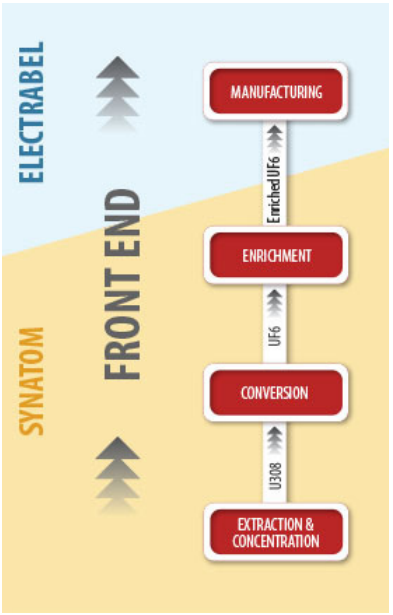
THE FRONT-END OF THE NUCLEAR FUEL CYCLE



The front-end of the nuclear fuel cycle covers all operations from the extraction of uranium ore to the supply of enriched uranium to the manufacturer of nuclear fuel assemblies.

From extraction to uranium concentrate

Uranium is a metal and is quite commonly found in the earth's crust in ores that are mined in open-pit mines or in underground galleries. A new technology, called in situ leaching has become increasingly popular in recent years. Using this process, metals, such as uranium, are dissolved directly where they are found.

Today, almost half of the world's production is obtained through in situ leaching.

The main uranium producing countries are Kazakhstan, Canada, Australia, Niger, Namibia, Russia, Uzbekistan, the United States, China, and Ukraine.

Cigar Lake Mine Site in Canada
(photo courtesy of Cameco Corporation)

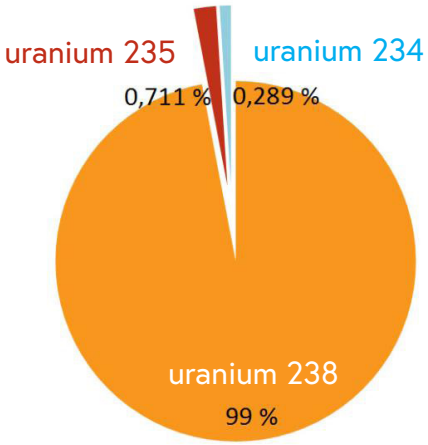
Uranium is extracted from the ore by a series of processes that produce highly concentrated uranium. The result is yellow cake, a yellow powder that contains about 75% uranium, or 750 kg of uranium oxide per tonne. Yellow cake is then refined further, to obtain almost pure uranium in the form of Triuranium octoxide (U_3O_8).

Yellow cake is converted into uranium hexafluoride

During the conversion phase, yellow cake is converted into pure uranium hexafluoride (UF6). This gas is then compressed and cooled to make it liquid, after which it can be transported to the enrichment plant using special containers where the gas is kept cool to maintain a solid state.

Only a limited number of countries provide conversion services: Canada, France, the United States, Russia, and China have this type of facilities.

Enrichment



Prior to enrichment, 1 kg of natural uranium is composed of 990 grams of uranium 238, 7 grams of uranium 235 and almost 3 grams of uranium 234. Only uranium 235 is fissile but, at 0.7%, its concentration is too low to be used in the pressurized water reactors (PWR) used in Belgium's nuclear power plants.

To power those pressurized water nuclear reactors, fuel is required with a uranium 235 content of between 3 and 5%. Only isotope 235 can undergo nuclear fission, which releases energy.

Today, the centrifugation enrichment method has completely supplanted the gaseous diffusion technique which is much too energy intensive.

Handling a container of uranium hexafluoride at the Orano site in Tricastin
(Copyright: Orano, LARRAYADIEU ERIC)

How does refining work? To put it simply…

Uranium 235 can be distinguished from uranium 238 by their slight difference in mass. This weight difference also means there is a difference in mobility.

The refining process consists of turning the uranium hexafluoride into a gas by heating it to 56°C and then rotating it at very high speed in a centrifuge.

Because of the centrifugal force, the heaviest molecules are pushed to the edge of the cylinder while the lightest (U235) migrate towards the centre and the top of the cylinder.

This operation has to be repeated a number of times to achieve the desired enrichment.

Did you know?

The SWU (Separative Work Unit) is the standard measurement unit for the uranium enrichment services. This unit indicates how much energy is needed to separate one kilogram of uranium into two fractions with different isotopes.

The SWU is used as a reference for contracts and to assess the production capacity of an enrichment facility.

SYNATOM's mission

SYNATOM's mission is to guarantee the supply of enriched fissile materials to the fuel assembly manufacturing plant designated by the nuclear operator ELECTRABEL. The delivery schedule is based on the reactors' scheduled shutdowns. The operator monitors the manufacture of assemblies, which are designed specifically according to the technical specifications of each reactor.

SYNATOM's front-end strategy

SYNATOM's supply strategy favours contracts with a diversified portfolio both in terms of suppliers and geographical origins.

Uranium must also be sourced from politically stable countries whose producers scrupulously respect the ethical and environmental standards of the World Nuclear Association.

SYNATOM's activities in the front-end of the nuclear fuel cycle are subject to very strict regulations.

International controls

All elements of the uranium market are tightly regulated on the basis of the Euratom Treaty and more particularly by the recommendations and controls of the Euratom Supply Agency (European Commission).

Corporate Social Responsibility

Over the years, greater societal awareness has led to specific standards for ethics and respect for the environment, which are included in our contracts.

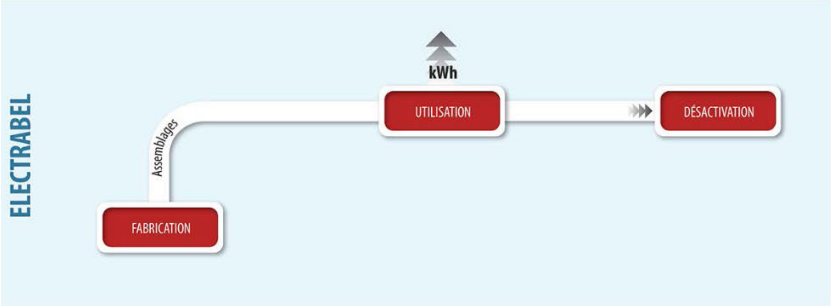
International associations such as the International Atomic Energy Agency (IAEA), the OECD's Nuclear Energy Agency (NEA) and the World Nuclear Association have issued specific rules for uranium mine operators. Compliance is ensured through external audits.

2023, the year of the agreement between the ENGIE Group and the Belgian Government on the extension of 2 reactors ("Phoenix Agreement")

On 13 December 2023, a final agreement was reached between the ENGIE Group and the Belgian Government on the conditions for extending the operation of the Doel 4 and Tihange 3 nuclear reactors by 10 years. This agreement includes a restart from the end of 2025, at the earliest.

Under this agreement, SYNATOM has entered into contracts to supply, within the specified timeframe, the enriched fissile materials required to continue operating the two reactors beyond 2025 for the entire 10-year period.

RESPONSIBILITIES **OF THE OPERATOR**



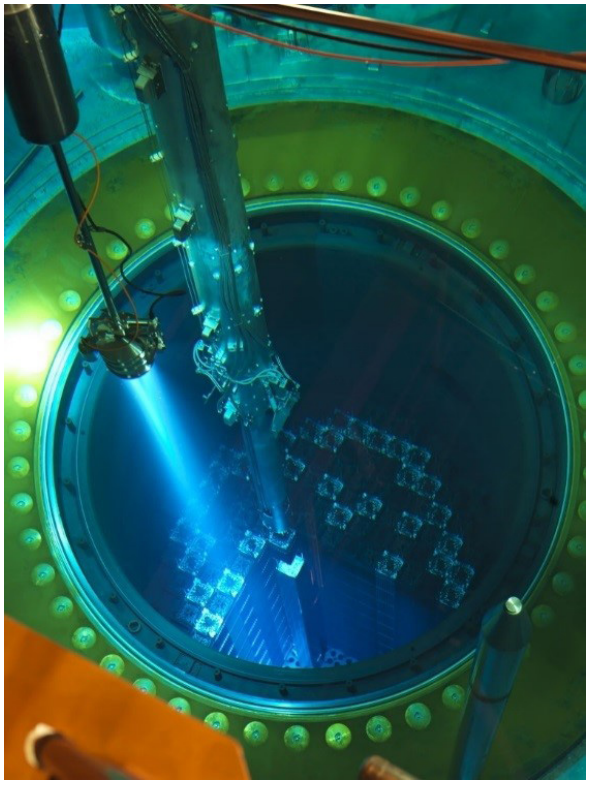
ELECTRABEL is the operator of the Belgian nuclear power plants of Doel and Tihange.
In this capacity, it is responsible for three key stages in the nuclear fuel cycle:

1. Manufacturing of the fuel assemblies

At the end of the enrichment process, the enriched uranium gas is converted into uranium oxide powder (UOX), a particularly stable form. This powder is compressed into 7-gram pellets and stacked in zirconium alloy metal tubes. These are called

«fuel rods». At 4 metres high, these rods are then assembled into assemblies, to form fuel assemblies, which are then transported to the nuclear sites.

Arrival of new fuel assemblies (Electrabel photo library)



Reactor vessel: refuelling
(Electrabel photo library)

2. Use in the reactor core

The fuel assemblies will generate significant amounts of heat over three cycles each lasting 12 to 18 months.

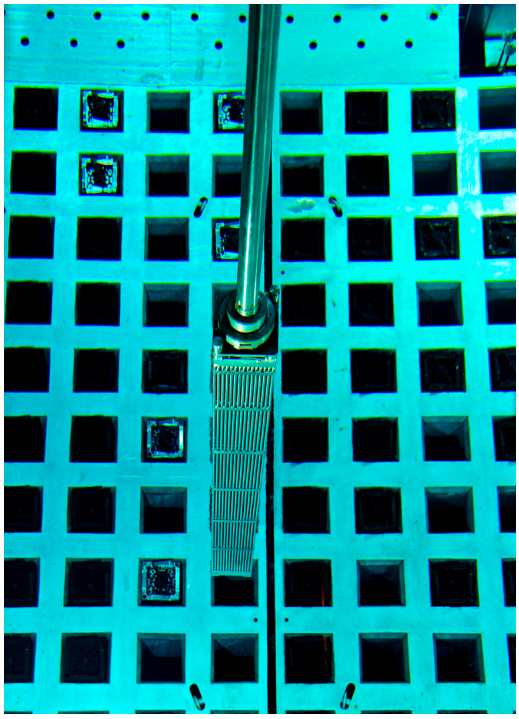
3. Storage in deactivation pools

After the production phase is completed, the nuclear fuel assembly is placed in a deactivation pool for 3 to 5 years.

These three stages are subject to strict safety rules, which are constantly monitored by independent bodies, both at national and international level.

ELECTRABEL ensures the daily and long-term management of the intermediate storage of spent fuel assemblies on the Tihange and Doel sites on behalf of SYNATOM.

Once the operational lifespan of the reactors has been completed, the operator is responsible for dismantling the nuclear power plants.



Handling of an assembly
in a deactivation pool
(Electrabel photo library)