



28th Exchange Meeting:
Belgian R&D programme on Spent Fuel

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NIRAS ONDRAF

	Time	Presented by
1. Context	13.40 – 14.50	*Where we stand*
Belgian context for the management of spent fuel		Sophie Pedoux (NIRAS-ONDRAF)
Spent nuclear fuel: Why should we know more … today?		Kevin Govers (NIRAS-ONDRAF)
Knowledge management, the spent fuel platform		Valentin Kerleguer (FANC)
The global work programme of the spent fuel platform explained		Tomas Vandoorne (NIRAS-ONDRAF)
Q&A		
Coffee break	*14.50 – 15.20*	
2. Practical aspects	15.20 – 16.00	*From reactor to research*
Rod extraction at Doel-3		Jonas Stichelbout (Engie)
Loading of the container, transport to SCK CEN		Xavier Bairiot (SCK CEN)
Q&A		
3. R&D programme details	16.00 – 16.50	*Gaining insights*
The experimental spent fuel R&D program		Marc Verwerft (SCK CEN)
Characterizing of spent nuclear fuel through modeling & calculations		Augusto Hernandez Solis (NIRAS-ONDRAF) Gert Van den Eynde (SCK CEN)
Q&A		
Way forward	16.50 – 17.00	Didier Leonard (SCK CEN)
Drink	*17.00 – 18.00*	



Belgian programme
on radioactive waste management

Context – where we stand

24-11-2026

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Belgian Context for the Management of Spent Fuel

Sophie Pedoux

24-11-2026

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Vocabulary*

- **SPENT FUEL :** Nuclear fuel that has been used in a reactor and permanently discharged. It can either be reprocessed and reused as a resource or managed as radioactive waste for final disposal.

- **SPENT FUEL MANAGEMENT :** All activities linked to, among others, the manipulation, transportation, temporary storage, reprocessing or disposal of the spent fuel
- **REPROCESSING :** Process or operation dedicated to extract radioactive isotopes from a spent fuel for later use
- **IRRADIATED FUEL :** Fissile or plutonium-bearing material encapsuled in a structure allowing their use in a reactor, after their definitive discharge from the reactor
- **ENRICHED FISSILE MATERIAL :** Any material that contains uranium fissile isotope in higher concentration than in natural uranium, in any other form than fresh or spent fuel

* ONDRAF/NIRAS Law (08/08/1980) & Royal Decree (30/03/1981)

NIRAS- ONDRAF's Missions and competencies

Missions regarding spent fuel :

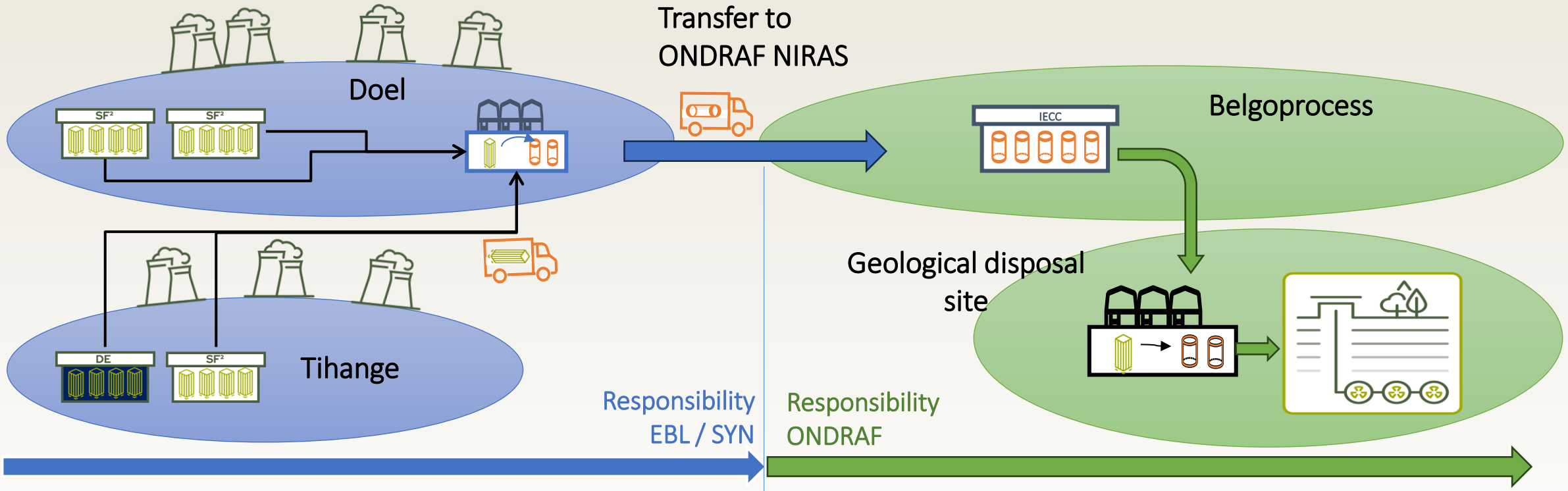
- Transportation
- Temporary Storage
- Final Disposal (options are open: either direct or after reprocessing)
- Collection and evaluation of all information necessary to execute these missions

Competency to make propositions regarding National policies

- SPENT FUEL : Provided that its proposition includes the accepted assumptions for later use by the owner of the spent fuel, after consultation of NIRAS-ONDRAF and FANC/AFCN

Spent fuel management before Phoenix law

Provisions Synatom + Reference Scenario



Phoenix Law

Law of 26 April 2024 to ensure the security of supply in the energy sector and the reform of the Nuclear Energy Sector

Phoenix law impacted the responsibilities for the spent fuel management :

- Operational transfer* of the spent fuel coincides with the site transfer (Tihange and Doel), Provided it is compliant with the Contractual Transfer Criteria
- The spent fuel is transferred to dry storage, along with the sites. Timing: when all sites are dismantled or 1st January 2050 (first to occur)
- Transfer of financial obligations related to the spent fuel to Hedera @closing (11/2024)

* The operational transfer is defined as the taking in charge and transfer of ownership to ONDRAF NIRAS

Article 28 of Phoenix law

Ensure that NIRAS-ONDRAF has access to the knowledge, data and materials required for the safe long-term management of radioactive waste and spent nuclear fuel.

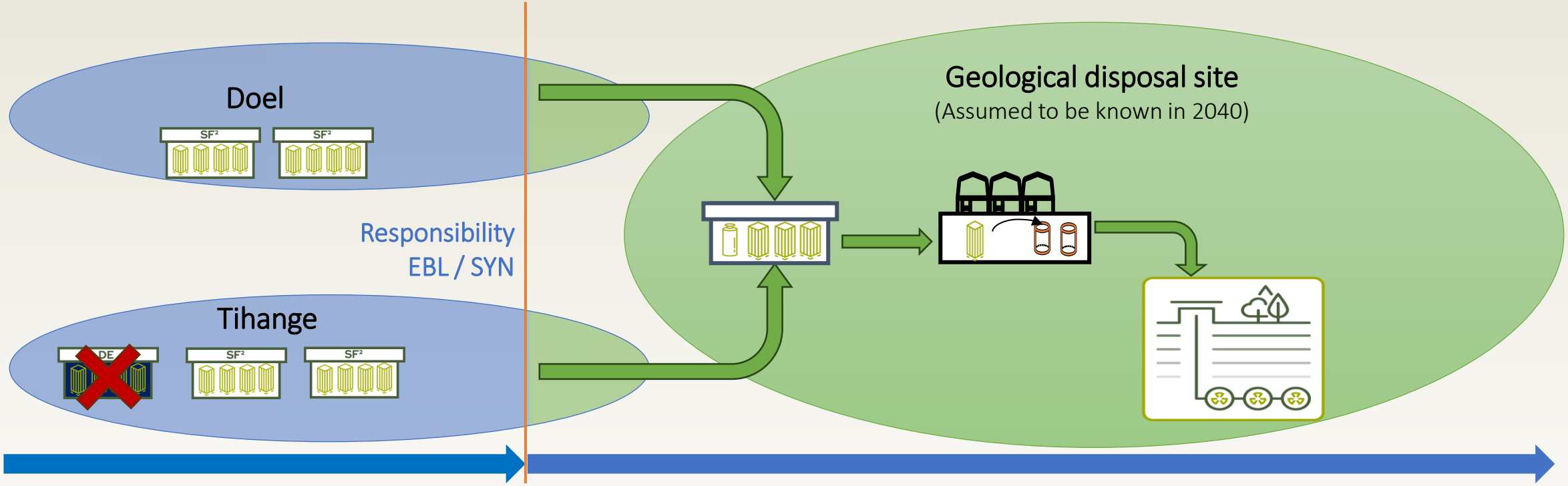
- NIRAS-ONDRAF and the nuclear operator (EBL) will convey:
  - The participation of its experts to the operator's technical teams for determined fuel activities
  - The access to knowledge, databanks and existing documents,
  - Jointly ask the providers for relevant information if not available with the operator
  - The right for N-O to have spent-fuel rods transferred for testing purposes
  - The right for N-O to perform measurements on UOX and MOX spent fuel before its removal from the nuclear power plants.
  - The participation of N-O to periodic safety reviews

New reference scenario by NIRAS-ONDRAF

The reference scenario is foreseen in the law and royal decree. It fixes all the assumptions necessary for the cost evaluations of the storage and disposal.

- It allows to complete and coherent technical scenario → cost evaluation in 2027
- It is fixed for maximum 5 years → new assessment in 2031
- The main assumptions for spent fuel management are :
  - ✓ The sites are transferred to NIRAS-ONDRAF in 2050
  - ✓ The spent fuel is declared as waste → Direct disposal
  - ✓ The Geological Disposal site will be known in 2040. A centralised dry storage will be built on that site. → minimization of transportation & optimization costs
  - ✓ The spent fuel in casks will be transported as soon as possible and stored
  - ✓ The storage casks will only be opened once to prepare the spent fuel for Disposal in Supercontainer → optimization of installations ICC and post-conditioning facility

Reference scenario of NIRAS-ONDRAF for spent fuel management



Temporary storage
→ Until end of dismantling or 2050

2050 : Transfer of the sites to ONDRAF

Transport to the geological disposal site ASAP
+ Temporary dry storage
2050 - 2130

Conditioning & post-conditioning followed by Disposal
2118-2130



Belgian programme
on radioactive waste management

Spent (nuclear) fuel:
Why should we know more … today?

Kevin Govers | NIRAS-ONDRAF

24-11-2026

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Why should we know more …

… after decades of safe reactor operations?



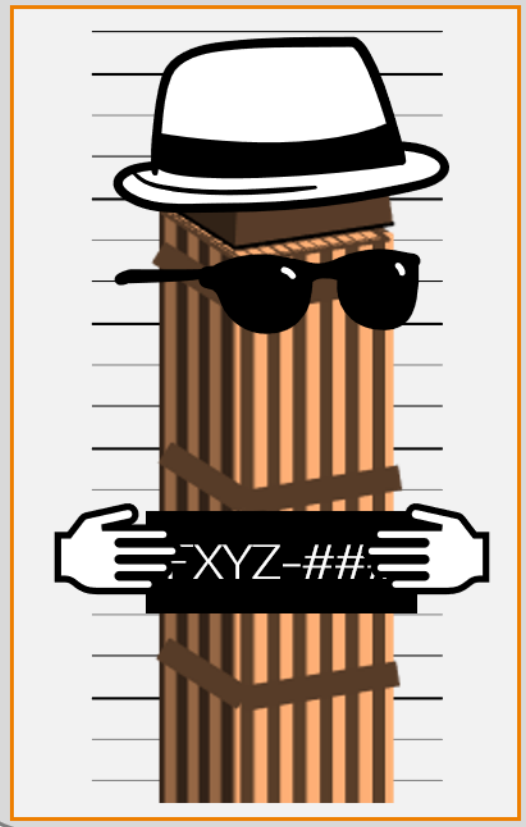


- Spent fuel management brings new questions and options.



⇨ R&D provides evidence for safety & guidance for decisions

Every assembly is shaped by a unique life



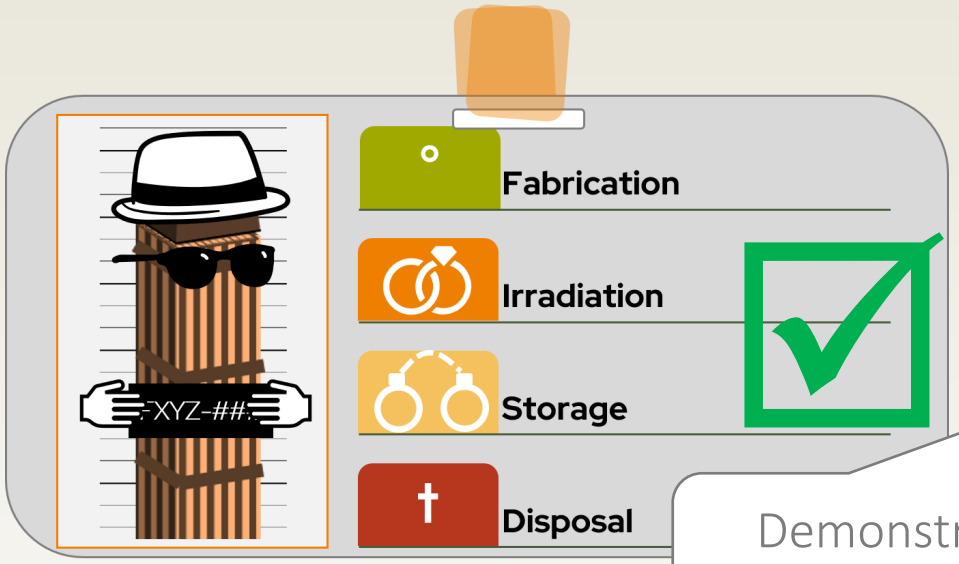
Fabrication

Irradiation

Storage

Disposal

Every assembly is shaped by a unique life



>60y R&D
in-reactor behaviour

We can characterize its conditions at discharge!

Demonstrating capabilities: **Confirmatory examination of extracted rods**

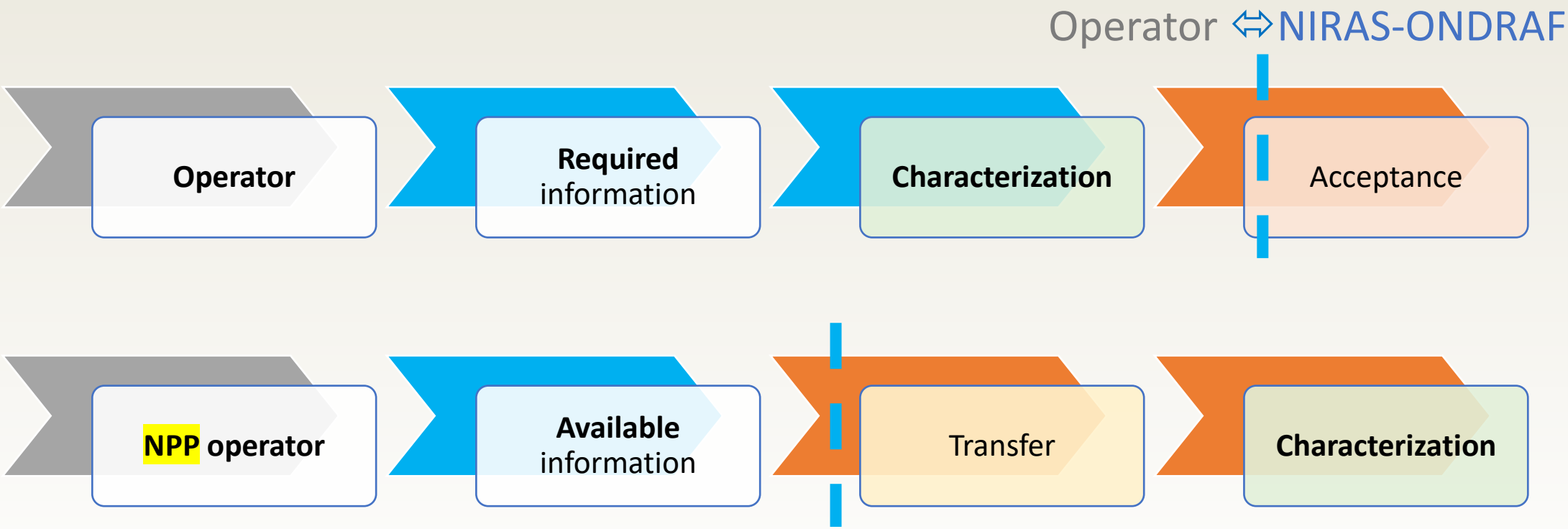
We need to refine our understanding of its future behaviour!

TESTING

! **operating histories not fully represented in *long-term* disposal studies**

The context changed, not the need for characterization!

- **The need did not appear with Phoenix. The responsibility moved.**

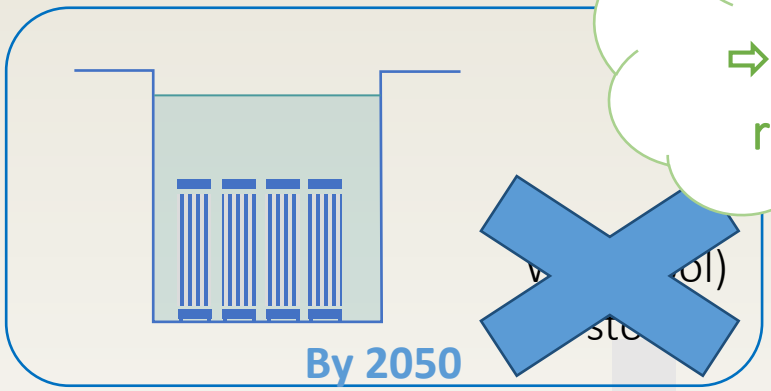


Phoenix also changes the journey of spent fuel !

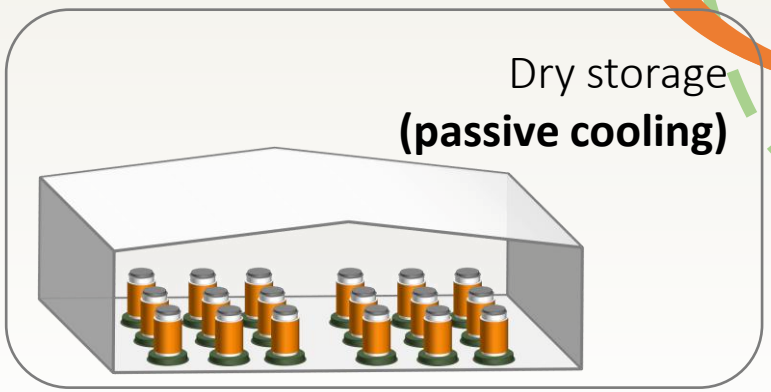
Reactor ⇨ storage

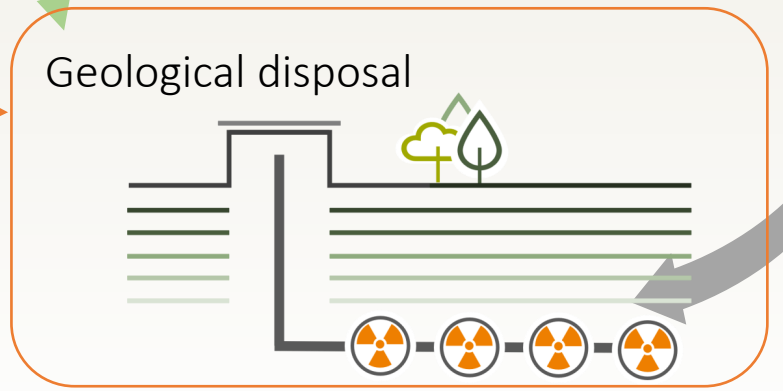
Further management route

Not yet industrially implemented
⇨ R&D to confirm reprocessability





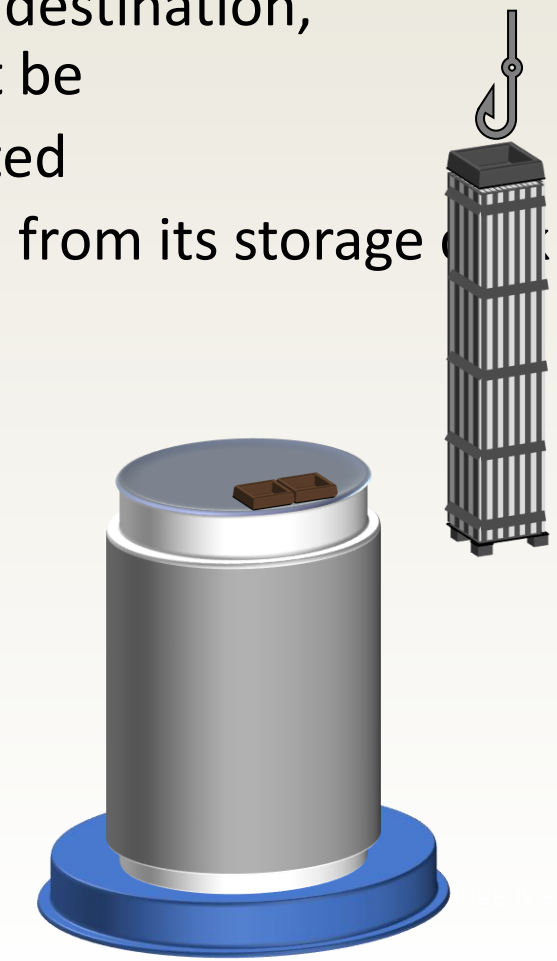






Common concern: will we still be able to handle it?

- Whatever its destination, the fuel must be
  - Transported
  - Retrieved from its storage (

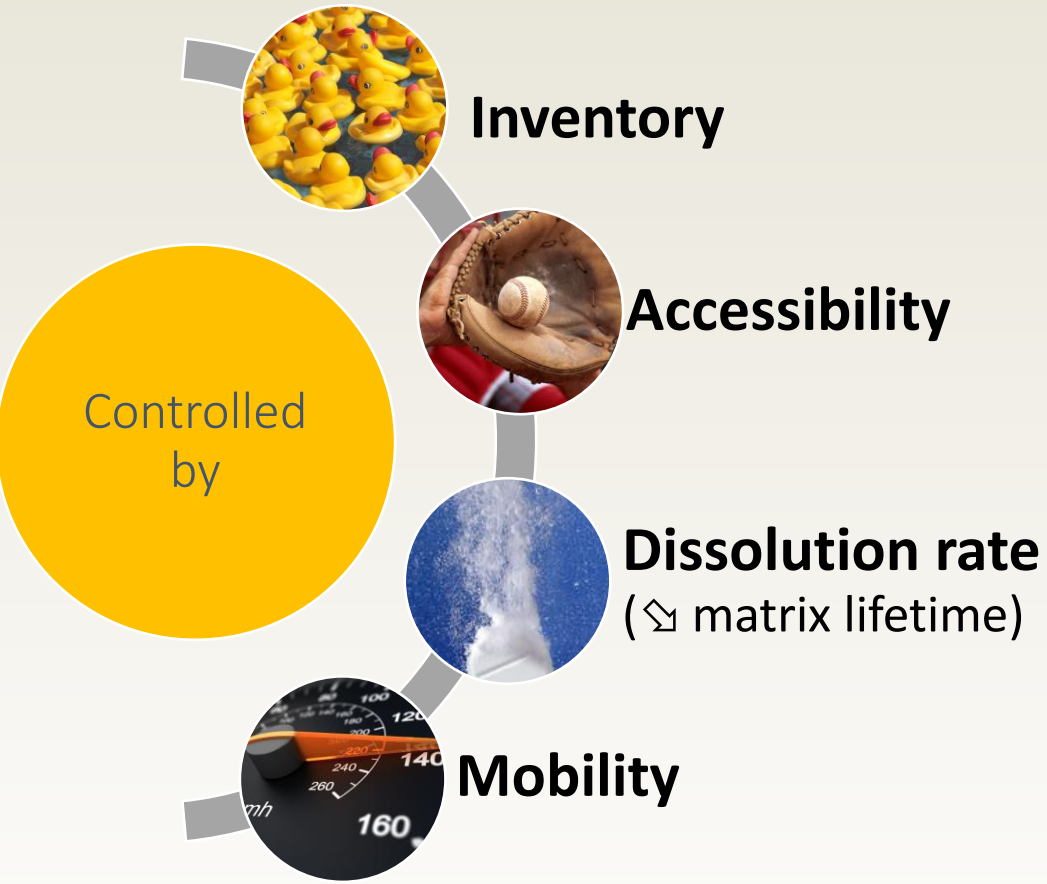


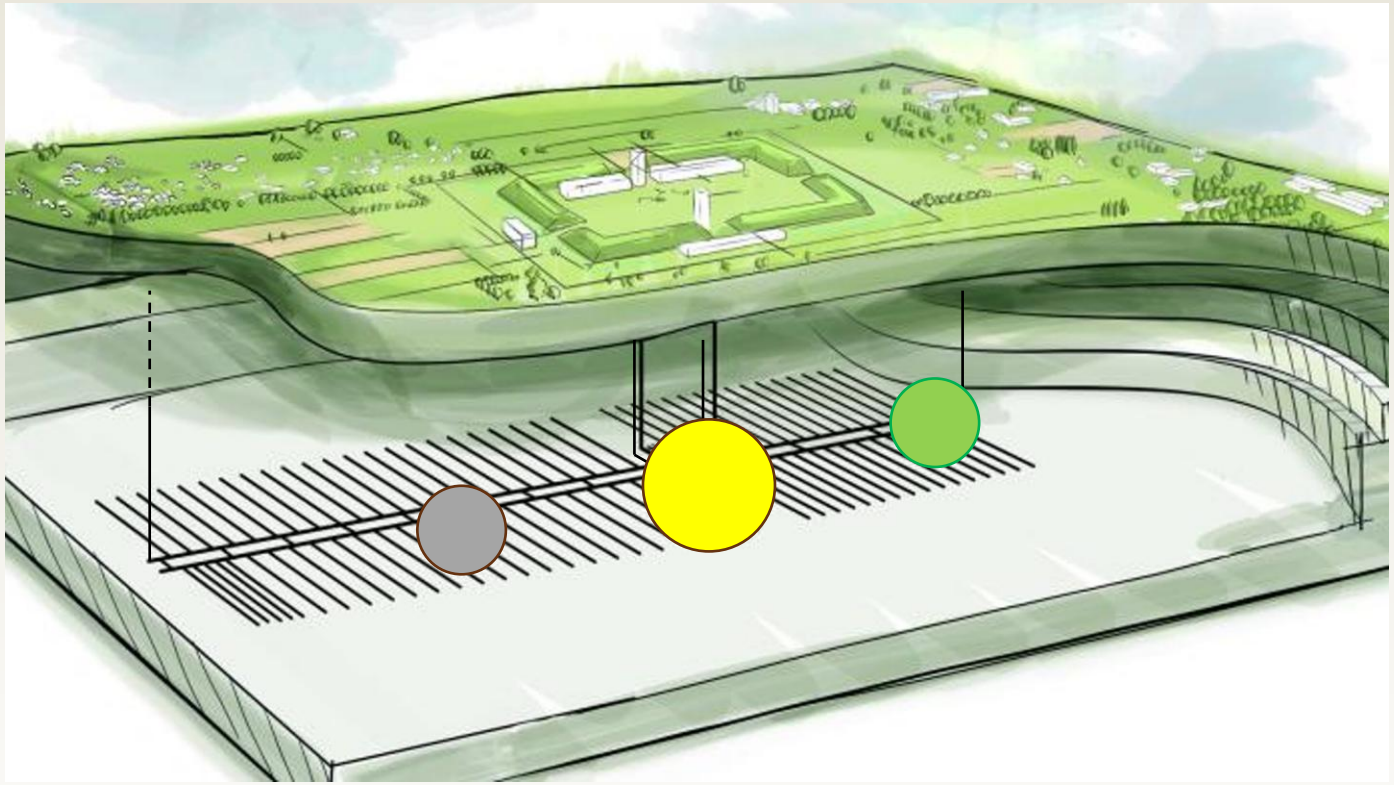
- Importance of cladding integrity
  - Safety function
    - **Confinement** = leak tightness & no contamination
    - **Containment** = limit dispersal in case of breach

+ Ageing management

+ Normal vs. accidental handling & transport
  ⇨ cladding embrittlement?

Disposal adds other questions

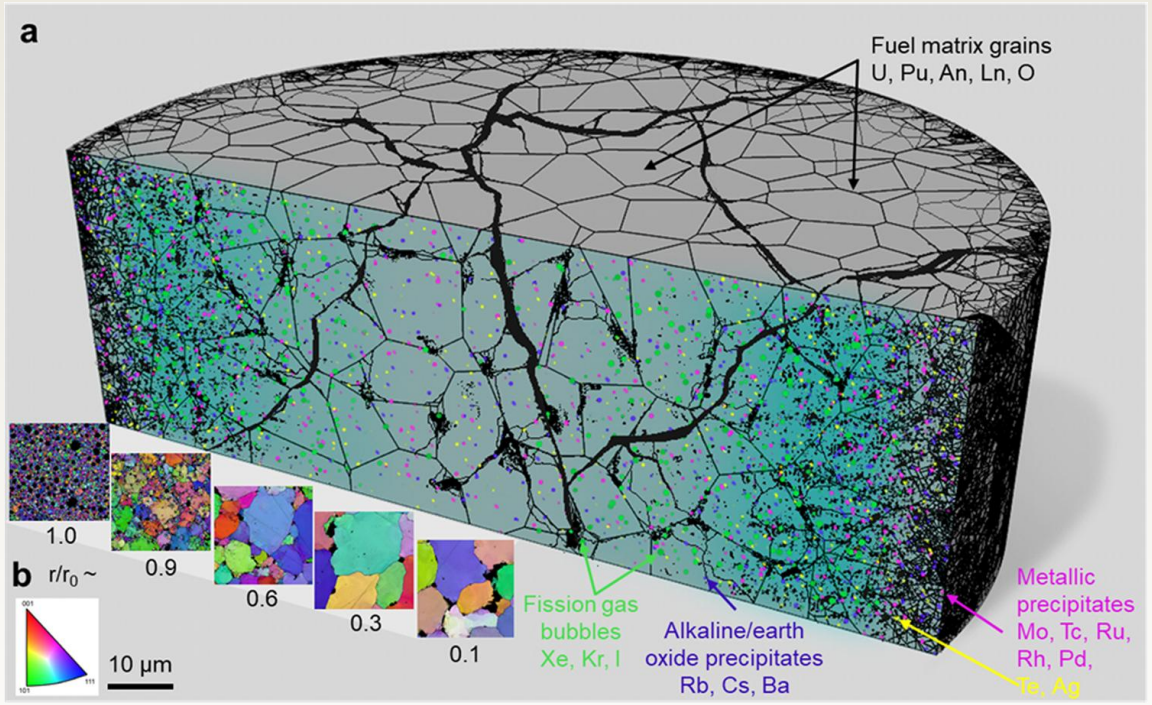




Leaching → Migration → Groundwater → Exposure

Which radionuclides matter for migration?

- Concern: mobile species in host rock
  - Few long-lived activation & fission products
    - Dominate exposure following to migration
  - Actinides
    - Dominate radiotoxicity
    - generally sorbed by clay ⇨ less mobile



Sources:
K. S. Mao *et al.*, "Identifying chemically similar multiphase nanoprecipitates in compositionally complex non-equilibrium oxides via machine learning," *Commun. Mater.*, vol. 3, no. 1, pp. 1–13, 2022, doi: 10.1038/s43246-022-00244-4.

Conservatism is essential

Fast

- Sudden total release

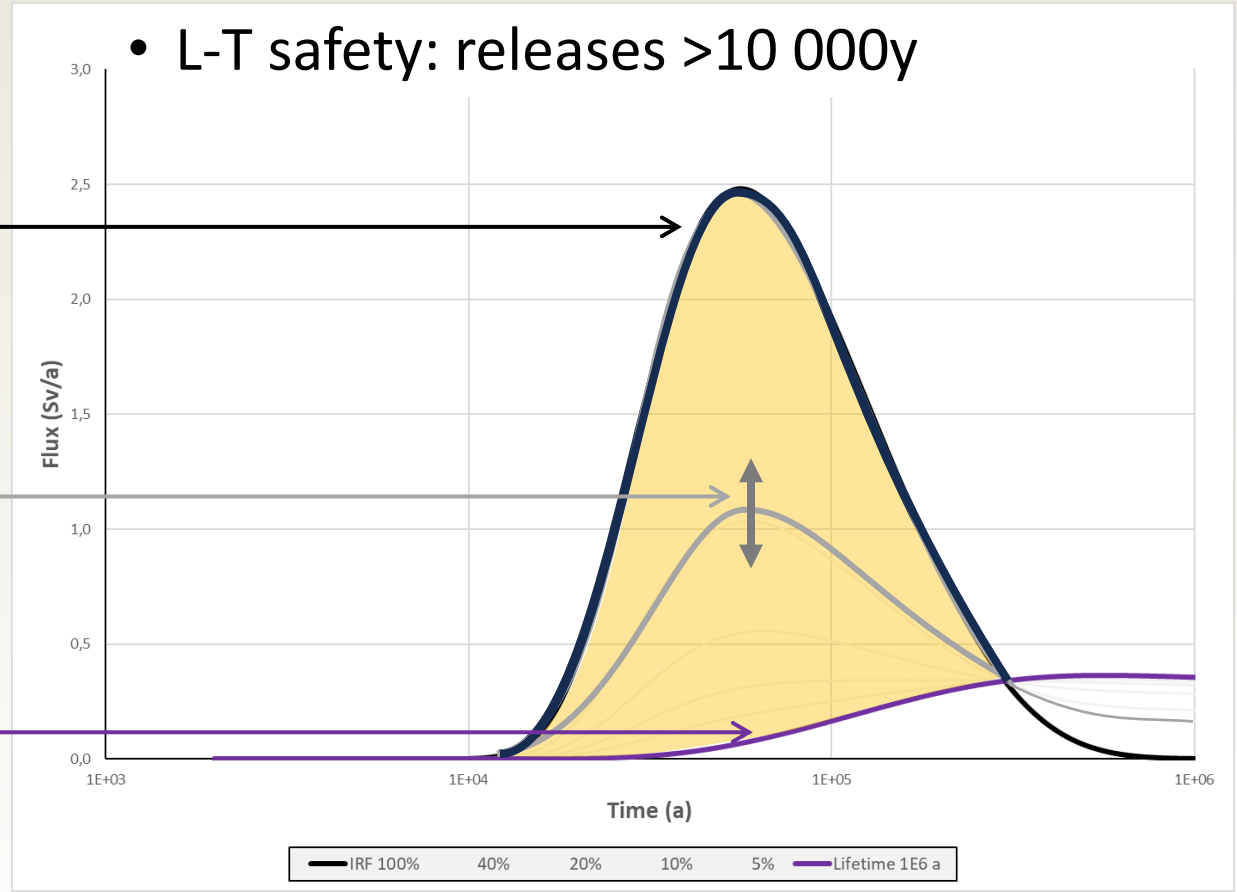
Inter-mediate

- Accessible fraction
- Seems to correlate with in-reactor parameter: fission gas release

Slow

- Only matrix dissolution

- L-T safety: releases >10 000y



Conservatism is essential, but…

- Risks of excessive conservatism
  - Overdesign of engineered barriers
  - Distorted weighting of site-selection criteria

    ⇨Potentially suboptimal site choice

⇨ Best-estimate (+ uncertainties)
+ Tests representative of the Belgian spent fuel inventory

Why today?

1

Fuel access will become more difficult

Transfer to dry storage will make access for sampling and examination much more difficult.

2

R&D needs a decade to deliver for the safety case

Around ten years of experimental R&D are needed to provide sufficient evidence for the **host rock and site selection** (around 2040) and the geological disposal **safety case** (targeted for submission around 2045).

3

First-hand operating knowledge is best captured

The operator will maintain spent fuel expertise until at least around 2050, but access to staff with first-hand experience of fuel cycle monitoring will progressively decline.

Take-aways

1. Geological disposal remains necessary!
2. We will get valuable information from Engie, but we need to complement it for our specific needs
3. R&D supports safety and decisions
4. Evidence gathering needs to start now!



Knowledge management within the spent fuel platform

Valentin KERLEGUER
FANC – AFCN

24-11-2026

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Why the emphasis on knowledge management?

Avoid knowledge loss in decades to come	Support safety assessment with R&D	Preserve future options
• Staff turnover • Data migration • Retain expertise	• Safety case for geological disposal • Licensing support	• Reprocessing possibilities for different types of spent fuel (dry vs wet storage) • Strategic flexibility

Collaboration: Spent Fuel Platform FANC, NIRAS- ONDRAF & SCK CEN

Objectives & scope

- Sharing
- Knowledge
- Developing
- Competences
- Preserving
- Infrastructure

in view of safe long-term management of Belgian NPP spent fuel

FANC

Regulatory guidance:
Advice on priorities and work programme

Facilitate information transfer from ENGIE, EURATOM

Build expertise for future regulatory work

NIRAS ONDRAF

Expertise in operational and long-term management radioactive waste

Prepare future management of spent fuel

- Coordination of platform
- Definition of needs
- Integration of results

Interactions ENGIE & Hedera

- Knowledge transfer from ENGIE
- Financing by Hedera

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Research expertise and infrastructure

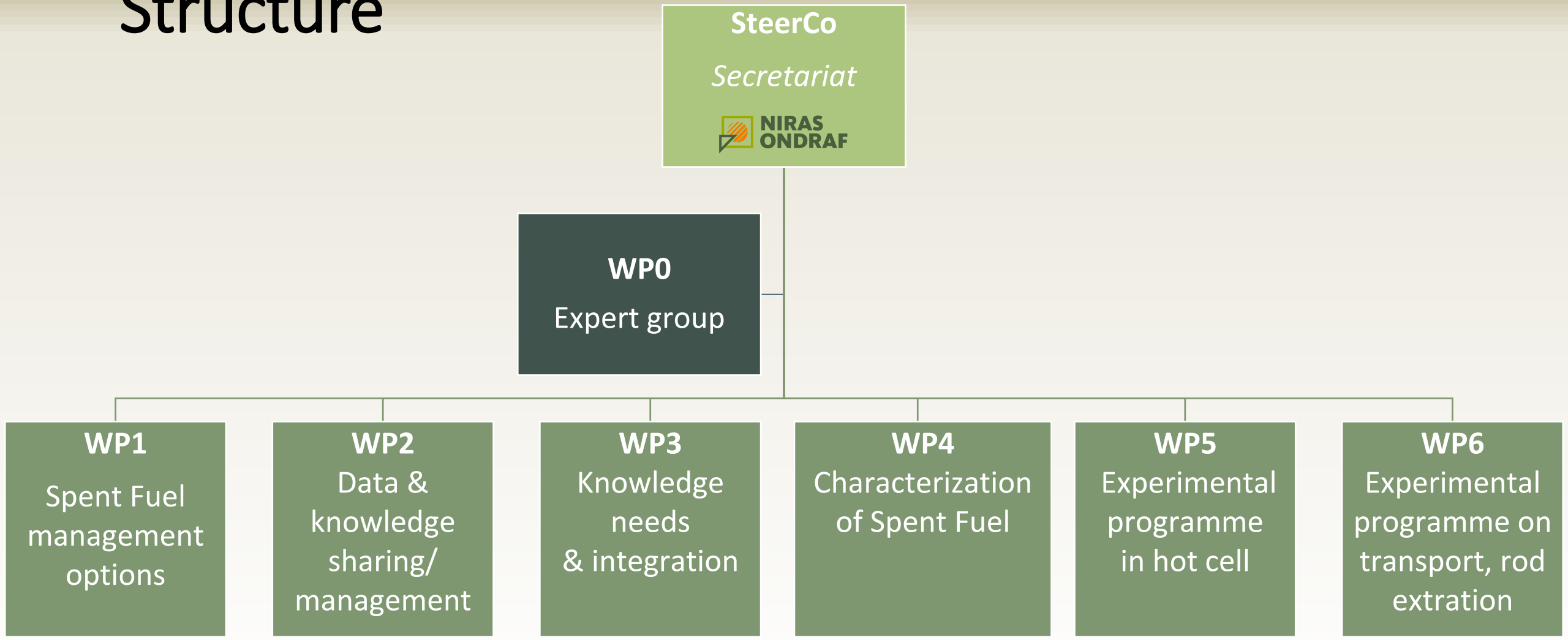
- Experienced workforce
- Nuclear labs
- Digital tools (calculation cluster, codes,…)

Management of data

BEL V

BELG PROCESS

Spent fuel knowledge platform – Structure



WP2: data and knowledge sharing/management → focus of FANC-AFCN, BelV

Goal: Knowledge, data and competency transfer

1. Consolidate available knowledge (old inspections reports, data received, etc..)
2. Perform thematic inspections on knowledge management
3. Collect and analyse international best practices and experience
4. Coordinate and/or participate in working group on the topic
5. Report and, if necessary, Guidance or Technical Regulation

Spent fuel data – Different necessities

Operational data
(ENGIE)



Reactor operation
Monitoring
Spent fuel records

Future needs



Disposal safety case
Reprocessing
Characterisation



Archived data



What is actually kept?
Long-term retention

Knowledge gap?

Objective: ensure that all data for future spent fuel management are identified, achieved and accessible

Belgian experience – thematic inspections

The authorities will verify existing practices in Belgium regarding spent fuel:

- Data management and validation
- Knowledge management
- Competencies management and training

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International experience



Key topics of discussion

Liabilities and responsibilities

Data for geological disposal (with/without reprocessing)

Access and transfer of information

Integration in the law

Law evolution



Based on lessons learned in Belgium and internationally (REX), assess **whether the legal and regulatory framework should evolve** to support the long-term management of spent fuel, including:

- Technical Regulation to frame the future transfer and to secure all the information
- Evolution of the law for the data, knowledge and competencies management
- Evolution of the law on reprocessing of spent fuel

Key Messages

- Long-term safety depends on maintaining knowledge, records and expertise over decades.
- National and international experience is being collected to identify best practices for knowledge transfer and preservation.
- A common framework is being developed to support the future transfer of responsibilities and information.
- Lessons learned may lead to new technical regulations or adaptations to the legal framework where necessary.



Belgian programme
on radioactive waste management

Overview of the work programme

Tomas Vandoorne

24-11-2026

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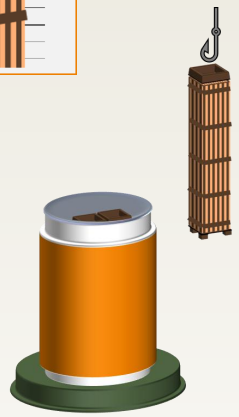
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High-level objectives



1. Determine radiological and chemical content of SNF inventory



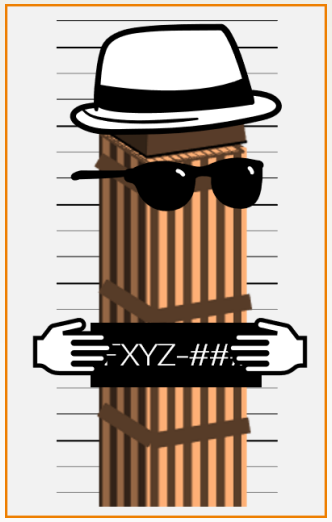
2. Determine the properties of SNF impacting the operational stages,
   to optimise management strategy and design/operation of the facilities



3. Determine the properties of SNF impacting the long-term safety
   to guide site selection and optimise disposal package/repository design & loading

1. Radiological and chemical inventory

Could we fully characterize the spent fuel inventory with measurements?



1. Radiological and chemical inventory

Could we fully characterize the spent fuel inventory with measurements?

- Measure every fuel assembly

  ➔ not feasible for fuel in dry storage containers

- Measure every property we are interested in

  Non-destructive measurements are essentially limited to neutron and gamma emission

NOT POSSIBLE





IAEA, 2011

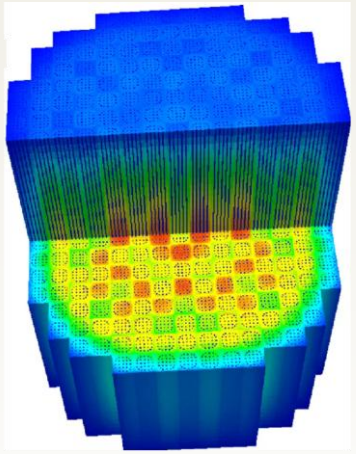
1. Radiological and chemical inventory





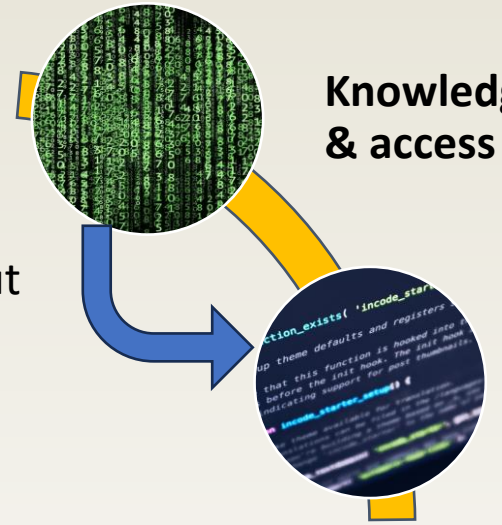
Modelling/ Calculation

Radiological and chemical **content**



- By developing calculation routes, starting from reactor cycles
- For all fuel types (UOX, UOX-Gado, MOX), Belgian reactor designs

1. Radiological and chemical inventory



Input

Knowledge transfer
& access to data/documents

Modelling/
Calculation

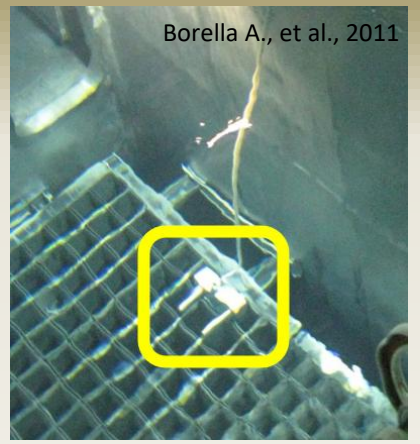
Radiological and chemical **content**

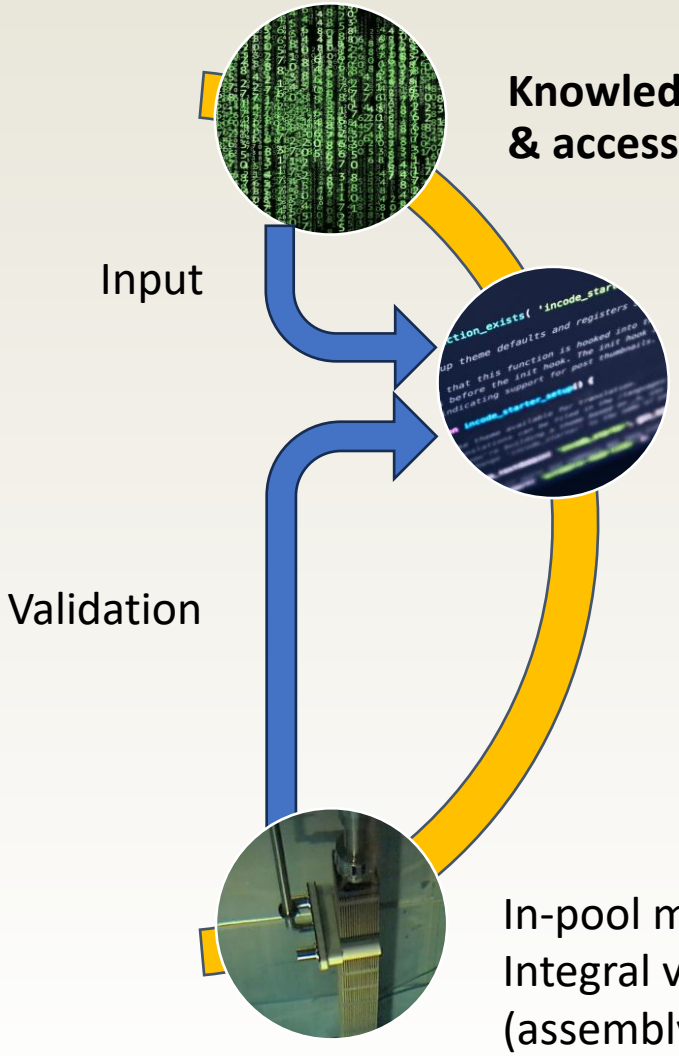
- Access to data & documents from ENGIE
- Knowledge and competence sharing

  ➔ Correct understanding and use of ENGIE data

1. Radiological and chemical inventory







Knowledge transfer
& access to data/documents

Modelling/
Calculation

Radiological and chemical **content**

In-pool measurements
Integral validation
(assembly-level)

- Measurements performed in Doel-3/4 in the framework of possible future reprocessing
- Complementary measurements in Doel-3 in 2025:
  - UOX fuel assemblies with lower burn-up
  - MOX assemblies with varying properties
- Non-destructive measurements are essentially limited to neutron and gamma emission

1. Radiological and chemical inventory



Knowledge transfer
& access to data/documents

Input

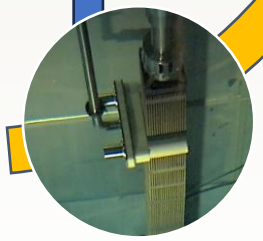


Modelling/
Calculation

Validation



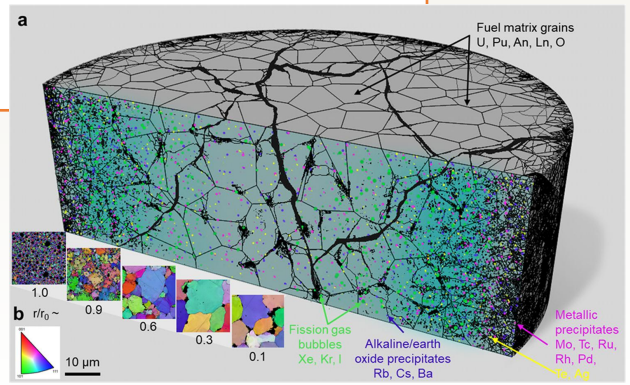
Hot-lab analyses
"Fine" validation
(sample-level)



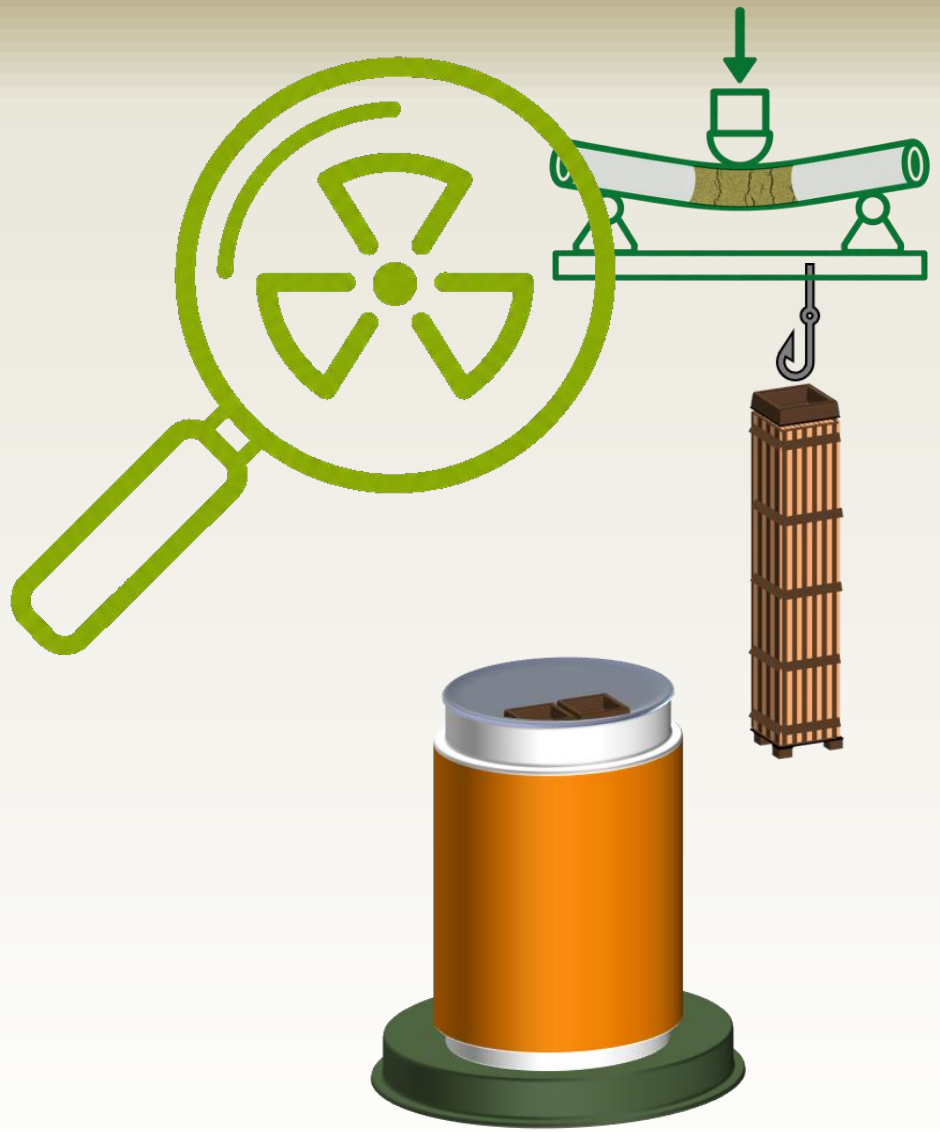
In-pool measurements
Integral validation
(assembly-level)

Radiological and chemical **content**

- Representative fuel rods for sampling
- Validation of:
  - difficult-to-measure radionuclides
  - fission gas release
  - …



2. Properties impacting operational stages



2. Properties impacting operational stages

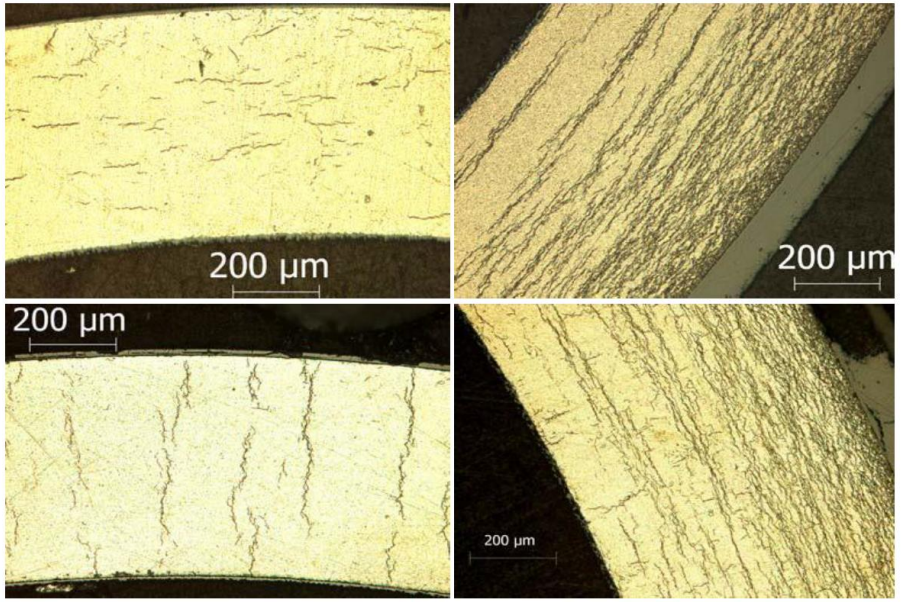
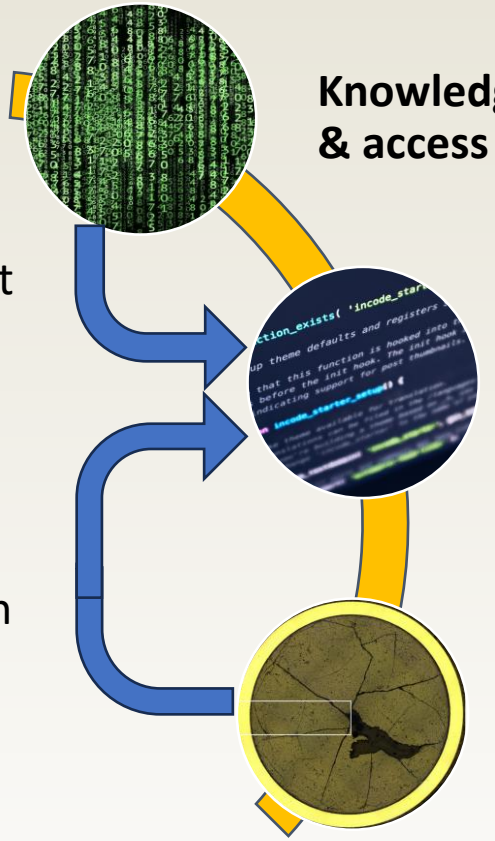


Figure 88 Hydride distribution and orientation in HBU fuel. The top figures show the cladding as irradiated, the bottom figures show the cladding after thermal treatment at 400°C and 140 MPa. Left) M5 with 76 µg/g (top) and with 94 µg/g H (bottom). Right) Zr-4 cladding with 640 µg/g (top) and with 615 µg/g H (bottom). Source: (Billone et al., 2013b) .

Experiments on behaviour of cladding

- Build knowledge on mechanical behaviour in function of cladding state after irradiation
- For all cladding types, but focusing on Belgian specificities (PCA-2b)
- International collaboration where possible/relevant
- Develop calculation route to determine cladding state after irradiation for each fuel assembly

2. Properties impacting operational stages



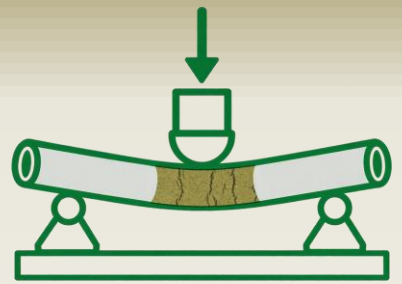
Knowledge transfer
& access to data/documents

Input

Modelling/
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Validation

Hot-lab analyses
"Fine" validation
(sample-level)



Experiments on behaviour of cladding

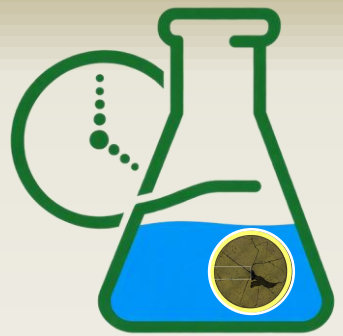
Mechanical behaviour for whole inventory

- Build knowledge on mechanical behaviour in function of cladding state after irradiation
- For all cladding types, but focusing on Belgian specificities (PCA-2b)
- International collaboration where possible/relevant
- **Develop calculation route to determine cladding state after irradiation for each fuel assembly**

3. Properties impacting the long-term safety

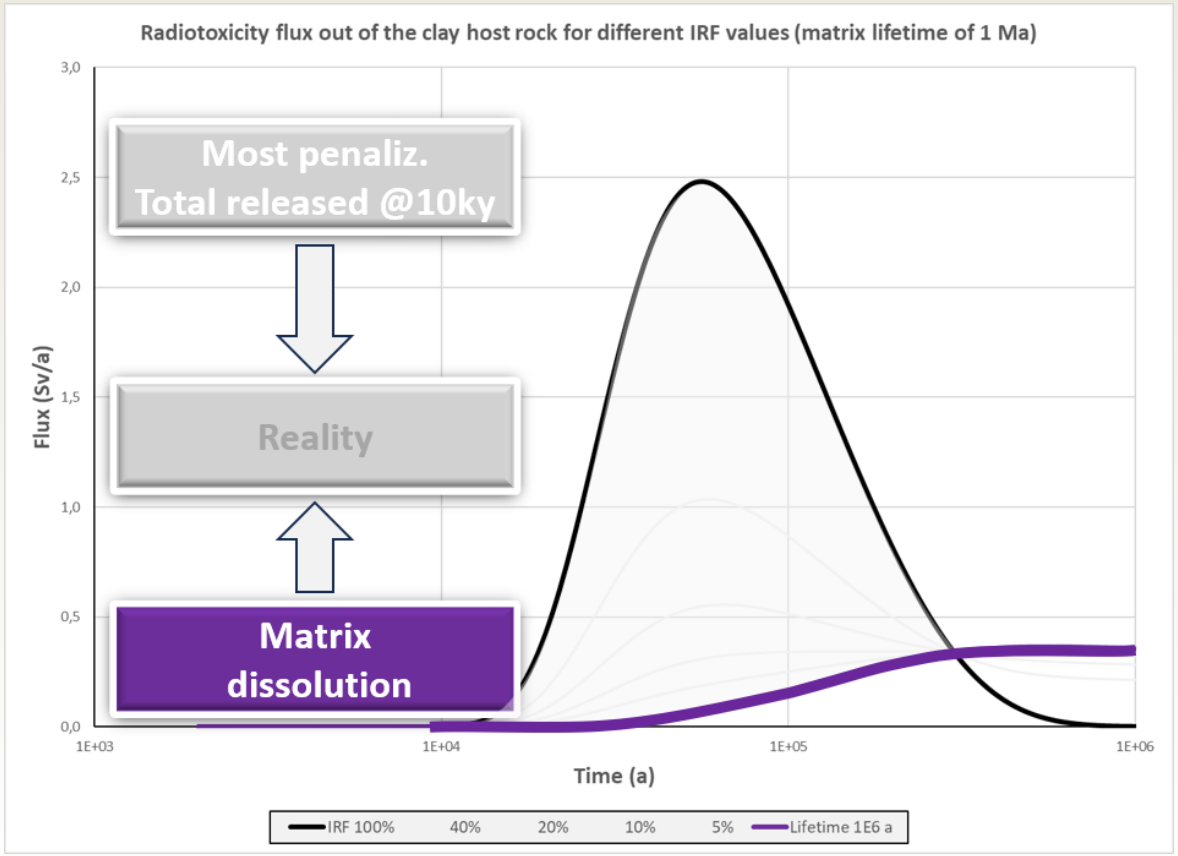


3. Properties impacting the long-term safety

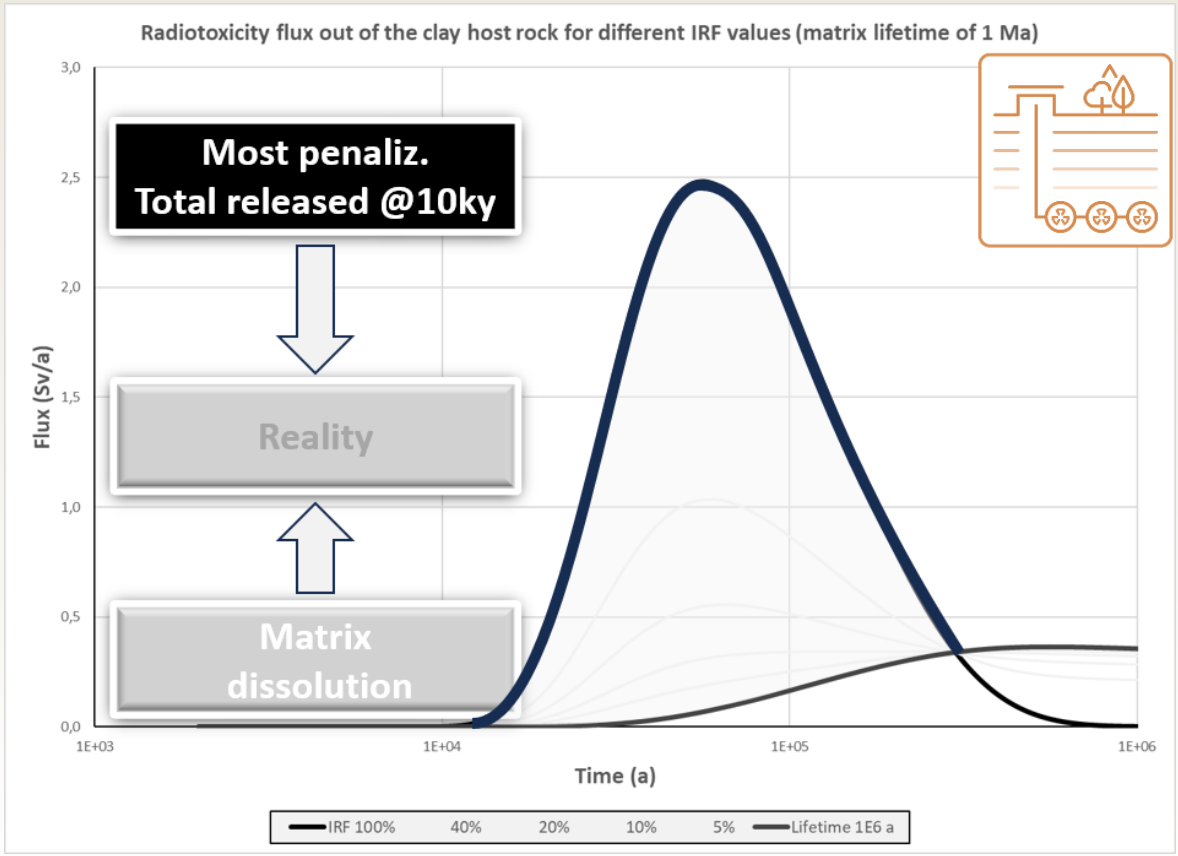


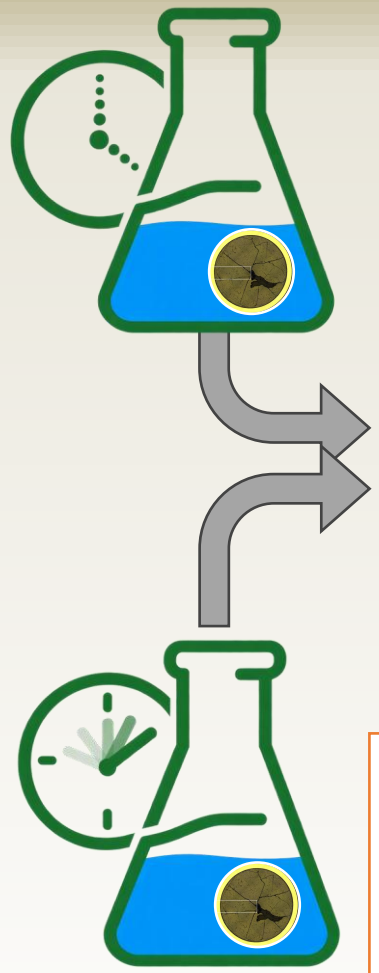
Experiments on slow fuel dissolution

- Continuation for UOX, to start for MOX
- International collaboration where possible/relevant



3. Properties impacting the long-term safety



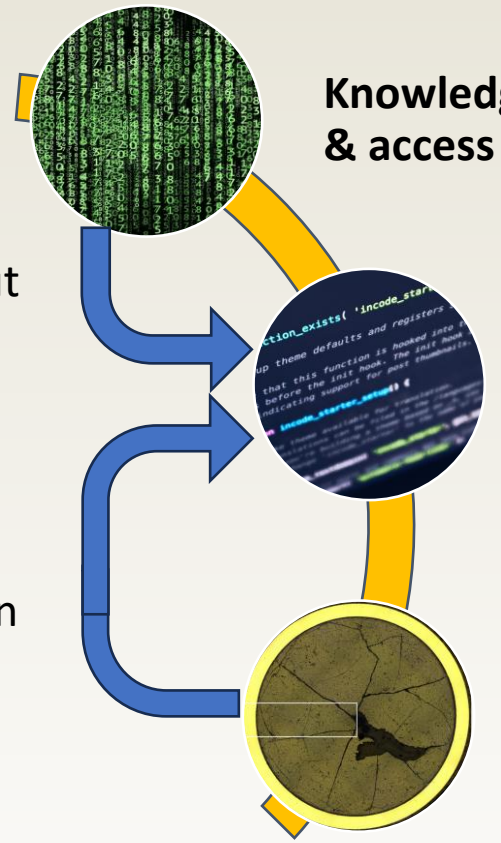


Experiments on slow fuel dissolution

Experiments on fast radionuclide release

- Establish **correlation** to Fission Gas Release
- For all fuel types, but focusing on Belgian specificities (high FGR, MOX)
- Develop calculation route to determine (best estimate) Fission Gas Release

3. Properties impacting the long-term safety



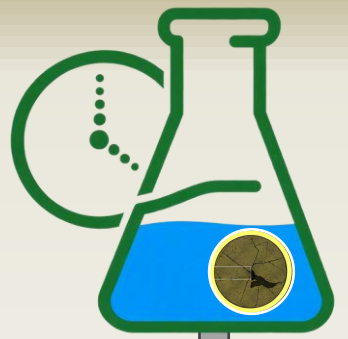
Knowledge transfer
& access to data/documents

Input

Modelling/
Calculation

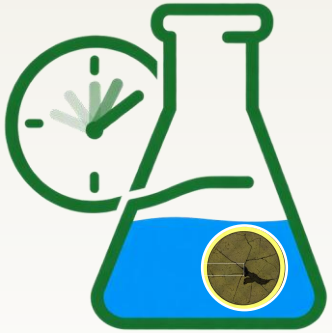
Validation

Hot-lab analyses
"Fine" validation
(sample-level)



Experiments on slow fuel dissolution

Long-term behaviour for whole inventory



Experiments on fast radionuclide release

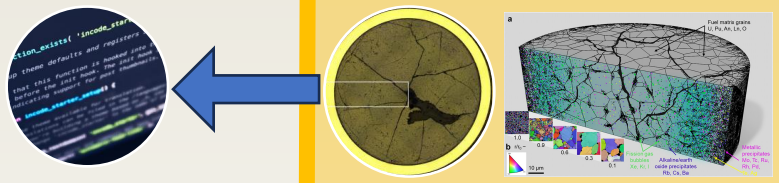
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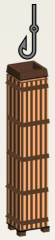
High-level objectives

Acquisition of representative samples
is key to the programme



1. Determine radiological and chemical **content** of SNF inventory





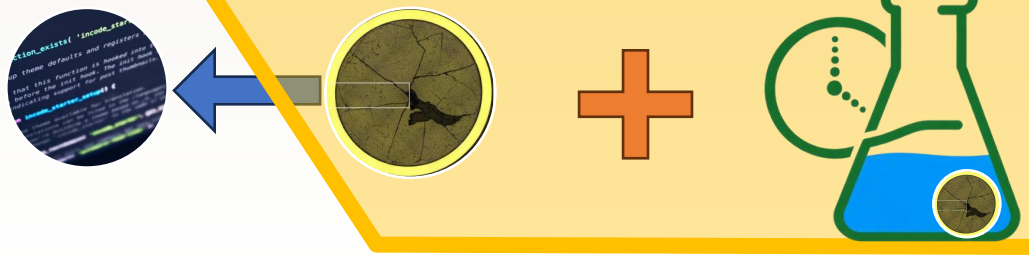


2. Determine the properties **of SNF** impacting the operational stages,





3. Determine the properties of SNF impacting the long-term safety





Acquisition of representative samples

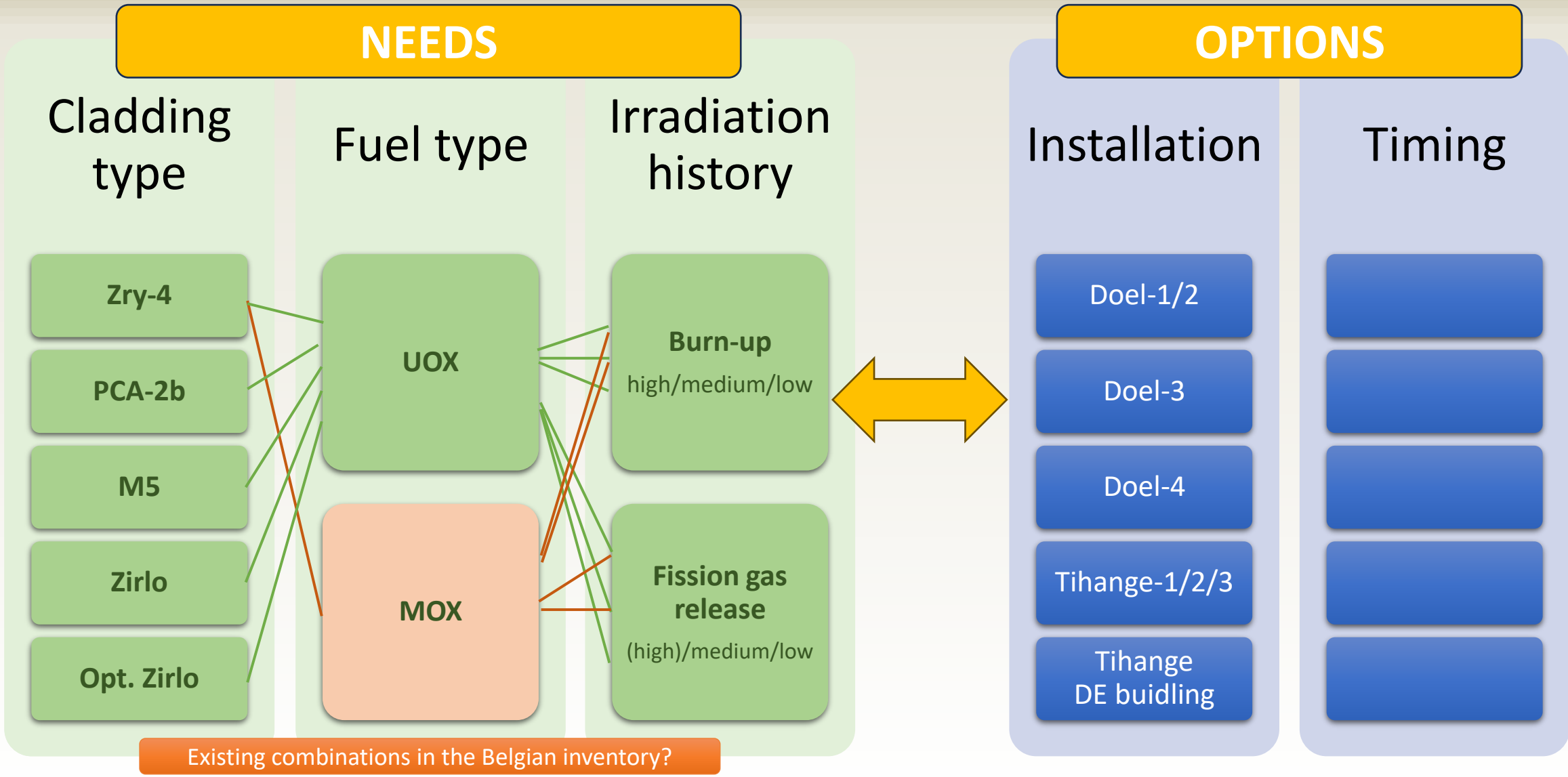
…



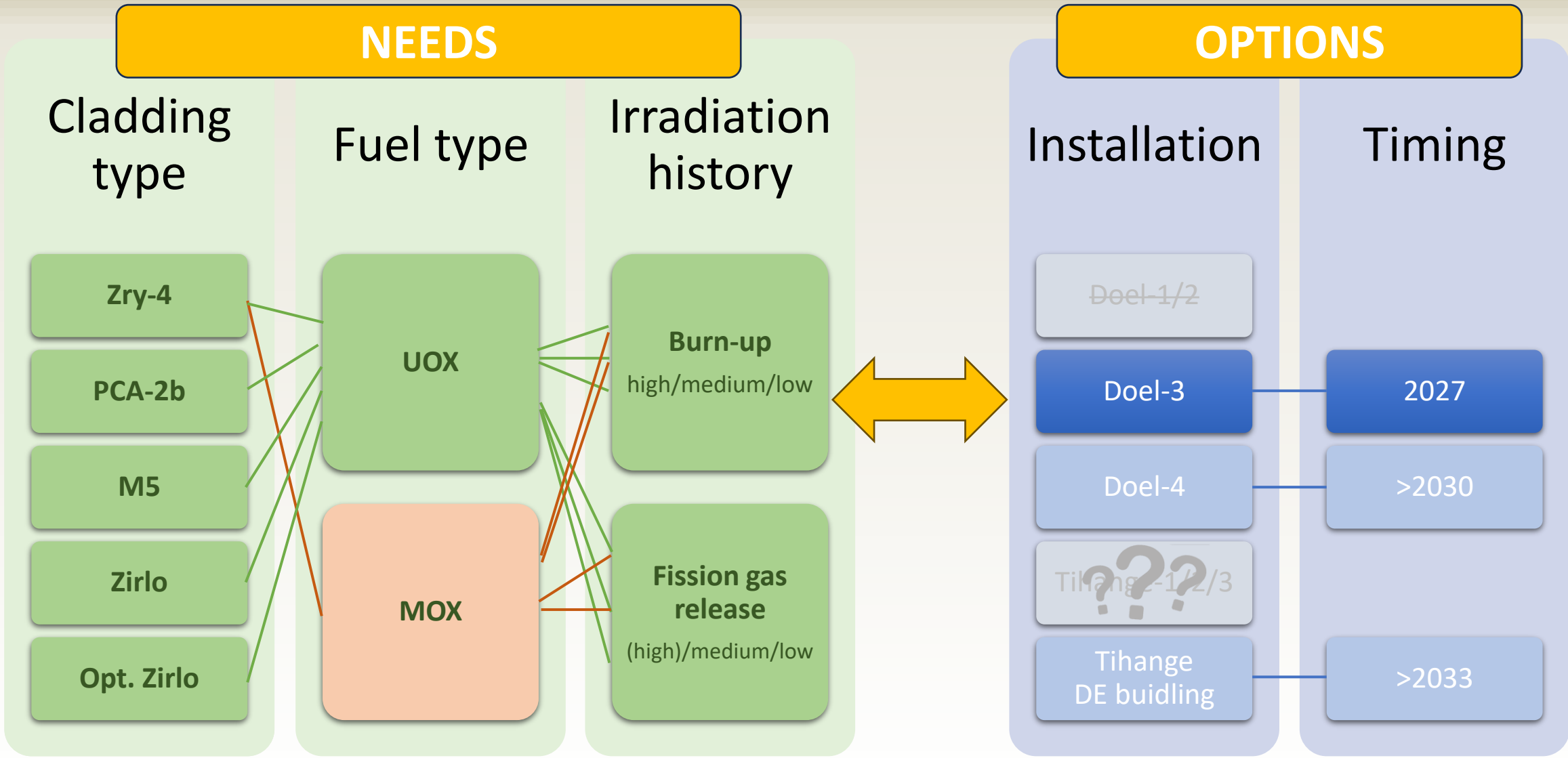
… by extracting fuel rods from their assembly

Images from Carrilho, L. (2012) and Nuclear Energy Agency

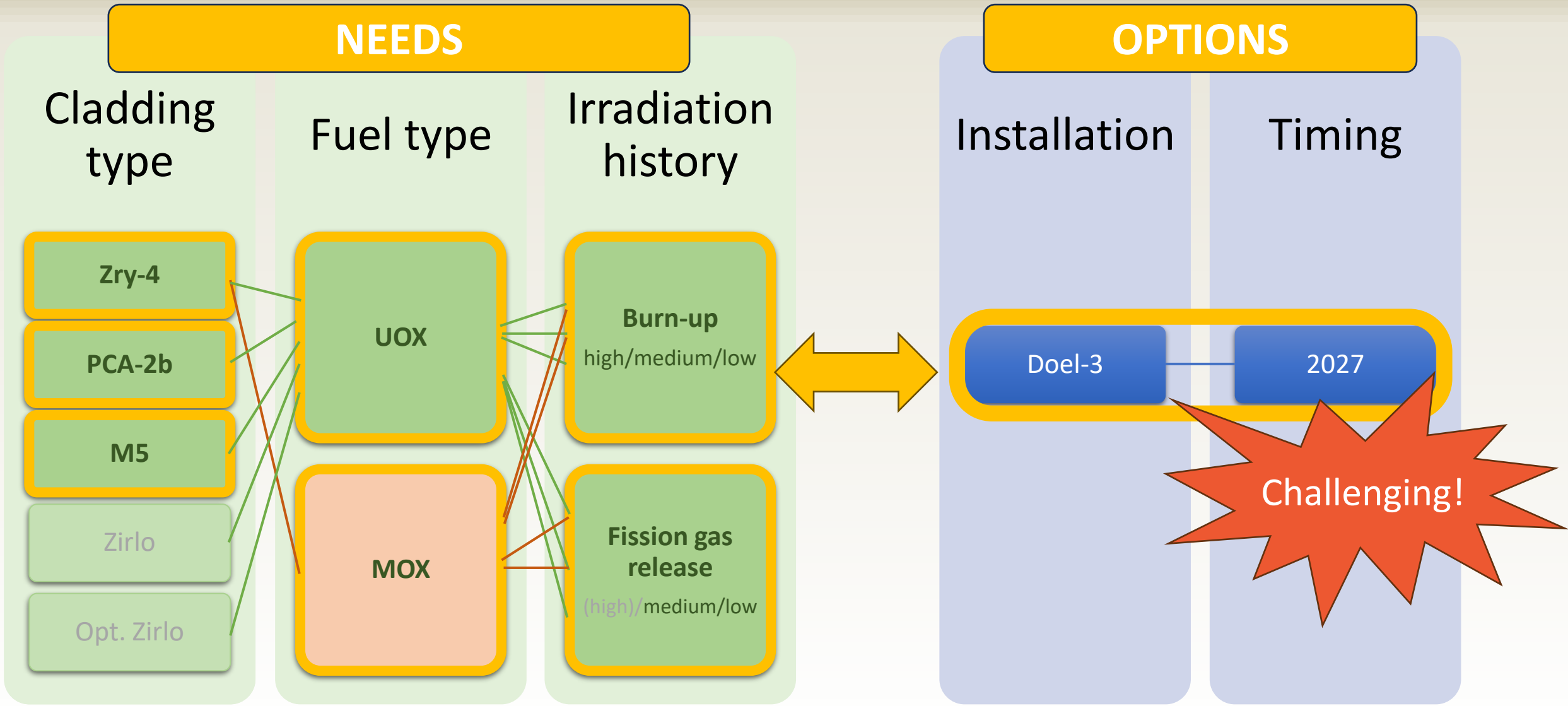
Acquiring samples by “Fuel rod extraction”



Acquiring samples by “Fuel rod extraction”



Acquiring samples by “Fuel rod extraction”



Take-aways "Why should we know more … today?"

1. Geological disposal remains necessary!
2. We will get valuable information from Engie,
   but we need to complement it for our specific needs
3. R&D supports safety and decisions
4. Evidence gathering needs to start now!

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- **Collaboration platform FANC – SCK – NIRAS**
- **Work program combines calculations & experiments**
  - **Knowledge & data sharing from ENGIE**
  - **Fuel rod extraction is key element**

foreseen in Phoenix law