

# **Comparative study of the management strategies for the Belgian nuclear spent fuel**

**Topical Day "Partitioning meets transmutation"**

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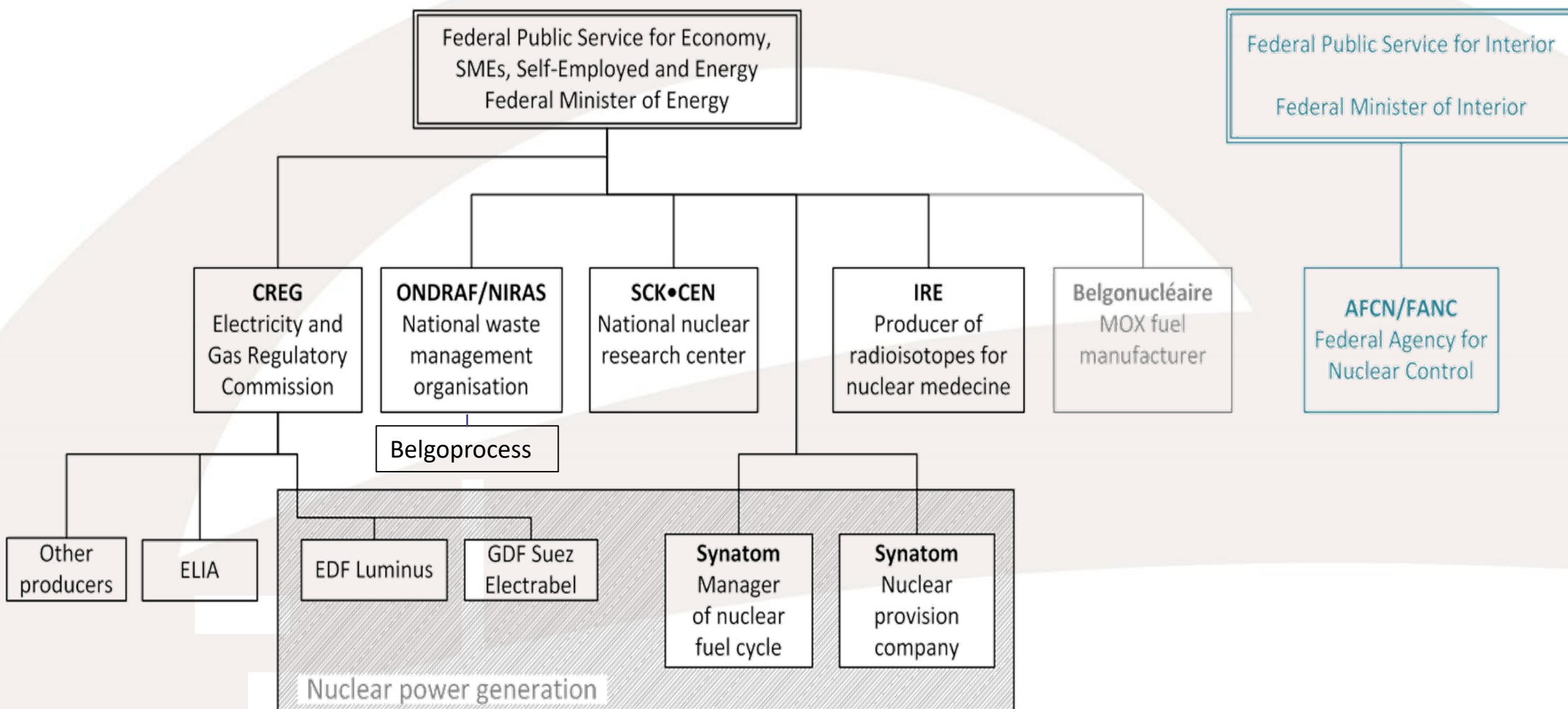
*FPS Economy, SMEs, Self-Employed and Energy*

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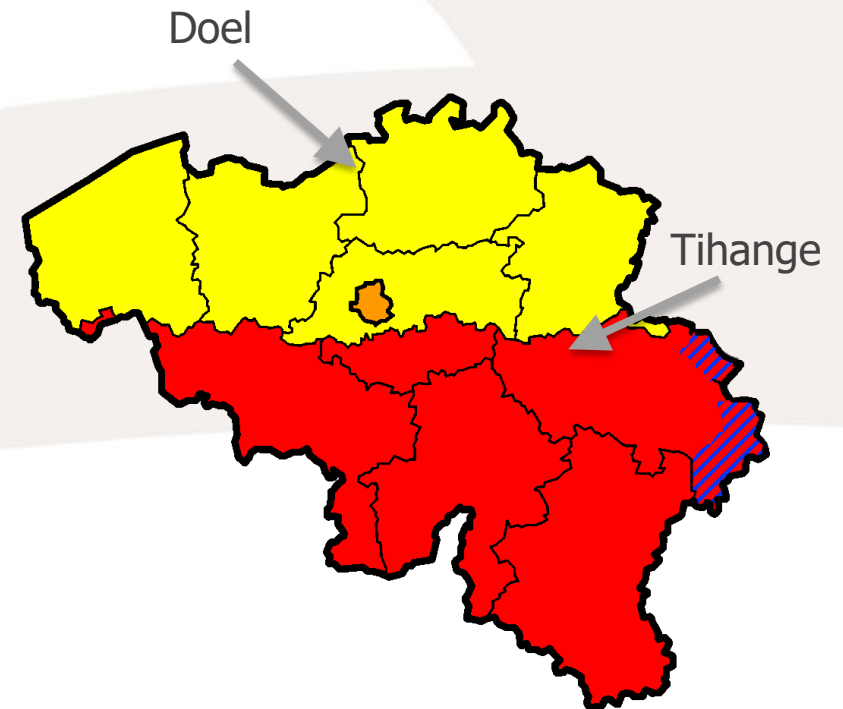
# Nuclear sector in Belgium in a nutshell



## Overview NPP's in Belgium

- In 2016, roughly 51 % of the belgian electricity was produced by nuclear power plants
- Only one nuclear operator: ELECTRABEL - ENGIE (part of ENGIE (FR))
- There are 2 nuclear sites in Belgium :
  - Doel, with 4 reactors
  - Tihange, with 3 reactors

With a total installed capacity of 5.921 MW



## Overview NPP's in Belgium

- EDF BELGIUM owns 50% of Tihange Unit 1
- EDF LUMINUS owns 10,2% of Tihange 2 & 3 et Doel 3 & 4

Reactor Unit	Type	Net Capacity [MW(e)]	Status	Operator	Reactor Supplier	Construction Date	First Criticality Date	First Grid Date	Commercial Date
DOEL-1	PWR	433	Operational	ELECTRAB	ACECOWEN	1969-07-01	1974-07-18	1974-08-28	1975-02-15
DOEL-2	PWR	433	Operational	ELECTRAB	ACECOWEN	1971-09-01	1975-08-04	1975-08-21	1975-12-01
DOEL-3	PWR	1006	Operational	ELECTRAB	FRAMACEC	1975-01-01	1982-06-14	1982-06-23	1982-10-01
DOEL-4	PWR	1033	Operational	ELECTRAB	ACECOWEN	1978-12-01	1985-03-31	1985-04-08	1985-07-01
TIHANGE-1	PWR	962	Operational	ELECTRAB	ACLF	1970-06-01	1975-02-21	1975-03-07	1975-10-01
TIHANGE-2	PWR	1008	Operational	ELECTRAB	FRAMACEC	1976-04-01	1982-10-05	1982-10-13	1983-06-01
TIHANGE-3	PWR	1038	Operational	ELECTRAB	ACECOWEN	1978-11-01	1985-06-05	1985-06-15	1985-09-01

# Phase-out of nuclear electricity production

- 2003** Complete but gradual phase-out the use of nuclear fission energy for commercial electricity production by 2025
- prohibits the construction of new nuclear power plants and
  - set a 40-year limit on the operational period of existing plants.
- 2012** Tihange 1 shutdown postponed by 10 years (2015 → 2025)
- 2015** Doel 1 and Doel 2 shutdowns postponed by 10 years (2015 → 2025)
- Belgium acknowledges the importance of investing in nuclear research to
    - Support safe operation of nuclear systems in Belgium and in Europe
    - Develop sustainable solutions for the management of radioactive waste
    - Maintain nuclear competences to guarantee the safe dismantling of nuclear power plants and the long term management of nuclear waste

## Spent nuclear fuel inventory

- The main assumptions are as follows (National report) :
  - the Doel 1 and 2 and the Tihange 1 commercial nuclear reactors will be operated during 50 years and the four other reactors will be operated during 40 years;
  - a total of about 1 000 tHM spent fuel from commercial nuclear reactors will still be reprocessed (including 66 tHM MOX spent fuel), in addition to the 672 tHM UOX that have already been reprocessed in the past.
  
- The estimated total inventory is :
  - 1 400 canisters Vitrified wastes
  - 8 500 assemblies Nuclear power plants spent fuel

# Nuclear waste management in Belgium

- Low and intermediate level short-lived waste
  - 2006: government approved **surface disposal** at Dessel (cAt)
  - 2012: request to obtain the license for the disposal facility itself has been introduced with the safety authorities (FANC)
- Medium high-level and long-lived waste
  - R&D program since 1974 on **geological disposal** started by SCK•CEN, presently managed by ONDRAF/NIRAS
  - ONDRAF/NIRAS prepared a « Waste plan » in 2011 that was submitted to the government to obtain a decision-in-principle on the geological disposal in clay (Boom & Ypresian clays)
  - New parliamentary debate on reprocessing of commercial spent fuel is in the make
  - ONDRAF/NIRAS asked to open the siting to all types of suitable host formations
- Belgian and Luxembourg signed in 2016 a bilateral treaty for the final disposal of Lux waste in Belgium
- First National Programme on nuclear waste management published in 2016 (transposition of the EU nuclear waste directive 2011/70)

[http://economie.fgov.be/fr/binaries/National-programme-courtesy-translation\\_tcm326-279459.pdf](http://economie.fgov.be/fr/binaries/National-programme-courtesy-translation_tcm326-279459.pdf)



## National policies are in place for spent fuel management

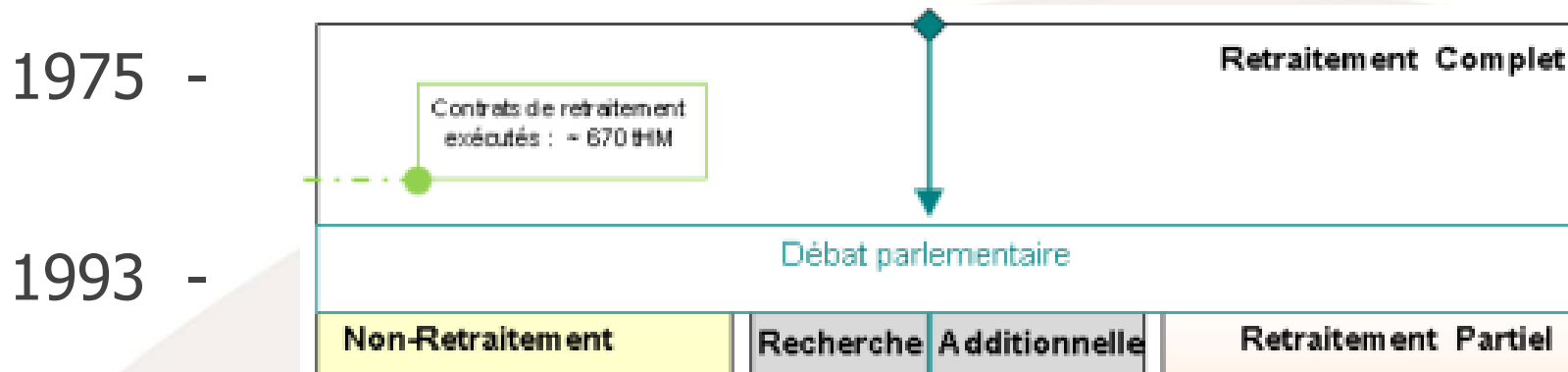
- The national policy for the management of spent fuel from commercial nuclear power plants, namely the safe storage of spent fuel followed by its reprocessing or direct disposal

**Table 7** – Synoptic view of the national programme for the management of spent fuel and radioactive waste, at 31 December 2014, according to several key indicators. [✓ : yes; ✗ : no; ● : interim situation]

	MANAGEMENT BY PRODUCERS / OWNERS					TRANSFER	MANAGEMENT BY ONDRAF/NIRAS										
							SHORT AND MEDIUM TERMS (treatment, conditioning and storage)					LONG TERM (disposal)					
	National policy?	Regulation		Operational management?	Financing mechanism?		National policy?	Regulation		Operational management?	Financing mechanism?	National policy?	Regulation		RD&D?	Operational management?	Financing mechanism?
		general?	dedicated?					general?	dedicated?				general?	dedicated?			
Very short-lived waste	✓ [1]	✓	✓	✓	✓		not applicable					not applicable					
Category A waste	n.a. [2]	✓	✓	✓	✓	⇒	✓ [3]	✓	✓	✓	✓ [4]	✓ [5]	✓	● [6]	✓	✗ [7]	✓ [4]
Category B waste	n.a. [2]	✓	✓	✓	✓	⇒	✓ [3]	✓	✓	✓	✓ [4]	✗ [8]	✓	● [6]	✓	✗	✓ [4]
Category C waste (reprocessing)		not applicable					✓ [3]	✓	✓	✓	✓ [4]	✗ [8]	✓	● [6]	✓	✗	✓ [4]
Category C waste (spent fuel)		not applicable					✓ [3]	✓	✓	✓	✓ [4]	✗ [8]	✓	● [6]	✓	✗	✓ [4]
Spent fuel from Synatom	✓ [9]	✓	✓	✓	✓		not applicable					not applicable					
Spent fuel from SCK•CEN	✓ [10]	✓	✓	✓	✓		not applicable					not applicable					
Radium-bearing radioactive waste (UMTRAP and Bankloop)	n.a. [2]	✓	✓	✓	✓	⇒	✗	✓	✓	✗ [12]	✓ [4]	✗	✓	● [6]	✗	✗ [12]	✓ [4]
“Potential” radium-bearing radioactive waste [13]	n.a.	✓	● [14]	✓	✓	⇒ ? [14]	✗	✓	✓	✗ [12]	✓ [4]	✗	✓	● [6]	✗	✗ [12]	✓ [4]
“Potential” NORM radioactive waste [13]	n.a.	✓	● [14]	✓	✓	⇒ ? [14]	✗	✓	✓	✗ [12]	● [15]	✗	✓	● [6]	✗	✗ [12]	● [15]



## Spent fuel : current situation



- From 1975 to 1993, The « national policy » was the full reprocessing
  - Contracts with COGEMA (AREVA) led to the reprocessing of 670 tHM of spent fuel.
- In 1993, a debate took place in the parliament that concluded in:
  - Reprocessing contracts put on hold,
  - R&D to further investigate both direct disposal and reprocessing,
  - Progress report due after 5 years.
- In 1998, the government confirmed the decisions of 1993:
  - Keep investigating both direct disposal and reprocessing,
  - Do not conclude reprocessing contract without its approval.
- No further policy developments since then.
- DG Energy has published a prospective study on the strategies for the management of Belgian nuclear spent fuel (2016, an update is foreseen in 2018)

- ONDRAF/NIRAS developed a reference project for the joint management of ILW and HLW based on:
  - a waste inventory (full reprocessing for spent fuel)
  - a geological disposal design in poorly-indurated clay formations
    - The design was updated in 2018
  - an operational scenario (planning, human resources, etc.)
- A costing of the reference project was published in 2013
  - 3.2 GEUR<sub>2013</sub> out of which 1.33 GEUR<sub>2013</sub> for HLW
  - EPRI margins included
- An update of the reference scenario was announced end of September 2018
  - 8 GEUR<sub>2017</sub> out of which 55% for HLW
  - 2.7 GEUR<sub>2017</sub> opportunities discount being studied in the 2 next years

## Spent fuel: nuclear provisions

- Since 2003 a legal specific arrangement to organize the prudential control of the provisions (existence, sufficiency and availability) for the dismantling of NPP's and the management of the irradiated fissile material in those NPP's
- All provisions are to be managed in a designated company, Synatom
  - Synatom = 100% daughter company of Electrabel-Engie but a separate legal unit
  - All owners must pay their part into the same fund
- Creation of a supervising body : Commission on Nuclear Provisions
- Methodology:
  - the net present value of future liabilities must be present in the accounts of the nuclear provision company (Synatom)
  - built up during exploitation of the reactors with yearly interest yield
  - if shortage when decommissioning: deficit must be covered by the nuclear operators
  - every three year: audit of the methodology

- Belgium is phasing out nuclear energy for electricity generation but recognise the need to invest in nuclear R&D to pass a « fair » burden to future generations
- Belgium intends to remain at the forefront worldwide in :
  - Transmutation (Partitioning & Transmutation) of radioactive waste.
  - Nuclear medicine and medical radioisotope production
  - Accelerator technology
  - Research in new materials
- The MYRRHA project consists of three phases:
  - Phase 1: Fully modular infrastructure able to function independently as of 2026-2027, and generate scientific results and revenue
    - MINERVA: Accelerator 100 MeV + target stations (ISOL and Fusion material testing facility)
  - Phase 2: accelerator upgrade to 600 MeV
  - Phase 3: Nuclear reactor

# Belgium decided to build a new large nuclear research infrastructure MYRRHA

- Belgium allocated 558 MEUR for 2019 – 2038:
  - Phase 1
    - 2019 – 2026: 287 MEUR investment (CapEx) for building MINERVA (Accelerator up 100 MeV + PTF)
    - 2027 – 2038: 156 MEUR for OpEx of MINERVA
  - Phases 2-3
    - 2019 – 2026: 115 MEUR for further design, R&D and Licensing
- A stage-gate decision will be taken in 2026 whether to proceed with phases 2 and 3, either sequentially, or in parallel
- Belgium will establish an International non-profit organization (AISBL/IVZW) in charge of the MYRRHA facility for welcoming the international partners

# **PROSPECTIVE STUDY ON THE STRATEGIES FOR THE MANAGEMENT OF BELGIAN NUCLEAR SPENT FUEL**

- In order to set the framework of the study, we identified 7 underlying hypothesis :
  - The 2003 phase out law is executed
  - Geological disposal is approved as long term management strategy
  - The geological repository facility as foreseen by our RWMO is implemented
  - The geological repository facility is build in Belgium and hosts all the radioactive wastes arising from the belgian nuclear fuel cycle
  - Reversibility as recommended is foreseen
  - There will be radioactive wastes arising from the belgian nuclear fuel cycle whatever the strategy
  - Safe intermediate storage will be ensured

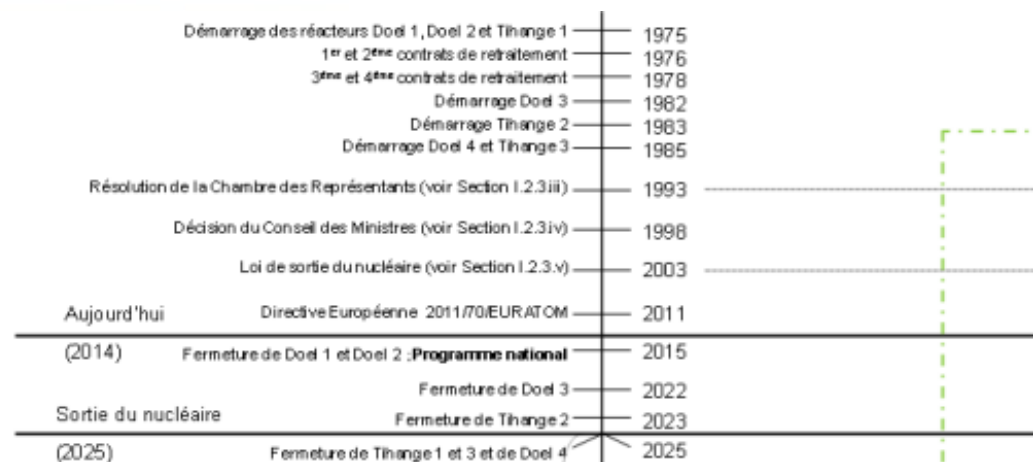


- We considered 4 dimensions or « reading keys »
  - Radiological aspects
  - Non proliferation
  - Stock of material with energetic potential
  - Economic aspects

Each strategy can be analysed with these dimensions in mind.

# Prospective study on the strategies for the management of Belgian nuclear spent fuel

- We considered 6 different strategies/options/possibilities
  - direct disposal
  - full reprocessing
  - partial reprocessing
  - advanced separation (partitioning)
  - incineration (transmutation)
  - additional research
- We integrated major planned milestones from different public authorities and private actors to identify critical policy « milestones »



### Hypothèses générales :

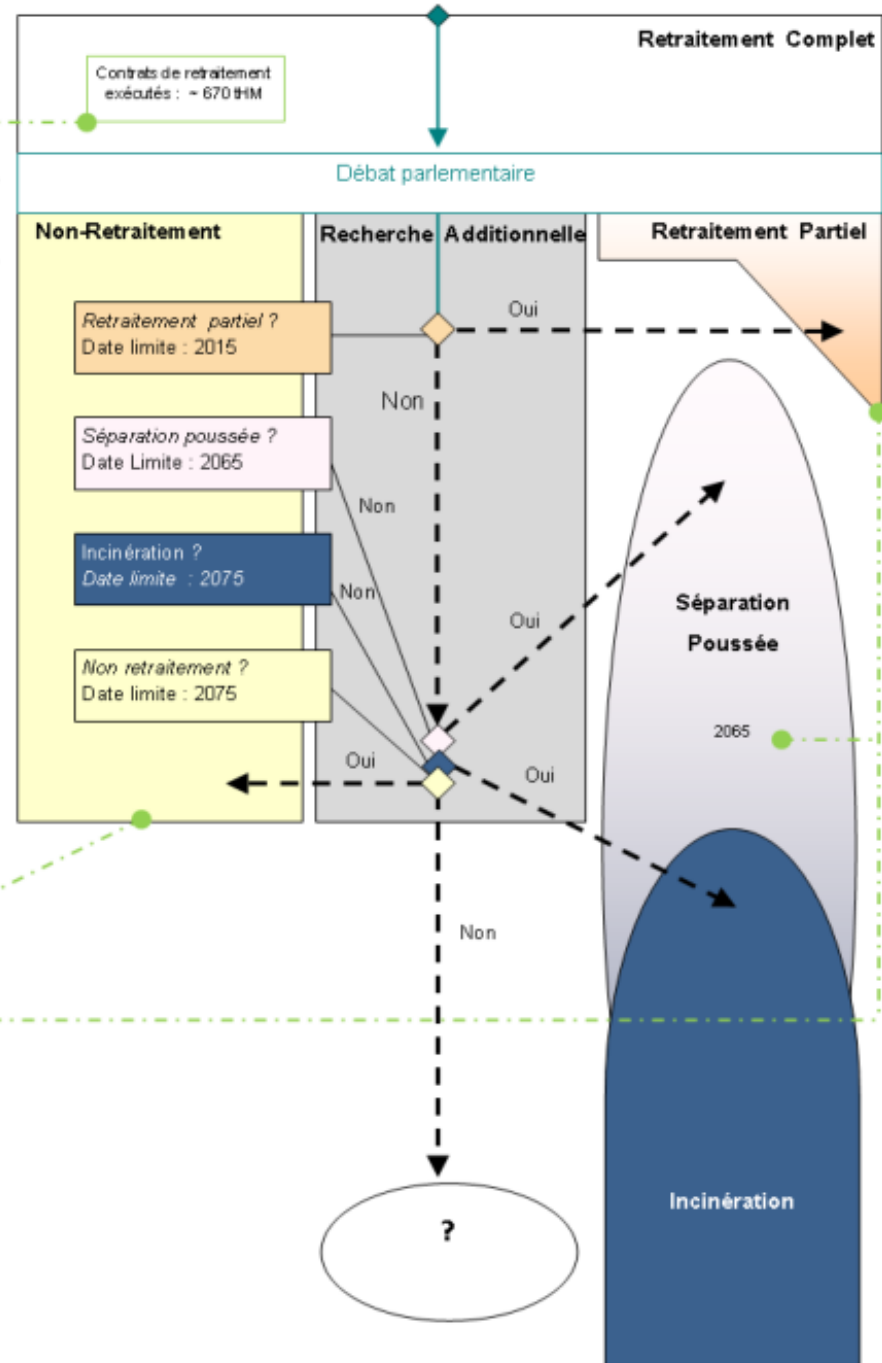
1. Sortie du nucléaire en 2025
2. Décision de principe pour le stockage géologique
3. Construction et exploitation d'un dépôt géologique selon le scénario de référence de l'ONDRAF
4. Réversibilité pendant 100 ans

### Légende :

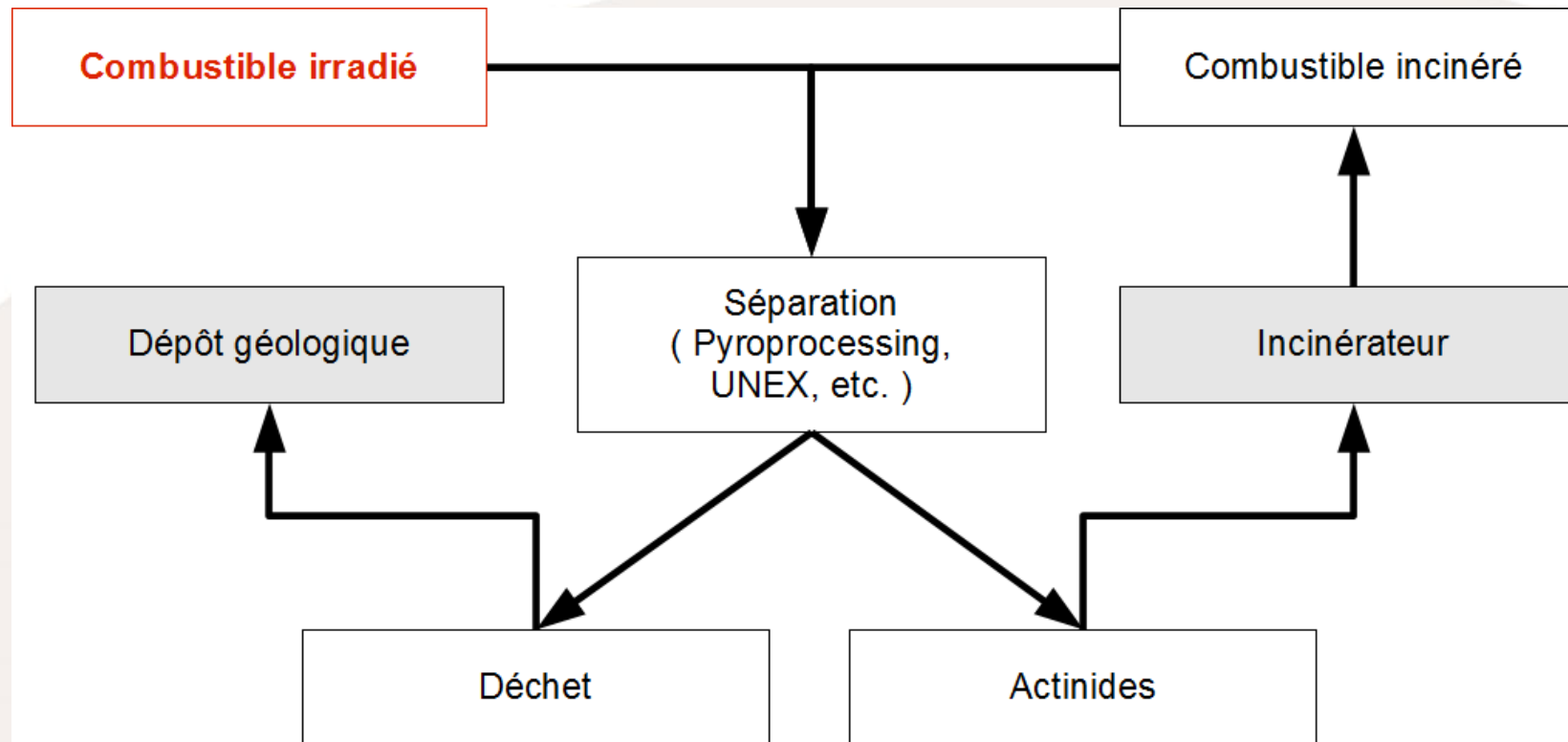
- ◆ Décision prise
- ◇ Décision à prendre
- Mise en dépôt des déchets
- Alternative limitée dans le temps
- Alternative sans délimitation temporelle précise
- △ Alternative dont la pertinence diminue avec le temps



**Dépôt Géologique**  
**Scénario de référence de l'ONDRAF**  
**Plan Déchet 2011**



## The incineration strategy



- The spent fuel is converted to make new fuel for an industrial incinerator reactor. The new spent fuel is recycled until all the actinides are incinerated.
- The remaining wastes are placed in a repository.

## Conclusions

- First National Programme on nuclear waste management published in 2016 (transposition of the EU nuclear waste directive 2011/70)
- National policies for spent fuel management are in place
- Parliamentary debate over reprocessing is in the make
- National policy for the geological disposal of ILW and HLW is under preparation
- Belgian government decided to support the development of MYRRHA