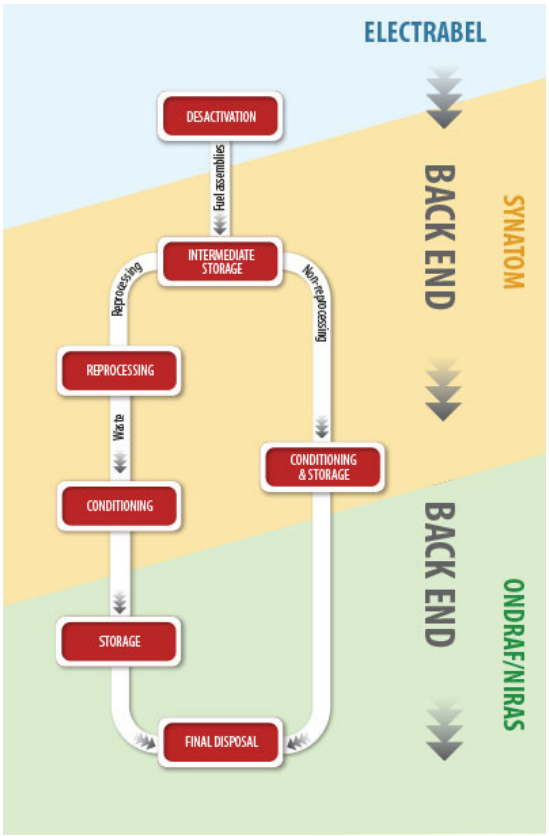
THE BACK-END OF THE NUCLEAR FUEL CYCLE



The back-end of the nuclear fuel cycle involves managing used nuclear fuel once it has been used for electricity production. For SYNATOM, this includes all activities that occur after the fuel has passed through the deactivation pool. These operations mainly consist of intermediate storage on the site of the Doel and Tihange power stations.

This stage will last several decades, until the spent fuel is finally transferred to the National Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF).

The back-end of the nuclear fuel cycle consists of three main steps:

Storage in deactivation pools

The deactivation pool is located in the nuclear island near the reactor building.

Spent fuel assemblies generally remain under water in the deactivation pools for at least 3 years. This allows the radioactive decay to start and some of the residual heat to dissipate.

Transfer of the assemblies to the deactivation pool is the responsibility of ELECTRABEL, which operates the Belgian nuclear power plants.

Intermediate storage

Intermediate storage of spent fuel assemblies is one of SYNATOM's missions.

The assemblies are stored on the site of the Doel and Tihange power plants.

Intermediate storage of waste from historical reprocessing contracts is carried out at the site of BELGOPROCESS (subsidiary of the National Agency for Radioactive Waste and Enriched Fissile Materials) in Dessel.

All the technical operations involved in transferring fuel assemblies from the reactor vessel to the deactivation pool of each unit are performed by experienced teams from the nuclear operator, ELECTRABEL. The same applies to transfers to the centralised intermediate storage facilities at the Doel and Tihange sites.

SYNATOM is responsible for covering the costs associated with these operations, and for financing the infrastructure and equipment needed to store spent fuel.

SYNATOM also pays the National Agency for Radioactive Waste and Enriched Fissile Materials for the intermediate storage of waste from the reprocessing of spent fuel assemblies (reprocessing contracts predating 1993).

Final storage

The National Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF) is ultimately responsible for the final storage of waste from the nuclear fuel cycle.

The Phoenix Agreement signed at the end of 2023 between the ENGIE Group and the Belgian Federal Government provides for the payment of a lump sum of 15 billion euros by the ENGIE Group, in full and final settlement, with 11.5 billion euros being paid at the Closing of the agreement expected in early 2025 and the balance at the restart of the units expected in late 2025.

This amount will cover all future costs related to the management of nuclear waste from ELECTRABEL's nuclear facilities in Belgium, as well as the spent fuel management from 2050 onwards.

Centralised intermediate storage

In 1993, the Belgian Government decided on a moratorium on the reprocessing of spent fuel assemblies.

Since then, SYNATOM and ELECTRABEL decided to store the spent fuel assemblies on the site of the Doel and Tihange nuclear power plants. To prevent the deactivation pools from reaching full capacity, a centralized storage building was built on each site.

Two approaches have been developed by SYNATOM and the operator ELECTRABEL:

1. Dry storage.

2. Underwater storage.

Dry storage at the Doel nuclear power plant

Dry storage in special casks was developed at the Doel nuclear power plant.

The centralized building was put into operation in 1995. It was designed to accommodate 165 casks, each holding between 24 and 37 assemblies.

At the end of their stay in the deactivation pool, the fuel assemblies are transferred to the centralized storage building.

This requires the spent fuel assemblies to be placed directly into the dry storage cask. This operation takes place in the deactivation pool.

The casks, once filled and dried, are placed on a trailer and transported to the centralized building housing the casks from the four units.

Dry storage casks at the Doel nuclear power plant (Electrabel photo library)

Underwater storage at the Tihange nuclear power plant

Underwater storage at Tihange is performed in a centralized building commissioned in 1997. This building includes 8 docks or pools, which can contain a total of 3,720 assemblies.

These assemblies are stored in racks covered by 8 meters of borated water. The boron in the water has a neutron-absorbing effect and thus prevents any nuclear reaction from developing.

To transfer the assemblies between the deactivation pools of the three units and the centralized building, they are placed in a shuttle. This shuttle can accommodate 12 assemblies.

Arrival of the shuttle in the centralized storage building of Tihange (Electrabel photo library)

Once it arrives at the central storage building, the shuttle is submerged and unloaded. It is then reconditioned for reuse.

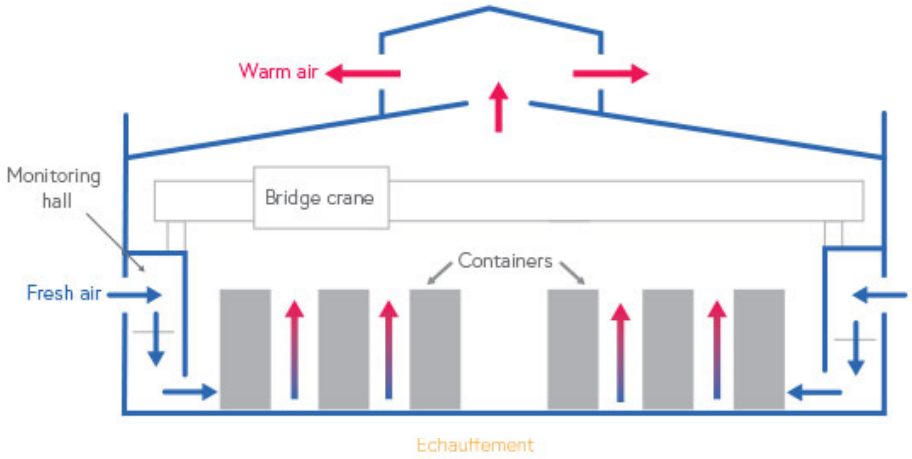
The various handling operations are performed by qualified ELECTRABEL staff on behalf of SYNATOM.

Both buildings are now full.

New intermediate storage capacity at the Doel and Tihange sites

To cover future intermediate storage needs, new buildings have been constructed at Tihange and Doel.

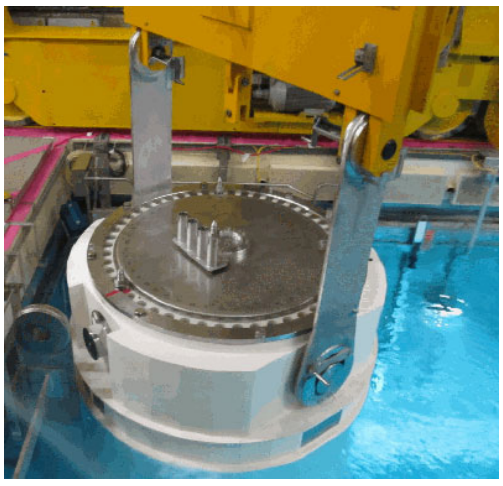
These buildings, called SF^2 (Spent Fuel Storage Facility), are designed for dry storage in casks. They are built to withstand exceptional natural phenomena, such as earthquakes. They also feature passive ventilation, requiring no electrical power. Evacuation of residual heat is therefore ensured in all circumstances. These new facilities offer excellent radiological protection and do not generate radioactive waste.



How the SF^2 building works (Electrabel information library)

Some more information

Deactivation pools have been designed to accommodate the spent fuel assemblies for a limited time period. They therefore have a limited capacity, and assemblies have to be regularly moved to centralized intermediate storage facilities.



Intermediate storage cask in the deactivation pool at the Doel nuclear power plant (Electrabel photo library)

In Tihange, a special cask, called a shuttle, is used to transfer the assemblies. This shuttle is unloaded at the centralized building where the assemblies are stored underwater.

In Doel, the casks are filled directly into the deactivation pool.

After its contents have dried, the cask is stored in the centralized storage building.

Over the next few years, the assemblies that are present in the centralized Tihange facility will be loaded into dry storage casks and moved to the centralized storage building, called SF^2.

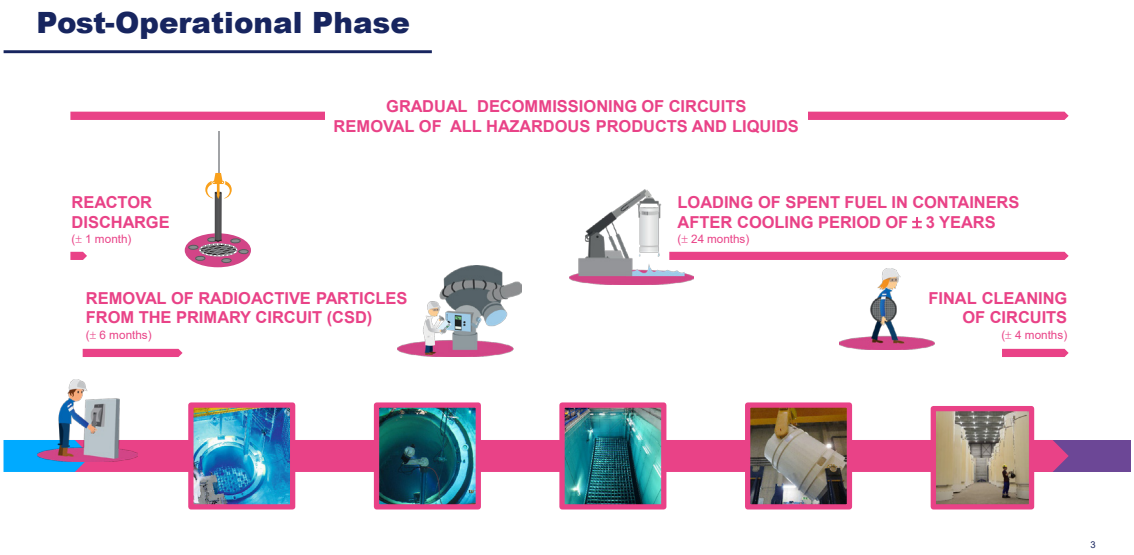
In Doel, as the casks are loaded in the deactivation pool, they are moved directly to the new SF^2 building.

...the importance of dry storage cask deliveries

Delivering these dry storage casks is essential for the proper operation of power plants, therefore.

This is even more true in light of the dismantling strategy of Belgium's nuclear reactors.

After all, when a reactor stops producing electricity, it enters a period of maximum 5 years, called the Post Operational Phase (POP). During that period, the deactivation pool is fully emptied.



Electrabel information library

SYNATOM aims for diversification among its cask suppliers. There are currently three: the French company ORANO, the German company GNS and the US company HOLTEC. This diversification makes it possible to respond to the various needs of the sites taking into account the technical characteristics specific to the various fuel assemblies.

This diversification also makes it possible to minimize risks linked to delivery times, in a global context of tight supply chains.

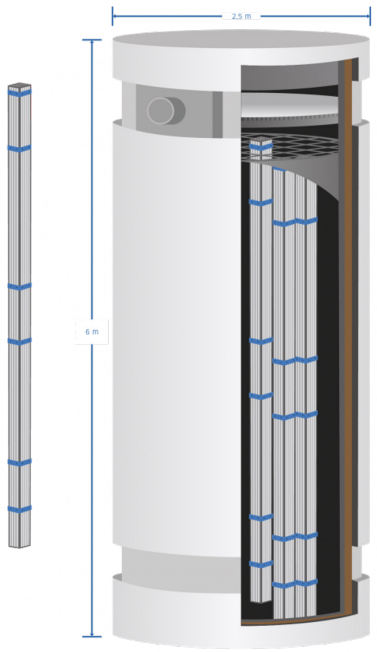
Each type of cask is subject to a qualification and approval file, issued by the Federal Agency for Nuclear Control.

The casks serve two purposes. They are designed not only to provide long-term intermediate storage but also to be used for the subsequent transport to their final destination.

The capacity of the casks varies between:

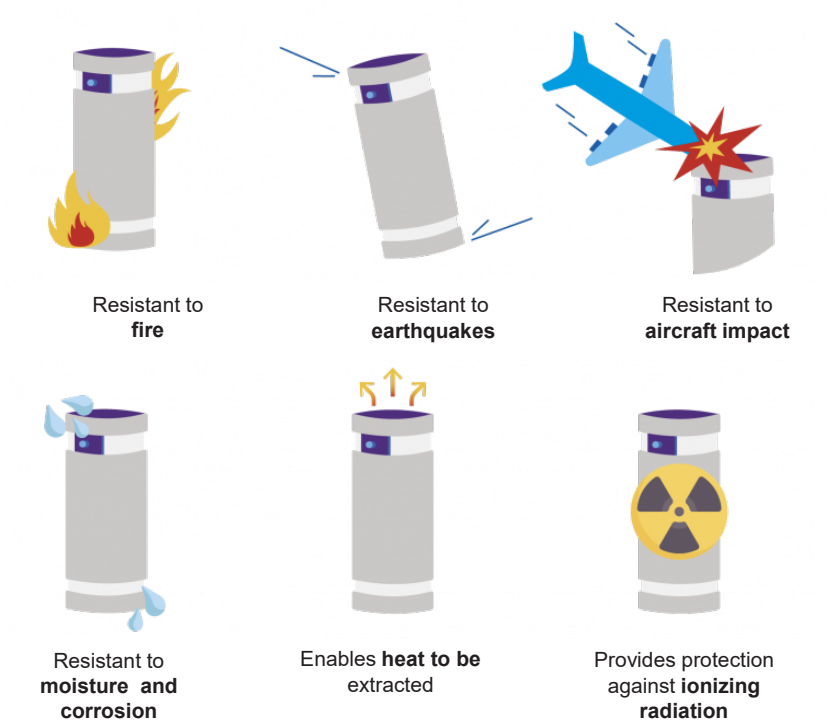
21 and 37 assemblies.

The casks are stored upright and are around 6 m high and 2.5 m in diameter. Each cask weighs about 120 tons when it is empty.



Cross-section of a cask
(Electrabel information library)

Characteristics of a fuel container



The casks help contain radioactive materials, protect against radiation and evacuate the heat they emit. They are resistant to internal and external risks such as humidity, corrosion, fire, explosions, earthquakes and aircraft impacts.

The impact of Doel 3 and Tihange 2 entering the Post Operational Phase (POP)

Under the Belgian Nuclear Phase-out Act, the Doel 3 and Tihange 2 reactors were permanently shut down in October 2022 and January 2023, respectively.

The two reactors then entered the Post Operational Phase (POP). This phase extends over a period of maximum 5 years. This is a mandatory step before starting the actual dismantling operations.

A key element is emptying the deactivation pool, which is adjacent to each reactor.

For SYNATOM, the long-term operation involves providing storage casks and associated infrastructure and equipment.

The 10-year operating extension of the Doel 4 and Tihange 3 reactors will therefore require additional storage casks.

Where are the spent fuel assemblies located?

Today, more than 85% of the spent fuel is located on the sites of the Doel and Tihange nuclear power plants, either in the deactivation pools or in the central intermediate storage buildings.

Approximately 15% of the spent fuel was reprocessed, under contracts signed before 1993. The uranium and plutonium recovered through this reprocessing, i.e. 96% of the spent fuel, have already been reused in Belgian reactors in the form of new fuel assemblies. The final waste that remains after this reprocessing was returned to Belgium after specific conditioning. It is now stored safely on the site of BELGOPROCESS (a subsidiary of the National Agency for Radioactive Waste and Enriched Fissile Materials) pending their final disposal.