THE USE OF NUCLEAR DATA IN THE FIELD OF NUCLEAR FUEL RECYCLING

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AREVA NC

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Summary

1. AREVA NC La Hague reprocessing facility
2. Calculate the inventory of used fuels
3. Prepare, optimize and monitor the process
4. Quantities driving the process, and associated radionuclides of interest

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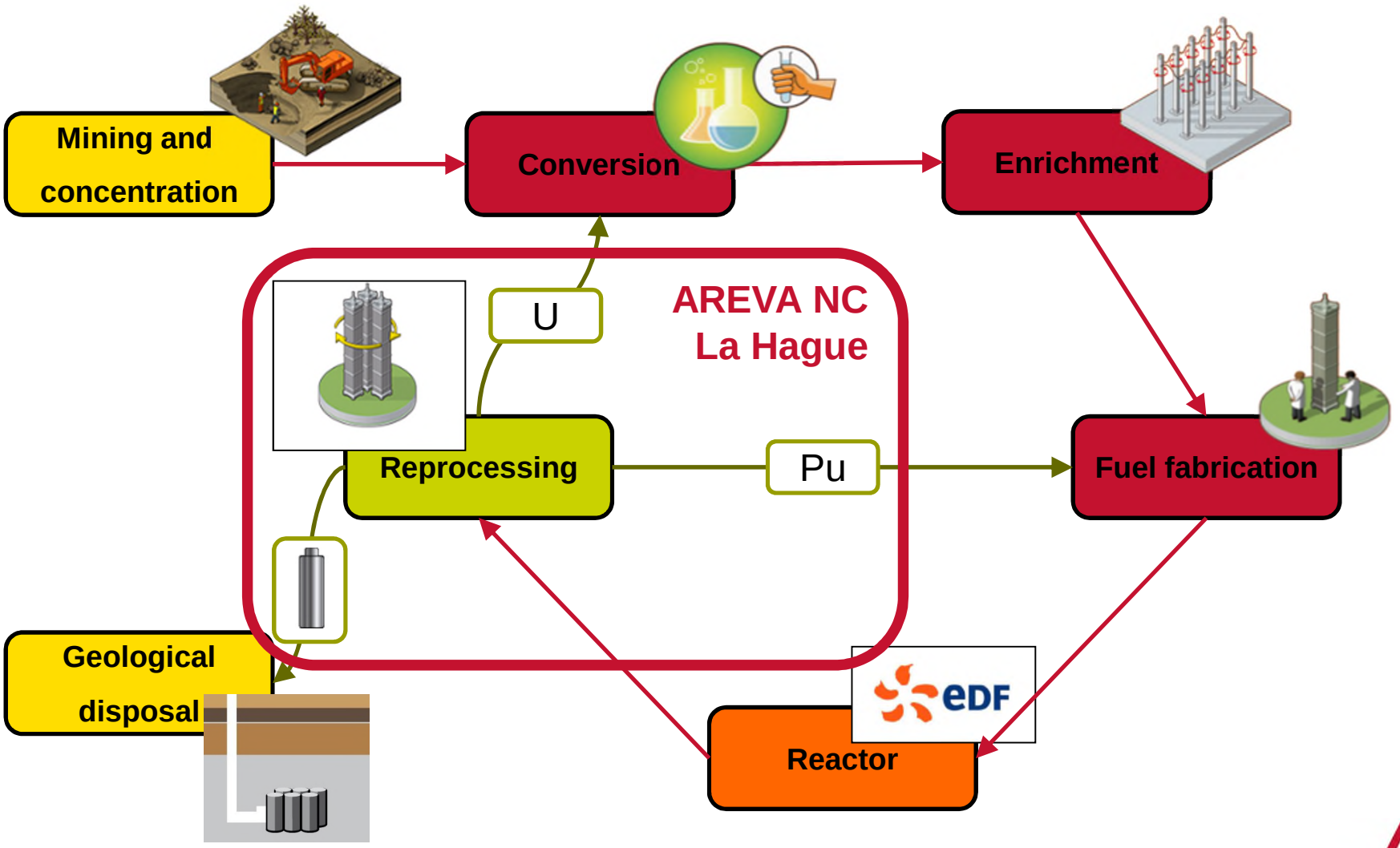
Nuclear fuel cycle in France



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AREVA NC La Hague reprocessing plant

- **The La Hague facility allows the separation of products from used fuel assemblies, in order to**
  - **recycle valuable materials (U, Pu) for energy purposes**
  - **minimize the amount and radiotoxicity of ultimate waste**
  - **ensure the high quality of ultimate waste packages for long term storage**
- **Context**
  - **first facility running from 1966**
  - **one new facility in 1990, and another one in 1994**
  - **situated close to Cherbourg, in La Hague, France**

Types of fuels

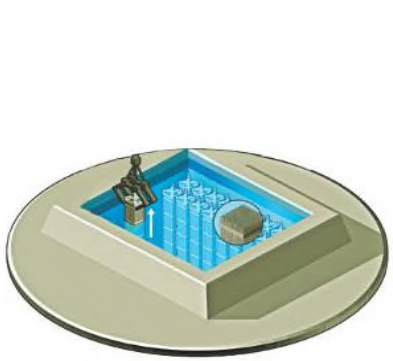
- Processed and/or to be processed fuels
  - UOX PWR & BWR
  - MOX PWR & BWR
  - URE PWR
  - UNGG
  - RTR both French and foreigner
  - RNR PHENIX
- Associated range of burn up and enrichment
  - LWR up to 62 GWd/t (enr. up to 4.55%)
  - RTR up to 700 GWd/t (enr. up to 93.5%)
- Cooling time
  - Reception from 6 months
  - Processing from 3 years (LWR) or 5 years (RTR)

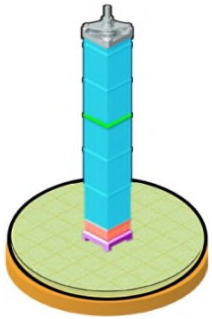
Reprocessing process (1/2)

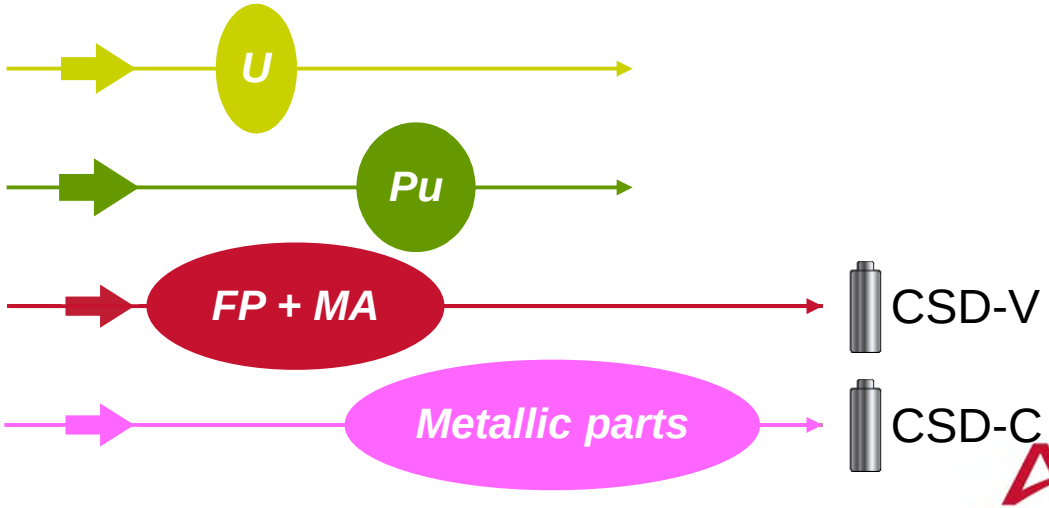
- **Reception and interim storage in pools**
- **Shearing and dissolution**
- **Metallic parts mechanical separation**
- **U/Pu/FP+MA chemical separation**
- **Final products :**
  - **U, Pu for further energy production**
  - **CSD-C, CSD-V for long term storage**

CSD-C
***C**onteneur **S**tandard de **D**échets **C**ompactés*
Standard compacted waste container

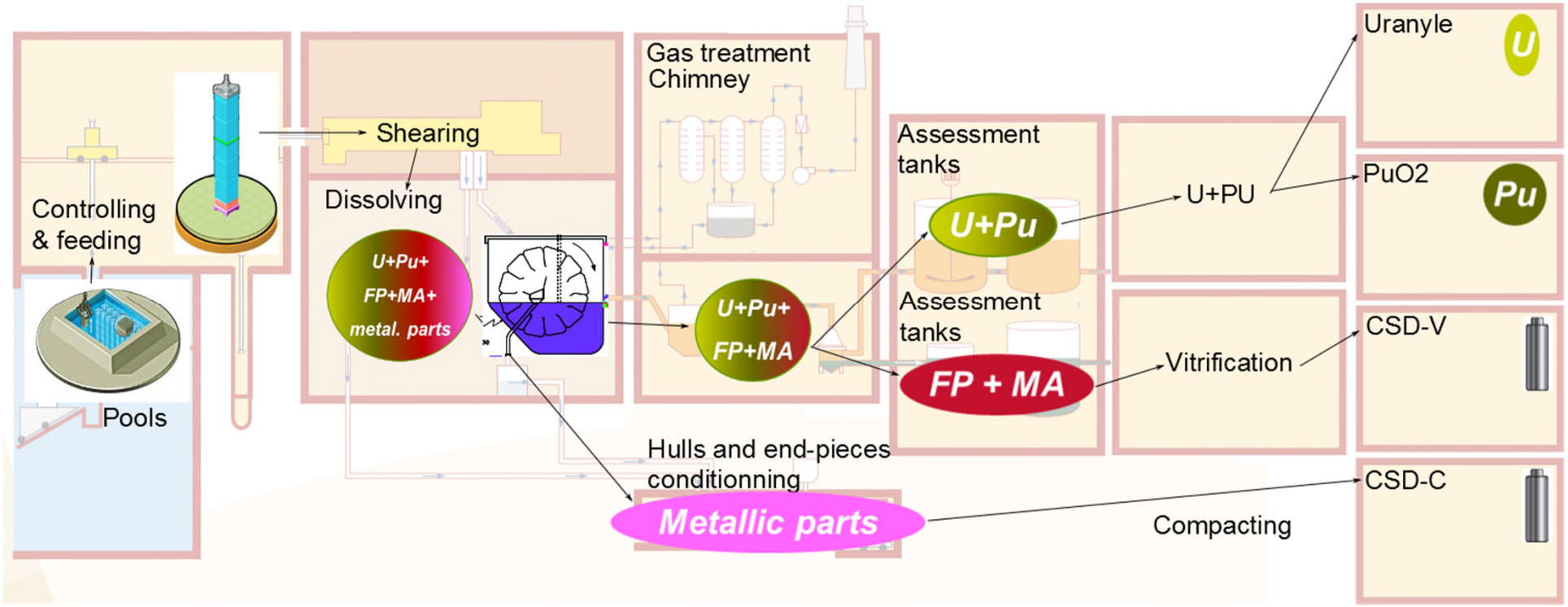
CSD-V
***C**onteneur **S**tandard de **D**échets **V**itrifiés*
Standard vitrified waste container







Reprocessing process (2/2)



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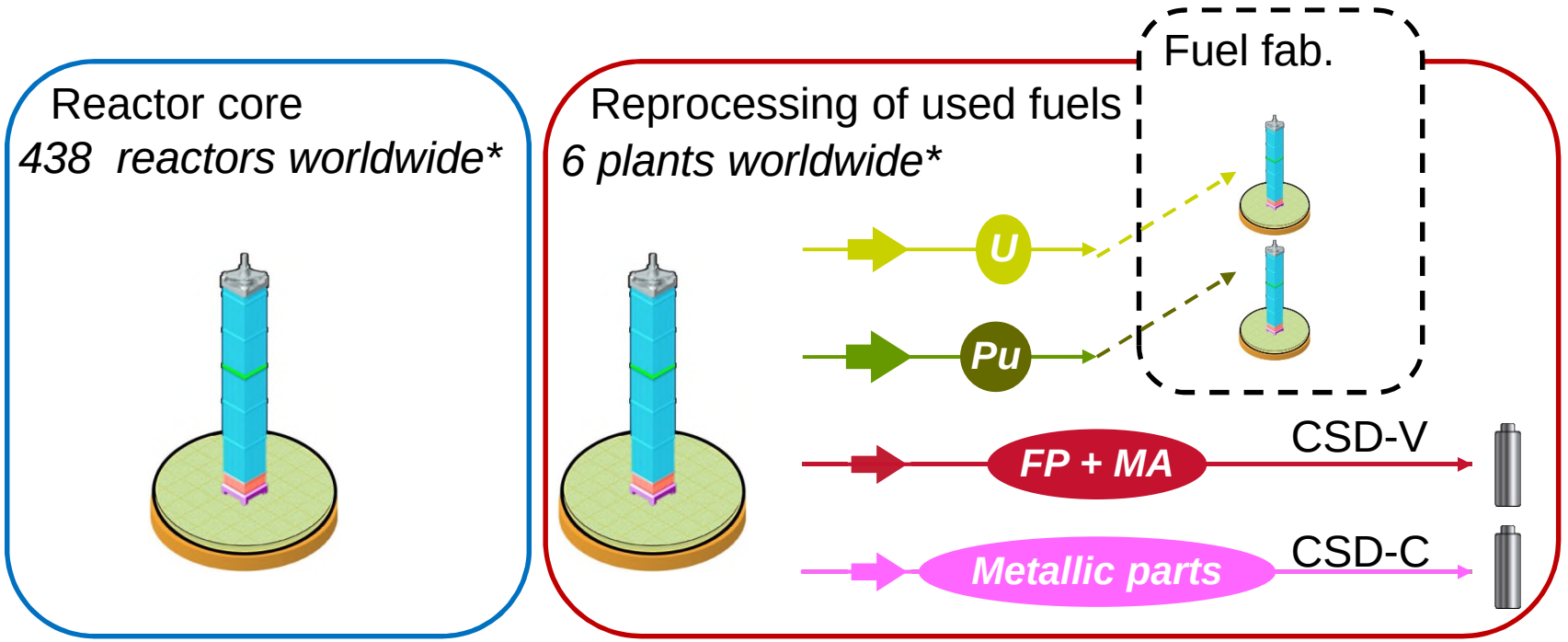
Life time of nuclear energy materials



*As of 31/12/2014, Data from Energy handbook and ElecNuc, CEA, 2015

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CALCULATE THE INVENTORY OF USED FUELS

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Depletion code

- **Simplified depletion calculation code** ND *Fission yields, activation reactions cross-sections, decay rate, filiation chains, branching ratios, …*
- **Provides mass inventory of**
  - **109 HNs, 212 FPs, 165 activation products**
- **Post-processing allows computing**
  - **decay heat**
  - **emission spectra**
  - **…**

  ND *γ and n emission, specific thermal power, (decay energy & half-life)*
- **Mainly used for**
  - **Preparing the reception of used fuel assemblies**
  - **Optimizing the process beforehand**
  - **Monitoring the process in-line**
- **Current version in use with nuclear data from JEFF3.1.1.** ND

PREPARE, OPTIMIZE AND MONITOR THE PROCESS

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Preparing the process

- Specificity of fuel assembly
  - anticipating the level of ease for the reprocessing,
  - anticipating the amount and quality of end-products
- Capacity to handle and reprocess fuel assembly is checked before reception
  - based on data provided by the client (history, linear power, initial content, etc.)
  - and depletion calculation

- Then, assembly is received, and stored in pool until reprocessing

Optimizing the process

- A set of assemblies is scheduled
- and these need to be given an order of reprocessing
  - to accommodate all constraints on the facility
  - and optimize the quality of end products
- Based on the calculated used fuel inventory

Monitoring the process

- **Many on-line measurements to ensure smooth-running of the plant**
- For example, consistency between calculation and real fuel assembly is checked ahead of processing
  - Relation from measured quantity (*eg*. ^{134}Cs-^{137}Cs ratio) to quantity of interest (*eg.* total burn up) is calculated with correlations from depletion code

Preparing, optimizing and monitoring the process

- What are the constraints?
- What can be optimized?
- And to what data do these refer?

QUANTITIES DRIVING THE PROCESS, AND ASSOCIATED RADIONUCLIDES OF INTEREST

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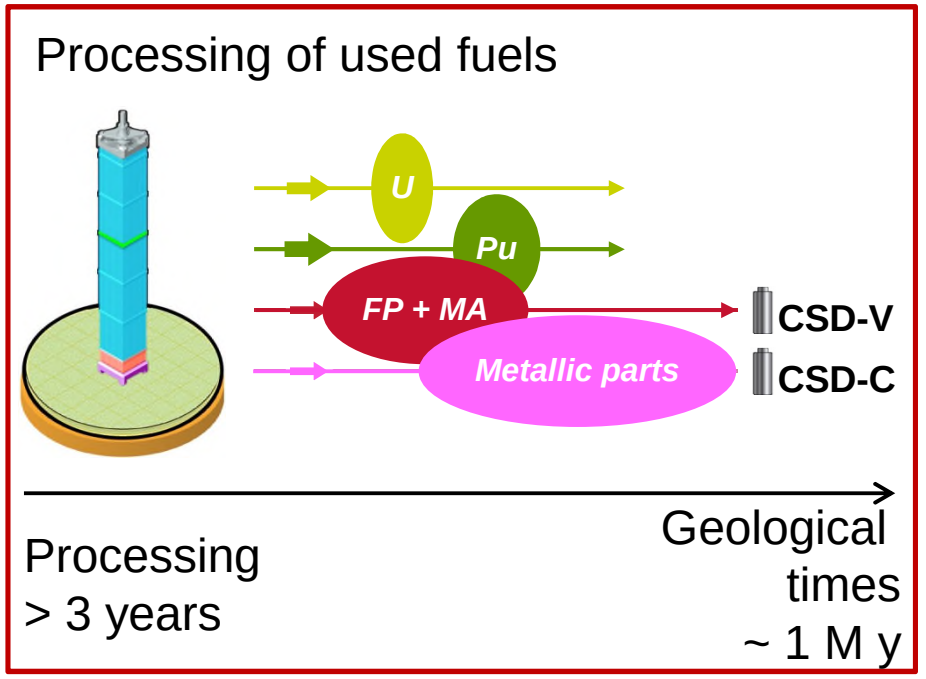
Quantities driving the process

- Just as everywhere in the nuclear energy field
  - Radioprotection
  - Criticality safety
  - Decay heat
  - Gaseous emissions of the plant
- But with specific features
  - Separated materials
  - Long cooling times



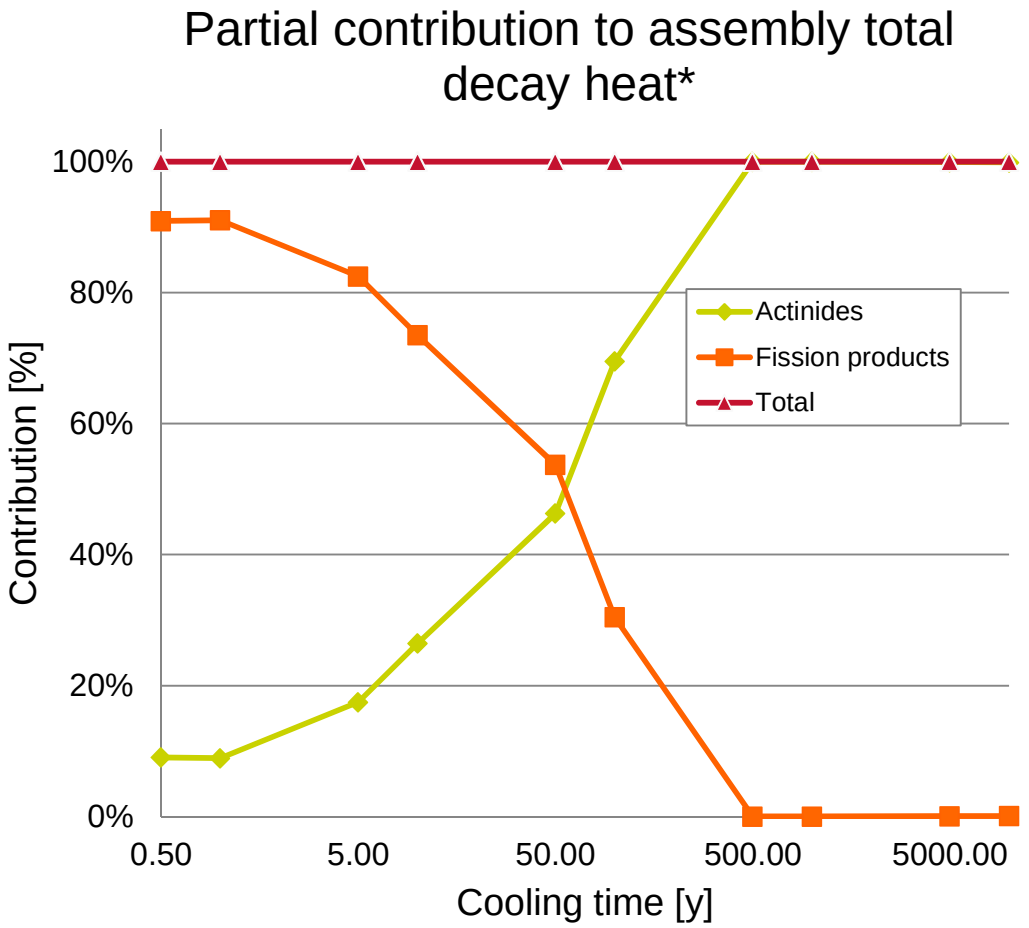
Hence, specific expectations on nuclear data

Effect of material separation

- Uranyle
  - Wide range of isotopes $^{232\text{-}238}U$
  - Criticality safety
  - *Eg* radioprotection, only few ppm ^{232}U, yet strong contributor
- Plutonium oxide
  - Wide range of isotopes $^{236\text{-}244}Pu$
  - Criticality safety
  - Decay heat
    - contrib. ~ 5% of full assembly at CT=6 months,
    - becomes 100% for separated PuO_2
- Also in-between steps : for example, FPs + MAs solution
  - Represents approx. 4% of total assembly mass, yet is responsible for most of its decay heat up to 40 years after last irradiation.
  - And yet, we have solution of exclusively FPs + MAs : high specific heat

Effect of time scale

- Short lived RNs do not come into account
  - CT > 6 months before reception
  - CT > 3 years before processing
  - Final waste containers ~ 1My
- Yet contribution of actinides becomes prominent at longer times
  - For radioprotection
  - And decay heat



** PWR UOx, e_i=3.7%, BU=45 GWd/t*

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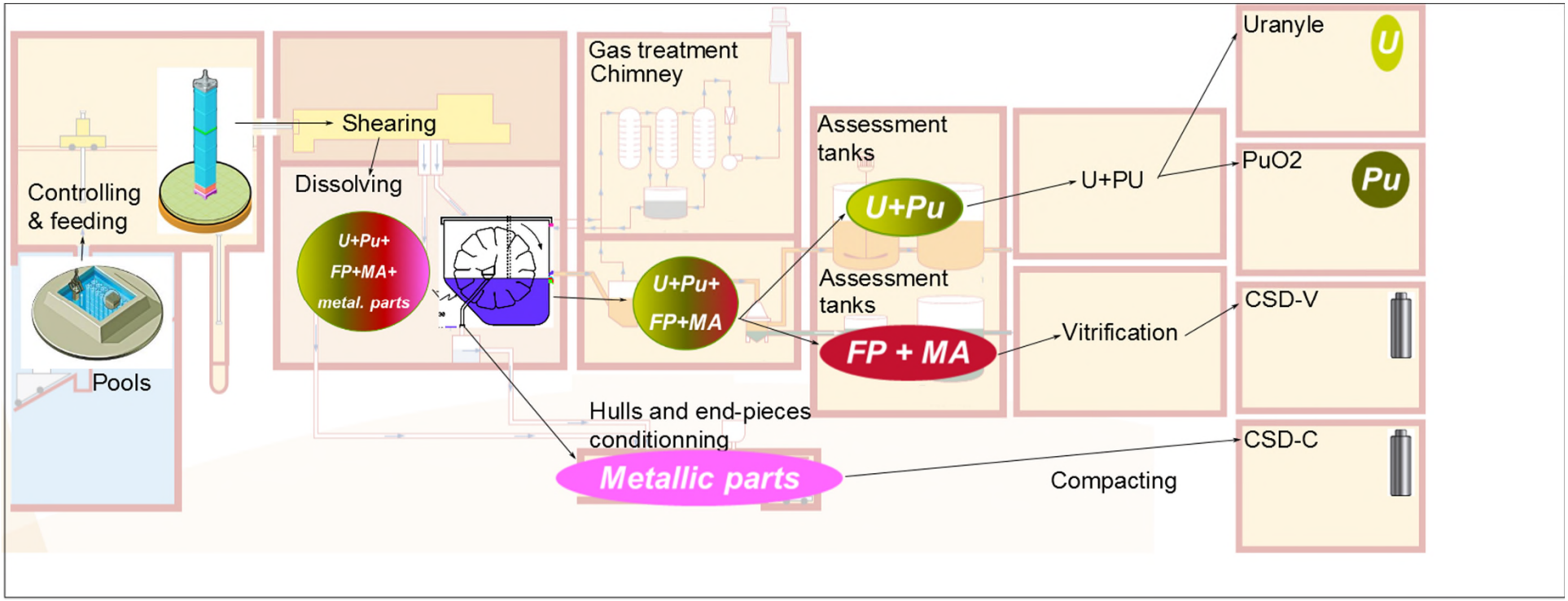
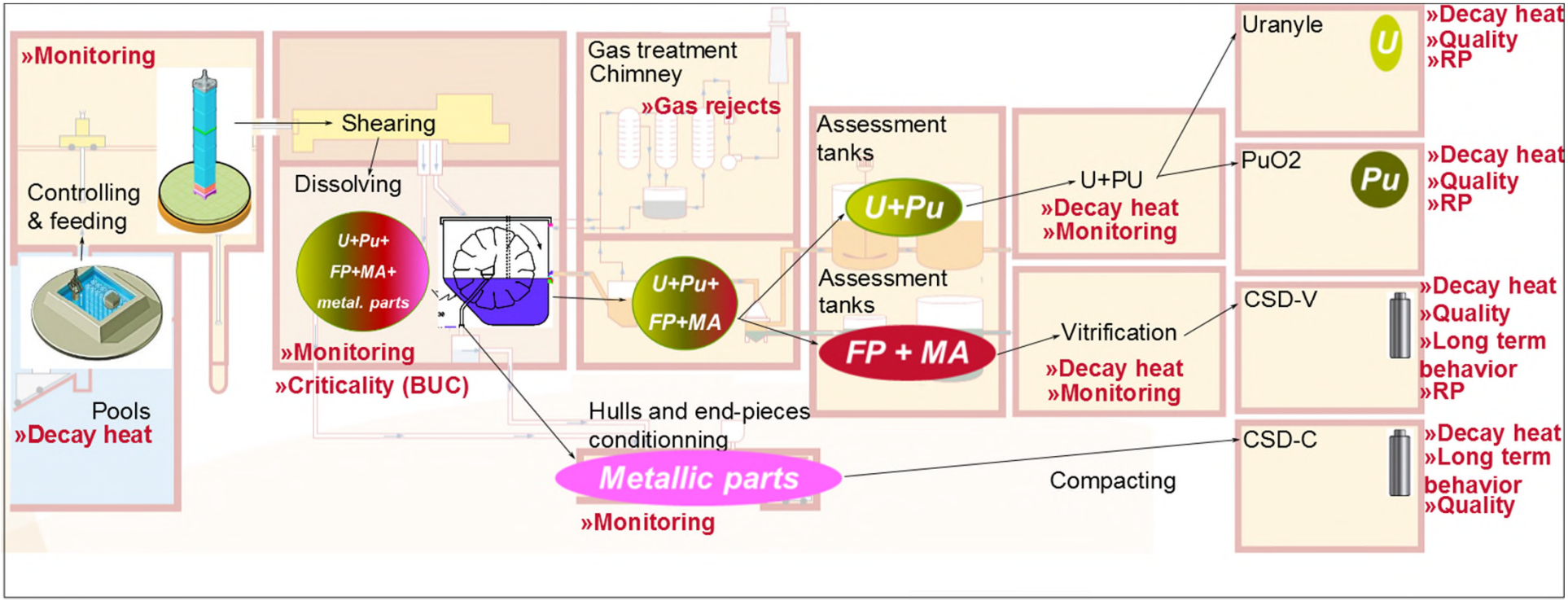
Reprocessing specificities (1/3)



Reprocessing specificities (2/3)



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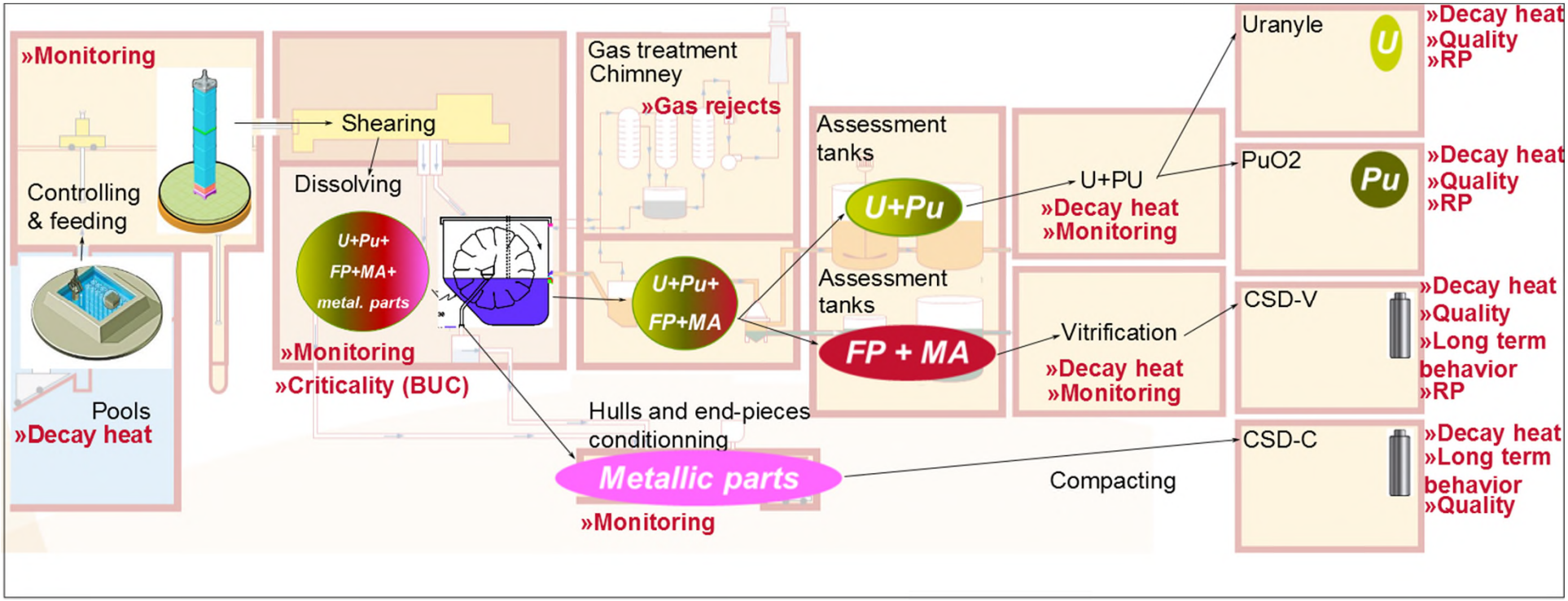
Reprocessing specificities (3/3)



Many RNs of interest

And calculation of one RN is impacted by all those of its filiation scheme!

Priority list

- **Prioritized according to the importance of their contribution to given physical quantity (specific heat, neutron/alpha emission, etc.)**

RN	Cat.	Related topic
^{137}Cs / ^{137m}Ba	FP	Process monitoring, decay heat
^{154}Eu	FP + Activ.	Process monitoring
^{244}Cm	HN	Decay heat / Neutron emission

- In collaboration with CEA, work is under way to identify improvement possibilities for the calculation of these RN
- *cf*. contribution A. Rizzo (*CEA*) (ND2016 - S212)

Summary

- Fuel processing has its specificities, as compared to other nuclear fields, and even within the field of nuclear energy
- Mostly due to two reasons
  - Time scale
    - from 6 months; reception, interim storage
    - to several years; processing, materials separation, sent for re-use
    - to geological time scales; long term storage of final waste
  - Separation of products
    - Full assembly
    - Uranyle nitrate
    - Plutonium oxide
    - CSD-C (structures)
    - CSD-V (FPs, MAs)
    - And all in-between products
- Hence, a different point of view on importance of some specific radionuclides
- Top priority list has been drawn
- Work under way with CEA, *cf*. contribution A. Rizzo (S212)

THANK YOU FOR YOUR ATTENTION

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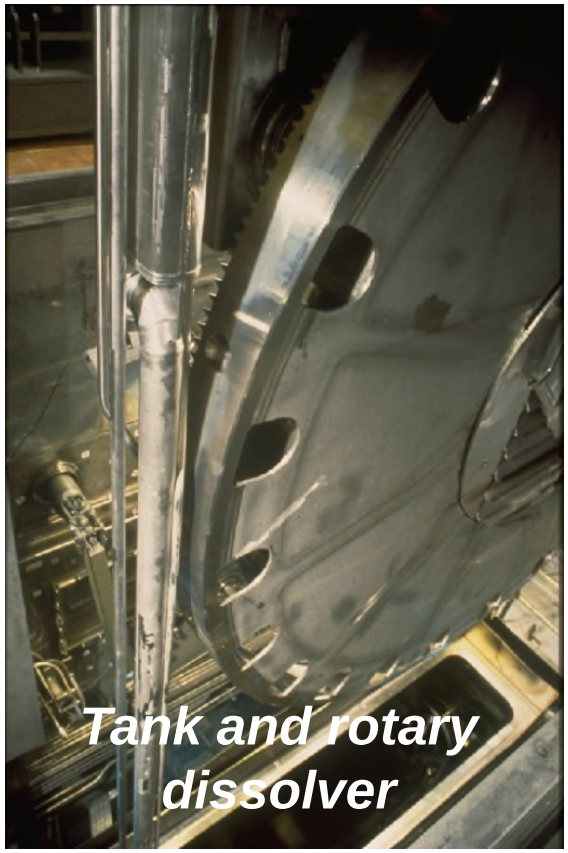
AREVA NC La Hague pictures



All pictures : AREVA, Établissement de La Hague Reprocessing Plant, Cherbourg, France

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