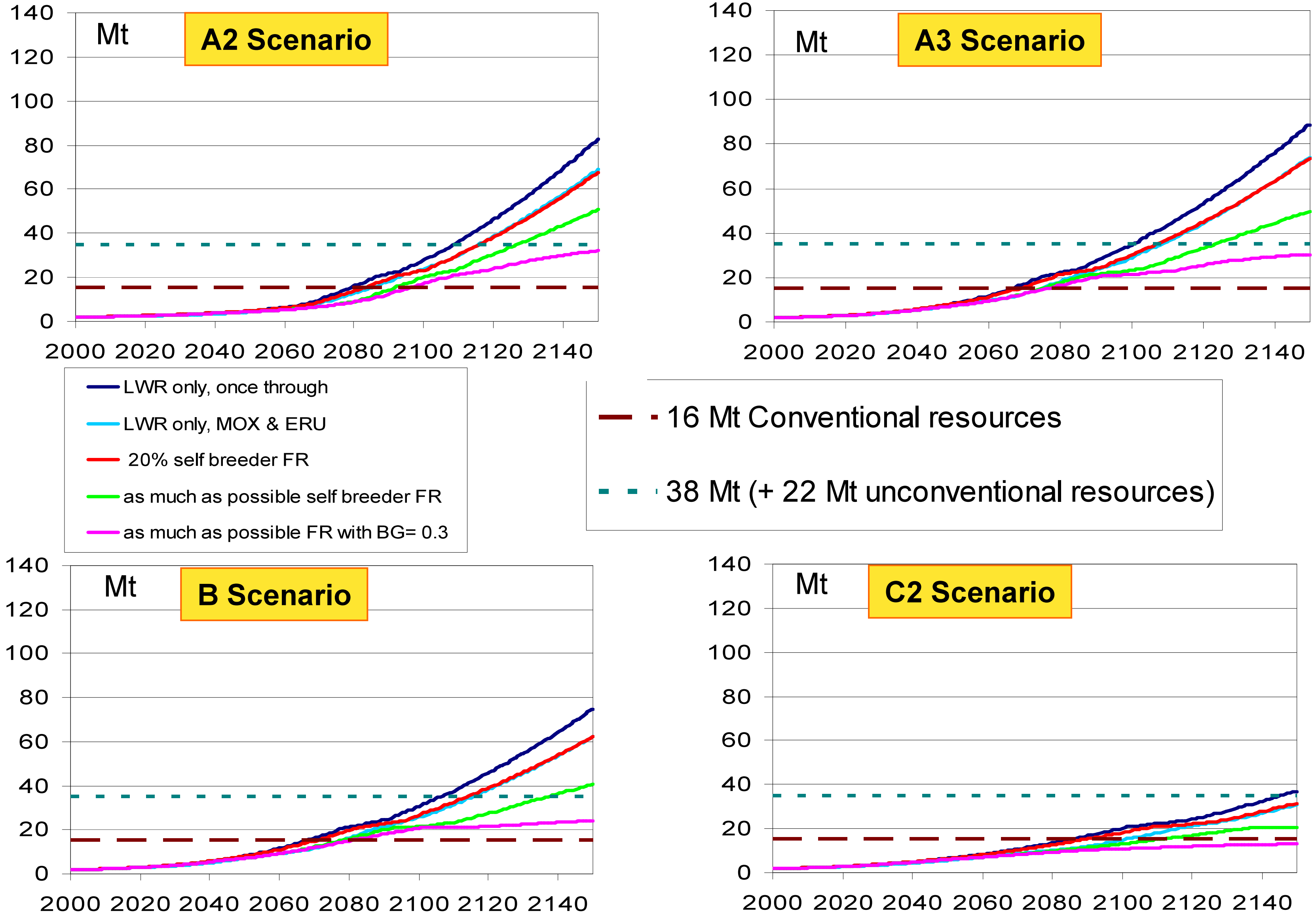
Throughout the period, the installation rate of FR fleet is driven by Pu availability rather than by energy demand.

- A2 real case
- A3 real case
- B real case
- C2 real case
- A2 ideal case
- A3 ideal case
- B ideal case
- C2 ideal case



The impact of the breeding will be significant after a first FR fleet generation, thus from the next century.

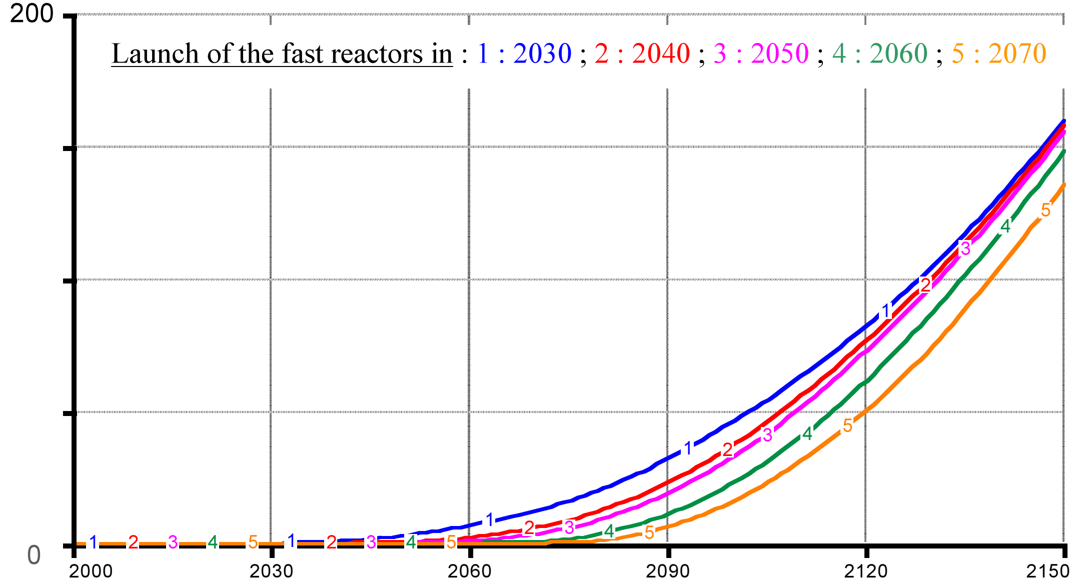
Cumulative natural uranium demand in Mt



Sensitivity to the launch date of FR

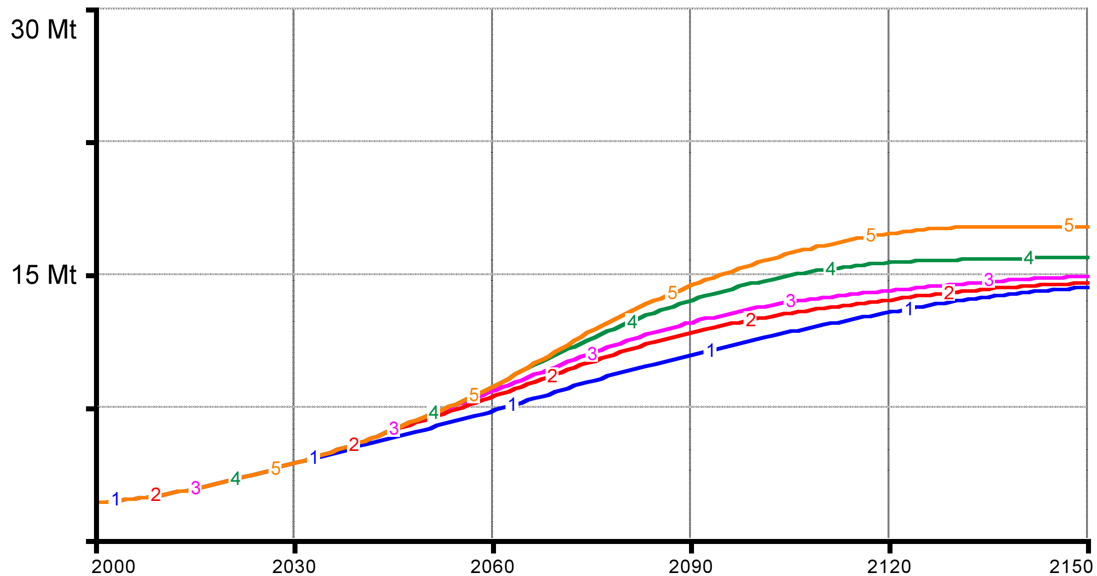
C2 Scenario BG=0.2

Cumulative FR installed capacity (in TWe)



A significant impact is seen when the launch date is later than 2050

Cumulative uranium consumption (in Mt)



Sensitivity to the burn up in LWR

3 burn up cases: 33, 45 and 60 GWd/t

- The **33 GWd/t** case gives **the highest penetration rate for fast reactors** .

(+11% on cumulative energy produced by FRs in 2150 compared to the 60 GWd/t case, under the C2 scenario).

- The **45 GWd/t** is the one which leads to **the lowest uranium consumption.**

(-8% to -9% on cumulative uranium consumption in 2150 compared to the 60 GWd/t case, still under the C2 scenario).

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Conclusion 1

If only LWRs deployed in this century:

- the uranium conventional resources consumed before the end of the century.
- the unconventional uranium already engaged by then.

=>The deployment of sole LWRs does not seem sustainable in the long term.

=> The FR deployment will be inescapable for a long term development of nuclear technology.

But the installation rate of the FR fleet is limited by the Pu availability.

=> Thereby third generation reactors will be operating until the end of the century even if FRs are introduced in the fleet.

Conclusion 2

- Importance of the nuclear energy boost.
- Some flexibility on the launch date of FR.
- Impact of the breeding gain on uranium consumption only after a first FR generation, impact on the engaged uranium.
- Optimization of the burn up in LWRs for a long term development of nuclear energy.