Industrial Research for Transmutation Scenarios

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FRAMEWORK OF EDF TRANSMUTATION STUDIES

French Act of June 28 2006 on a sustainable management of nuclear materials and radioactive waste :

- A retrievable geological repository, operated as from 2025

  ➔ reference solution, ANDRA repository design in a clay formation, very efficient confinement for actinides

- Pursuit of research on P&T, for evaluating the potential benefits and drawbacks of Minor Actinides recycling in GEN IV fast reactors

  ➔ This research is integrated to the R&D work performed for the assessment of industrial prospects of GEN IV systems, presented to the French Parliament in 2012, with the aim to built a fast reactor prototype in 2020

THE METHOD USED FOR ASSESSING MA TRANSMUTATION OPTIONS

❑ **Scenario studies are performed**, considering SFR deployment during the last phase of the current PWR fleet renewal, and **comparing various MA management options**.

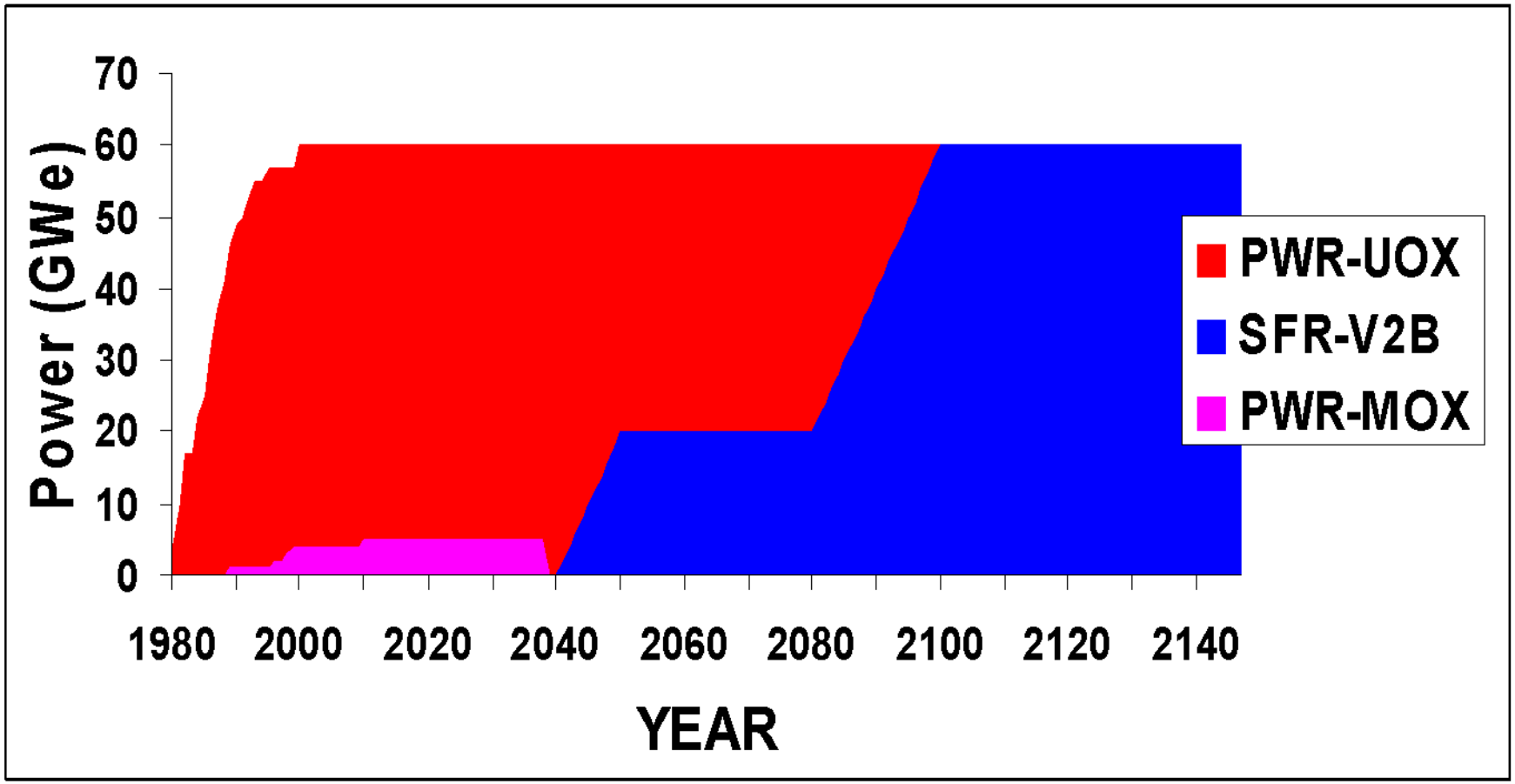
❑ **Transmutation benefit/drawback balance is assessed through a list of criteria :** inventories and characteristics of materials and waste, impact on fuel cycle facilities, transportation needs, impact on power plant, economical performance, etc…

❑ **Transmutation benefits are actually linked to the geological repository :**

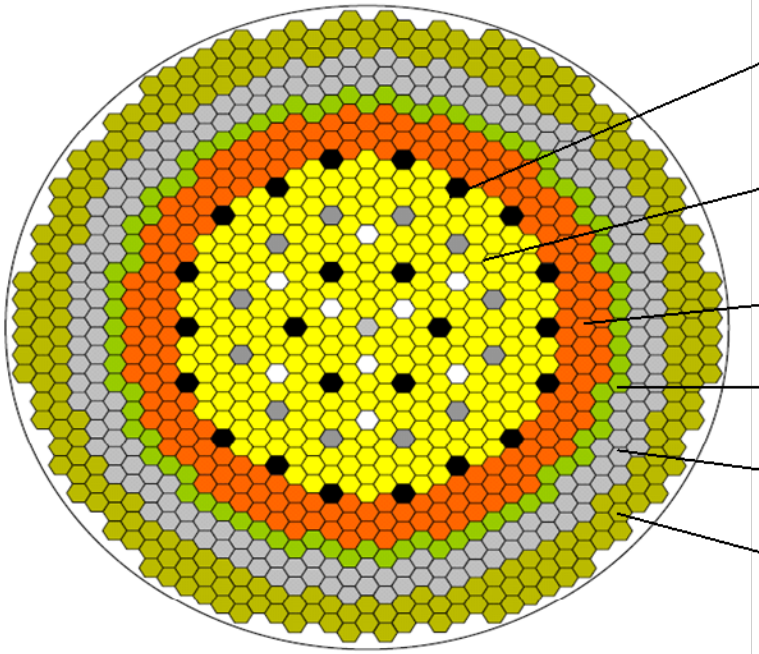
➢ **Repository Safety demonstration** : MA transmutation lowers the HLW radio-toxicity, but MA do not migrate and do not contribute to the residual dose at the outlet, in any normal or accidental scenarios of the repository evolution (2005 ANDRA report) ➔ **for EDF, HLW radio-toxicity is not a pertinent indicator**, MA transmutation does not ease the geological repository safety demonstration.

➢ **Repository optimization** : MA transmutation reduces the HLW packages residual power, thus the repository area. This reduction is mainly due to the Am transmutation. **Thus there is no incentive to transmute Np, neither Cm, which handling in the cycle would be very difficult and hazardous.**

REFERENCE SCENARIO



CEA SFR-V2B CORE DESIGN



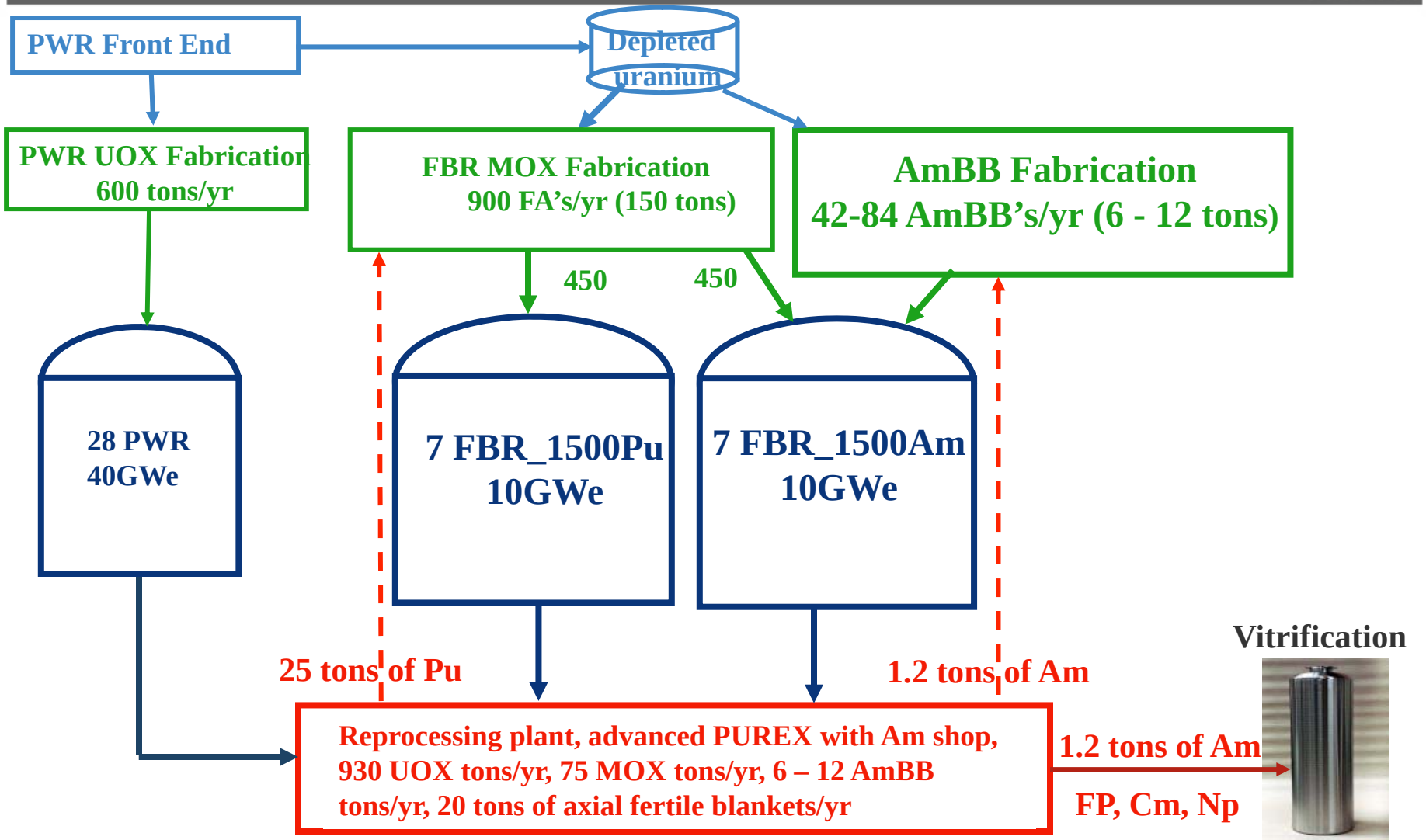
Power = 1.45 GWe, Inner Breeding Gain : 0.03, Heavy Metal Mass : 74 tons, Pu content : 16.5%, cycle length = 2050 FEPD, 5 batches, burn-up = 100 GWd/t

<u>Am heterogeneous transmutation</u> : 84 Am Bearing Blankets in the first row outside the fissile core, with 20% Am on a depleted UO2 support. Irradiation time :14 years ➔ ~10 times less Am bearing assemblies than in case of Am homogeneous transmutation

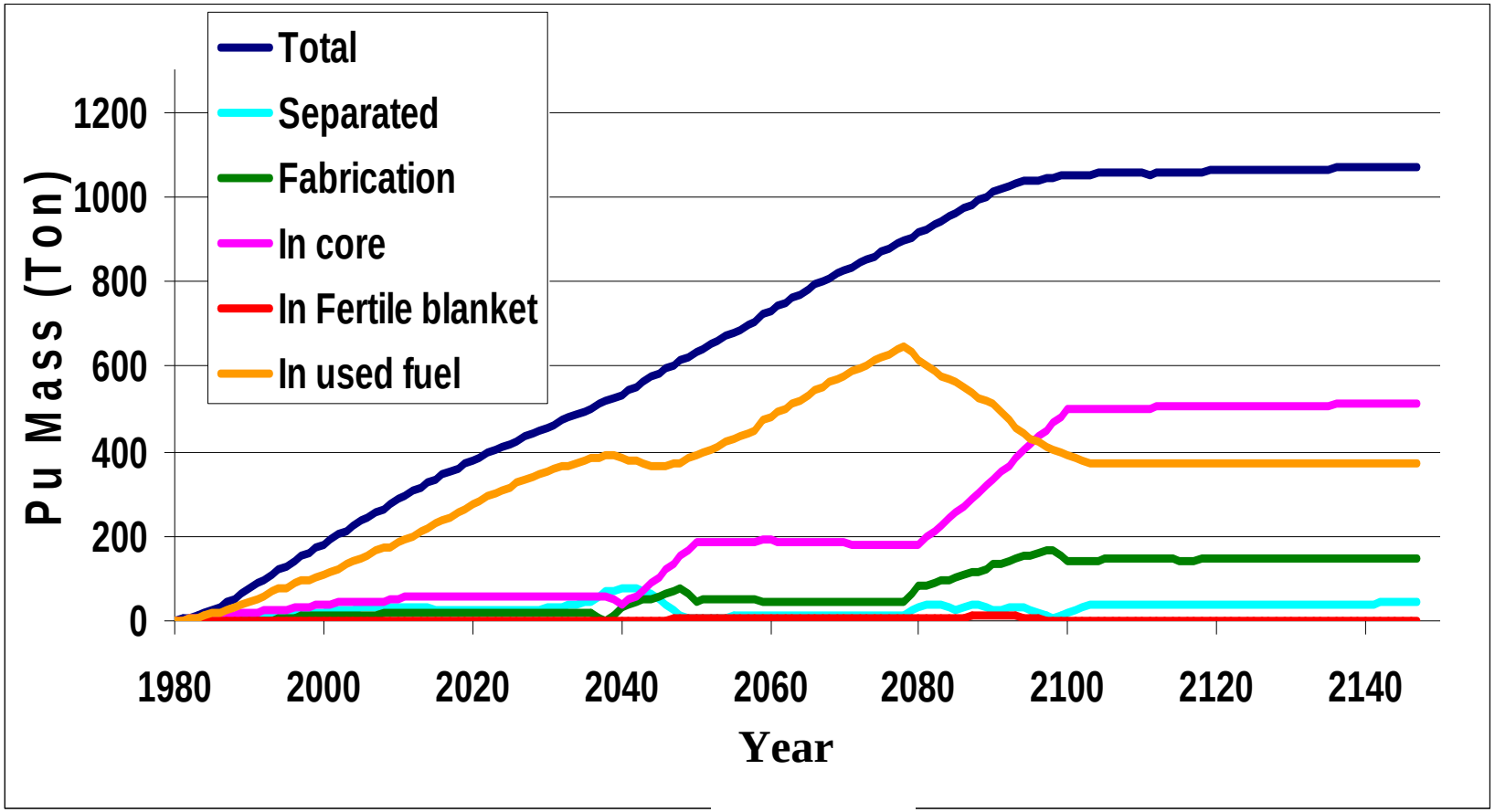
SCENARIOS AND CALCULATION TOOLS

- **Plutonium recycling** : reference scenario S_ref
- Americium **homogeneous transmutation :** scenario S_hom
- Americium **heterogeneous transmutation** in Americium Bearing Blankets assemblies (AmBB) :
  - Scenario S_het : All americium is transmuted as from 2040
  - Scenario S_het_50% : **only 50% of the SFR are loaded with AmBB**, part of the Am contained in the fuel reprocessed after 2040 is vitrified
  - Scenario S_het_2080 : Am transmutation is moved forward to 2080. **All Americium issued from SFR used fuel is transmuted.**
- **Codes used for the studies :**
  - o TIRELIRE-STRATEGIE scenario simulation code
  - o SYRTHES code for the repository thermal calculation

Photograph of the French Nuclear Fleet and Fuel Cycle Plants in 2065 – Scenario S_het_50%

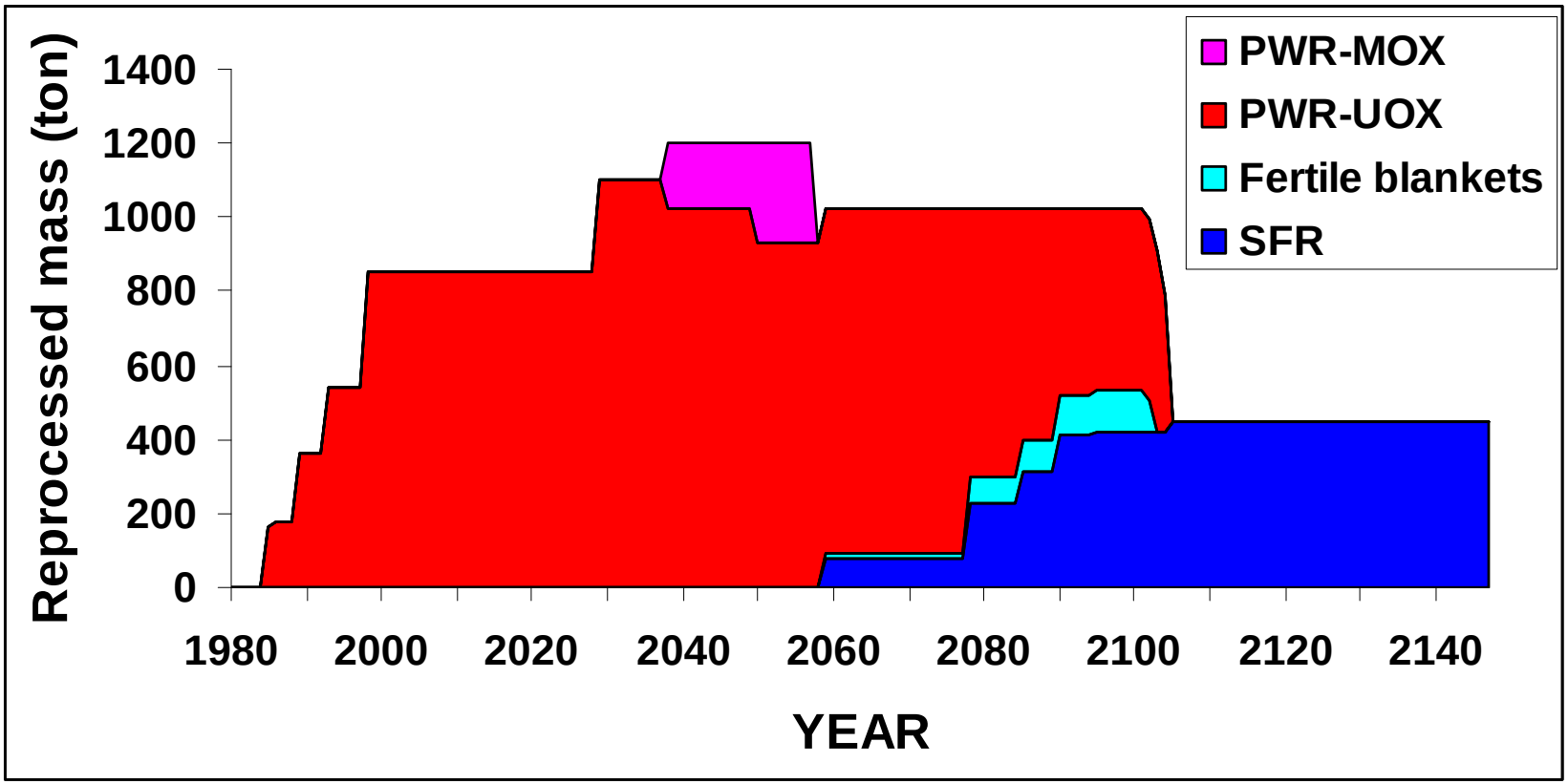


REFERENCE SCENARIO
PLUTONIUM INVENTORY



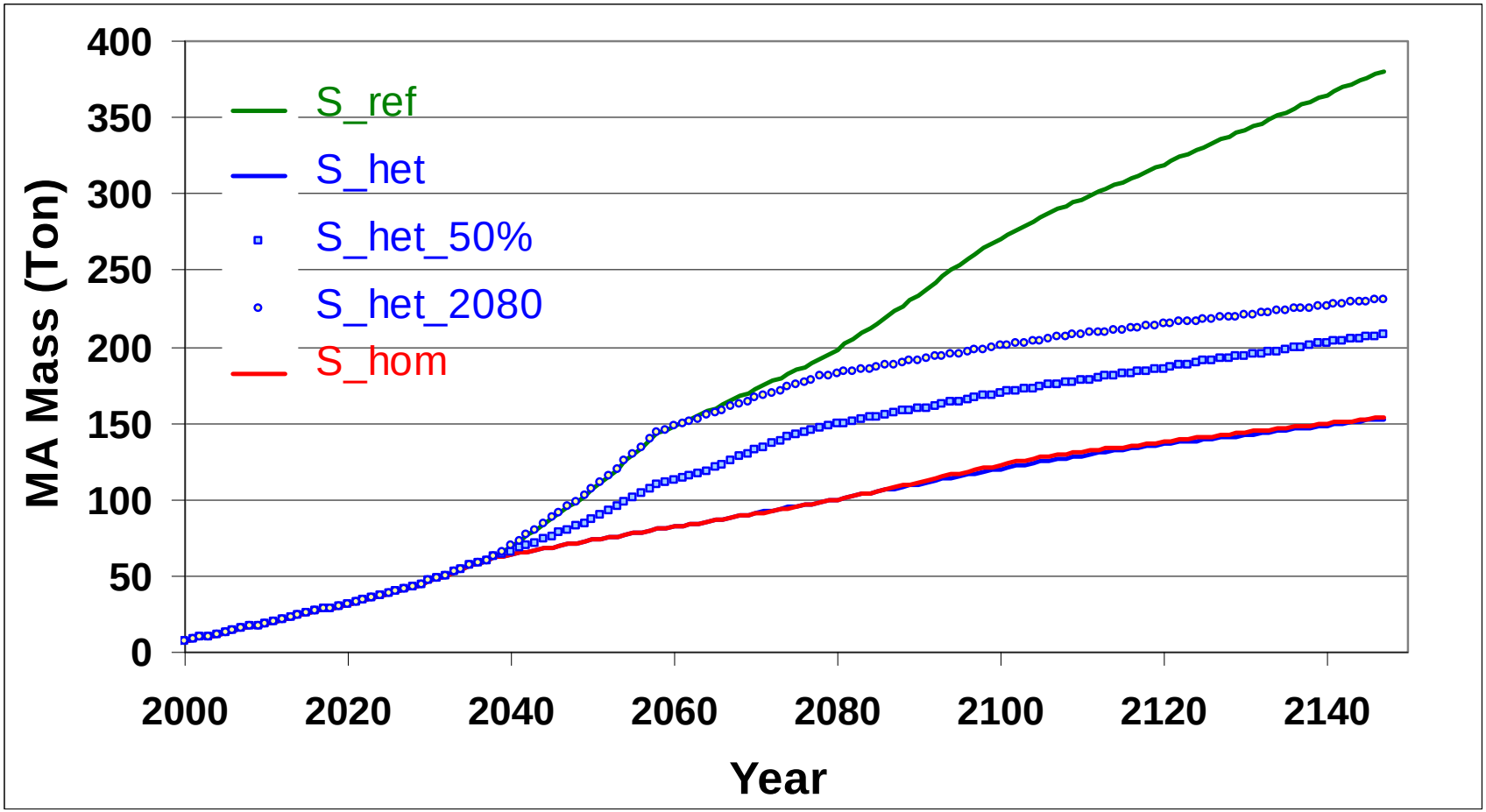
The total Pu inventory amounts to ~1050 tons at equilibrium, with a 16.5% Pu content ensuring the iso-generation

REFERENCE SCENARIO
USED FUEL YEARLY REPROCESSED

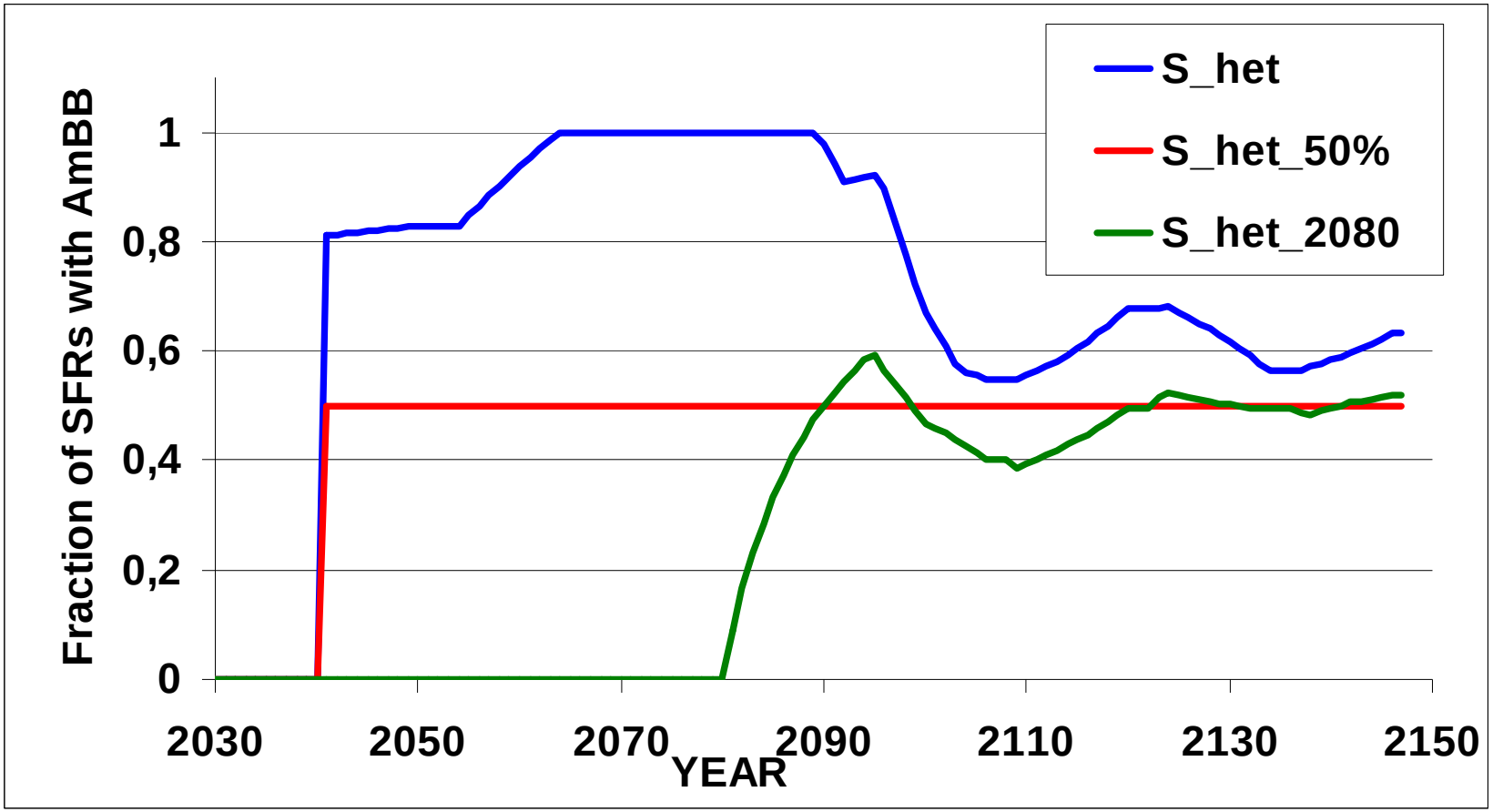


- Maximum : 1200 tons during used MOX REP reprocessing phase
- At equilibrium : 445 tons
- Fertile axial blanket are necessary during the deployment phase

MASSES OF MINOR ACTINIDES IN DISPOSAL FOR ALL SCENARIOS



Am HOMOGENEOUS TRANSMUTATION PROPORTION OF SFR EQUIPPED WITH AmBB

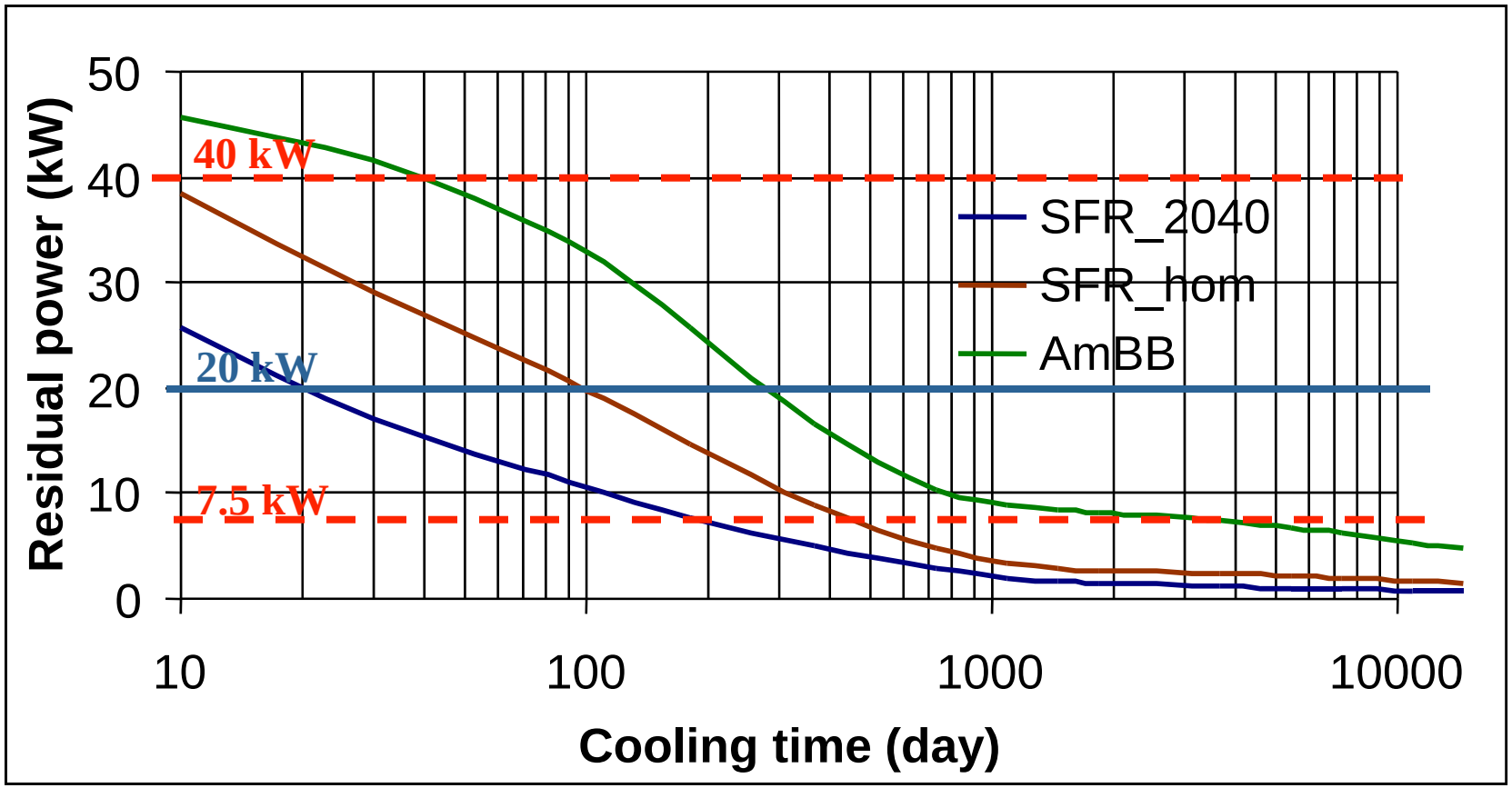


- S_het_50% : 47 tons of Am vitrified between 2040 et 2080
- S_het_2080 : 80 tons of Am vitrified between 2040 et 2080

Am TRANSMUTATION IMPACT ON HLW PACKAGES AND REPOSITORY AREA

Scenario	S_ref	S_het	S_het_50%	S_het_2080	S_hom
HLW packages	141000	141000	141000	142000	140000
HLW repository area	1	0.55	0.66	0.71	0.57
Total repository area	1	0.69	0.76	0.80	0.70

USED FUEL ASSEMBLIES RESIDUAL POWER



Maximal power for extracting the assemblies from the core : 40 kW

Maximal power for washing the assemblies : 7.5kW

CONCLUSION (1/2)

❑ **Most important EDF objective : to start bringing down as from 2025 its HLW packages in the geological repository at a reasonable cost**

❑ **The underground potential radio-toxicity is not a pertinent criterion, unless the safety regulator (and its TSO) requires it**

❑ **Industrial research scenarios are studied for partial or total Am transmutation**

❑ **Heterogeneous transmutation in AmBB is preferred, strongly limiting the flux of Am bearing assemblies, and separating fissile and transmutation fuels.**

➔ Small AmBB's fabrication plants of complex technologies

CONCLUSION (2/2)

❑**Total Am transmutation would allow a total repository area reduction by 30% (in 2150), partial Am transmutation with only 50% of SFR equipped with AmBB would allow area reduction by 25%, 20% if delayed in 2080.**

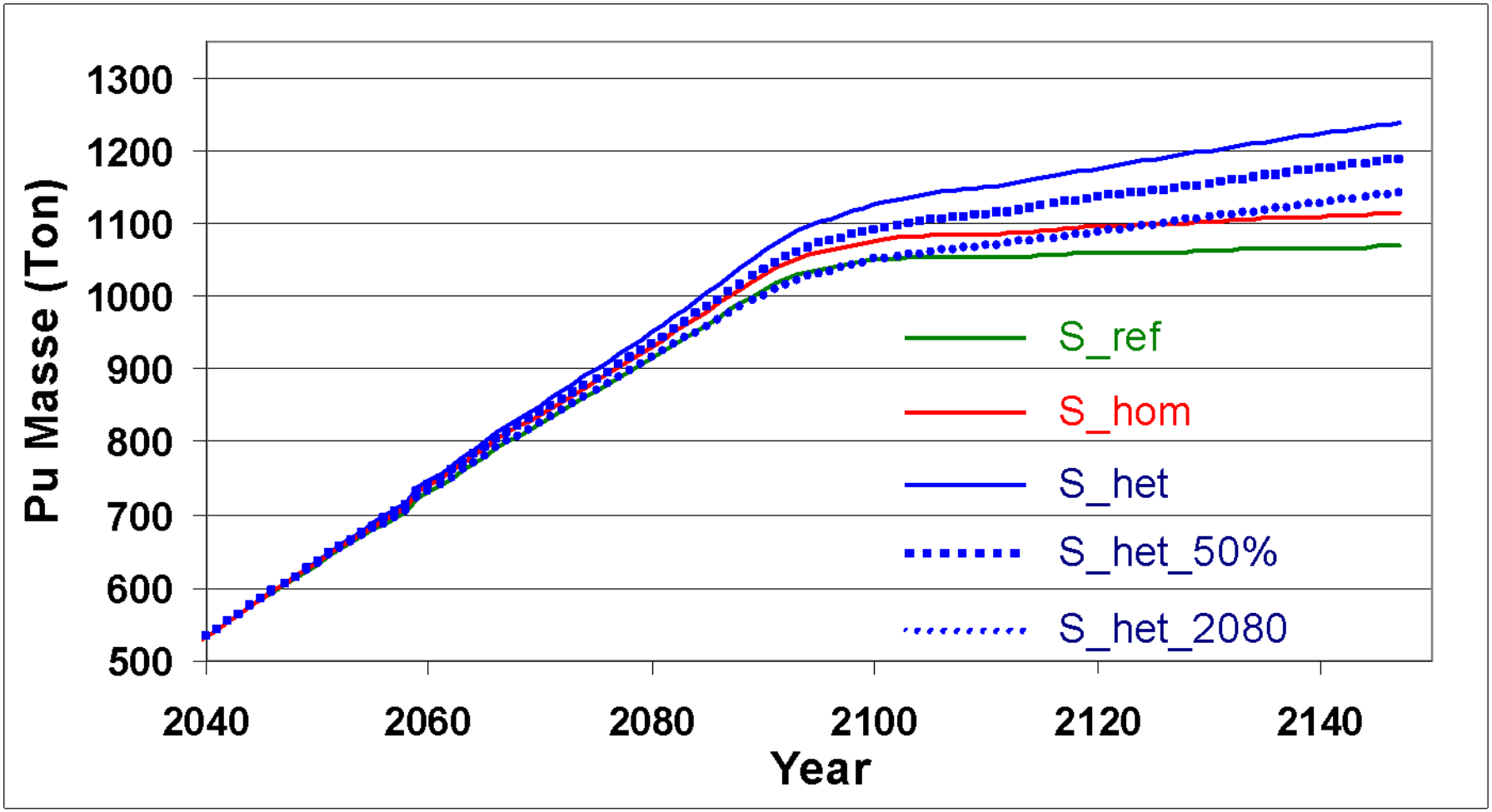
❑ **Am transmutation impact on reactors and fuel cycle plants have to be carefully studied in order to assess its industrial feasibility and the technical and economical balance between underground repository area reduction and extra investment in all the above the ground facilities.**

❑**Priorities for further R&D work for S_het_50% Scenario**

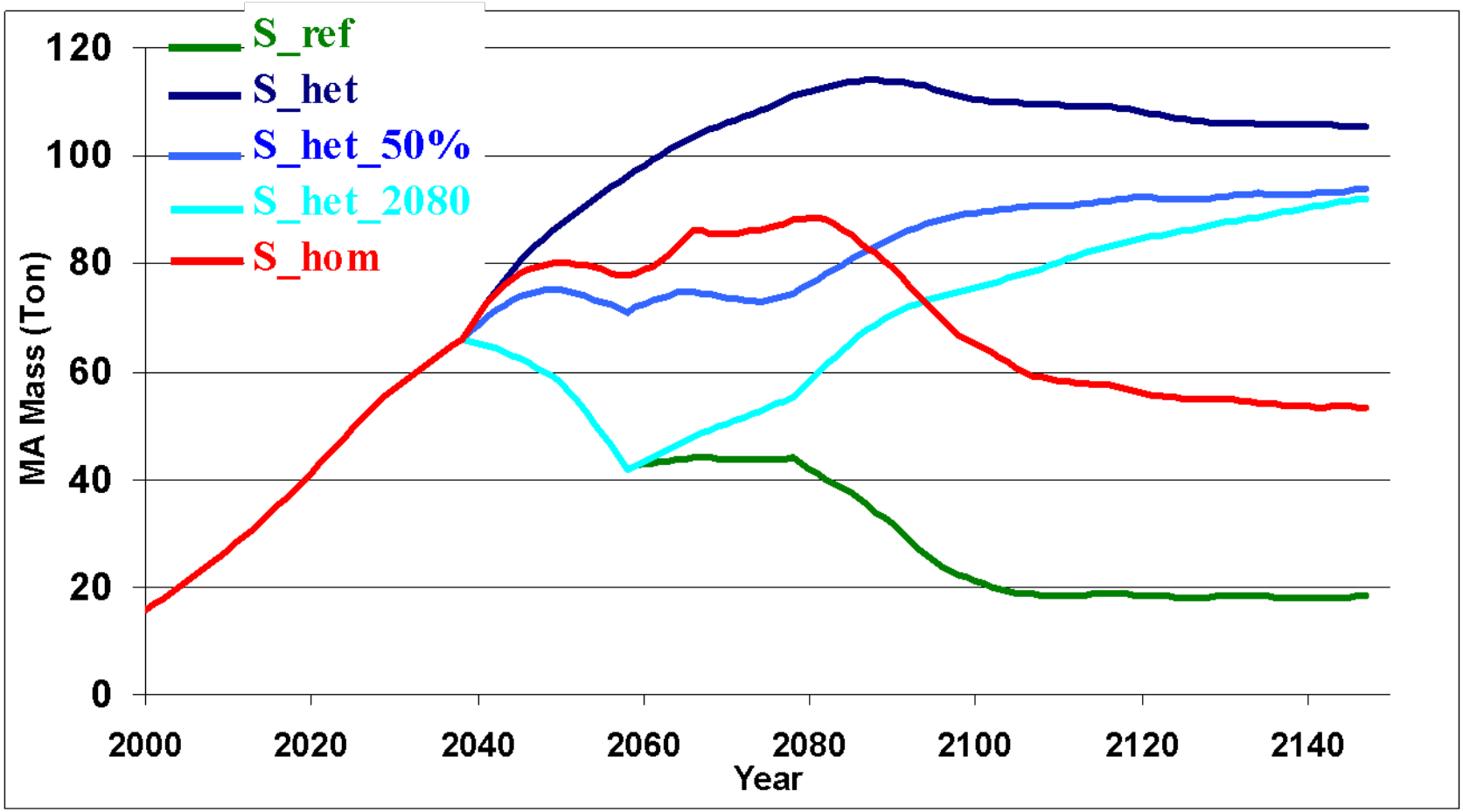
- Determine maximum Americium content in AmBB's through reactor experiments and post irradiation examinations
- Understand and overcome the 7.5 kW limit for AmBB residual power before Sodium washing and cask transport to the reprocessing plant.

SUPLEMENTARY SLIDES

Pu TOTAL INVENTORY FOR ALL SCENARIOS



MASSES OF MINOR ACTINIDES IN CYCLE FACILITIES FOR ALL SCENARIOS



IMPACT OF TRANSMUTATION ON TRU INVENTORIES, HLW PACKAGES AND REPOSITORY AREA

Scenario	S_ref	S_het	S_het_50%	S_het_2080	S_hom
TRU (t) in waste	410	180	235	255	185
Reduction	1	2.3	1.7	1.6	2.2
Total TRU (t)	1500	1355	1400	1440	1310
Reduction	1	1.11	1.07	1.04	1.15

TRU INVENTORIES (WASTE & TOTAL)

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HLW packages	141000	141000	141000	142000	140000
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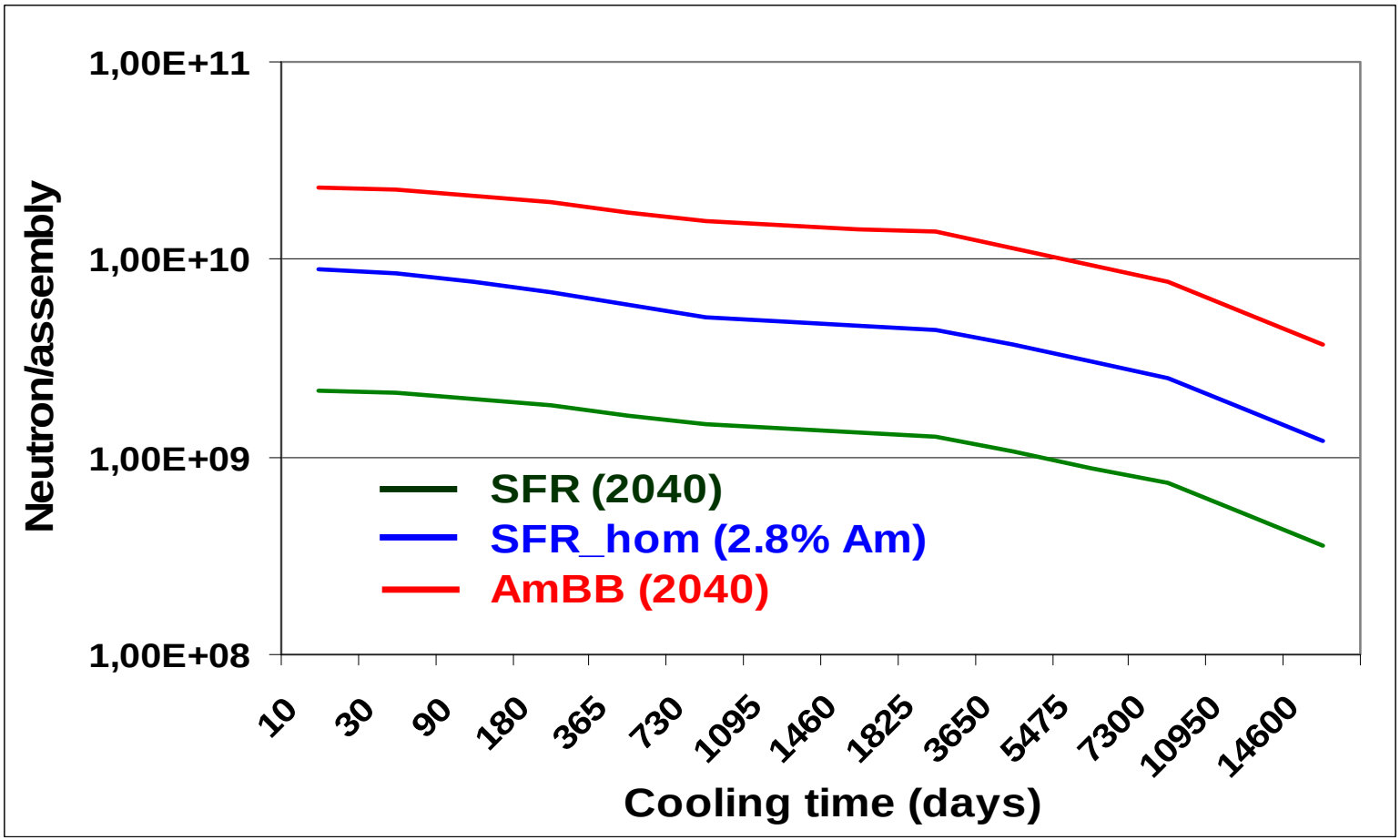
HLW PACKAGES & REPOSITORY AREA

POWER AND DOSE FOR FRESH SFR FUEL ASSEMBLIES AND AmBB

	SFR (2040)	SFR_hom (2040)	AmBB
Power (kW/assembly)	0.7	1.13	2.7
Contact dose (mSv/h) plan médian	14.8	19.3	70
Dose at 1 m (mSv/h) plan médian	0.5	0.80	2.9

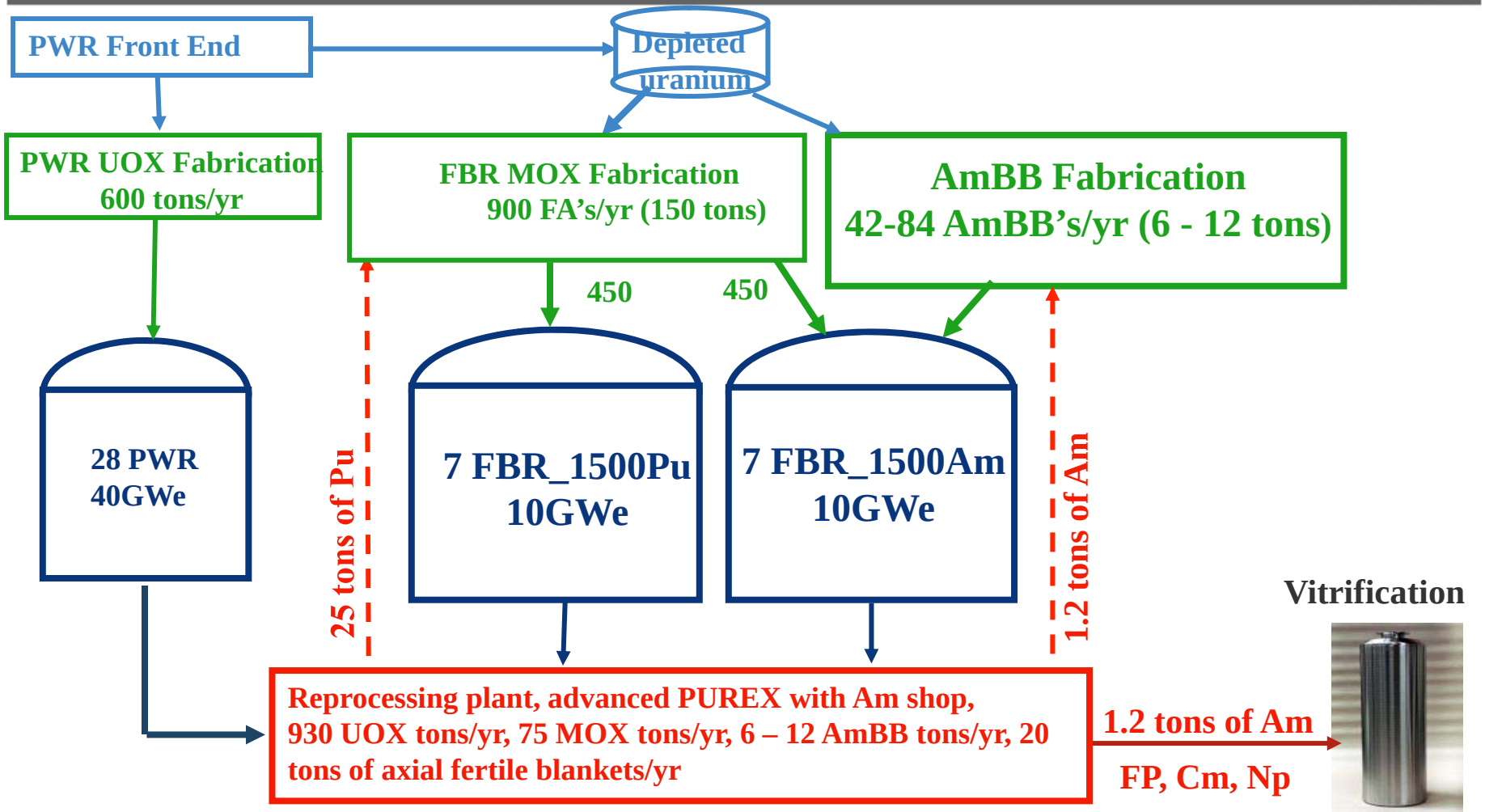
- Need to reinforce the shielding for fabrication and handling
- Need to use hot cells and remote control for AmBB

USED FUEL ASSEMBLIES NEUTRON EMISSION



Need to reinforce the shielding for used Am bearing assemblies transport

Photograph of the French Nuclear Fleet and Fuel Cycle Plants in 2065 – Scenario S_het_50%



Difficulties : maximum Am content in AmBB's, heat loads at interfaces between FR's and Reprocessing Plants