MEETING CHALLENGES THROUGH INNOVATION


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Belgoprocess, situated in the north of Belgium, is responsible for the safe processing of radioactive waste produced in Belgium and for temporary storage of this waste, pending final disposal, as well as for decommissioning the shutdown nuclear facilities on site. In addition, Belgoprocess offers services to national and international clients, ranging from treating foreign waste in our installations, to decommissioning off-site obsolete nuclear facilities, to implementing plasma and PRIME thermal treatment technology.

A LONG HISTORY

The history of Belgoprocess is intertwined with that of Eurochemic, an experimental reprocessing plant that was founded in Dessel in 1957 by an international consortium of 13 countries. Its mission was twofold: the recycling of spent nuclear fuel and conducting scientific research into new reprocessing methods.

When the international consortium was stopped in the late 70s, the Belgian government concluded an agreement in principle for the takeover of Eurochemic. To that end, Belgoprocess was founded in 1984 as a subsidiary of Synatom (responsible for managing the nuclear fuel cycle of the Belgian nuclear power plants) for the continuation of the reprocessing activities including dismantling of the installations after operations had ceased.

When, in 1986, the government decided to stop all reprocessing activities in Belgium, Belgoprocess was transferred to the National Institute for Radioactive Waste and Enriched Fissile Materials (NIRAS), responsible for the management of radioactive waste generated on Belgian territory. As a subsidiary of NIRAS, Belgoprocess is commissioned by NIRAS to safely process and temporarily store this radioactive waste. In 1989 the waste department of the Belgian Nuclear Research Center (SCK-CEN) was also transferred to Belgoprocess and renamed Site 2. Waste batches for which there was no solution in the 1960's are stored here.

Since the 90s, Belgoprocess has been operating its two sites safely and responsibly.

DECOMMISSIONING…A HISTORY OF FIRSTS

In decommissioning the experimental reprocessing plant Eurochemic, Belgoprocess has gained a unique experience in the decontamination and dismantlement of nuclear facilities. Eurochemic was the first civil plant in Europe to reprocess irradiated nuclear fuel and is the first reprocessing plant in the world to have been decommissioned.

The dismantling of the forty cells – or 106 cell structures – in the Eurochemic building always followed more or less the same procedure. First, the spots with high radioactivity in each cell were removed, thus reducing the radiation in the room and lowering the risk of operators becoming contaminated. During a second phase, all metal components were removed using plasma torches. During a third phase, the concrete walls were decontaminated using shavers (Figure 1).

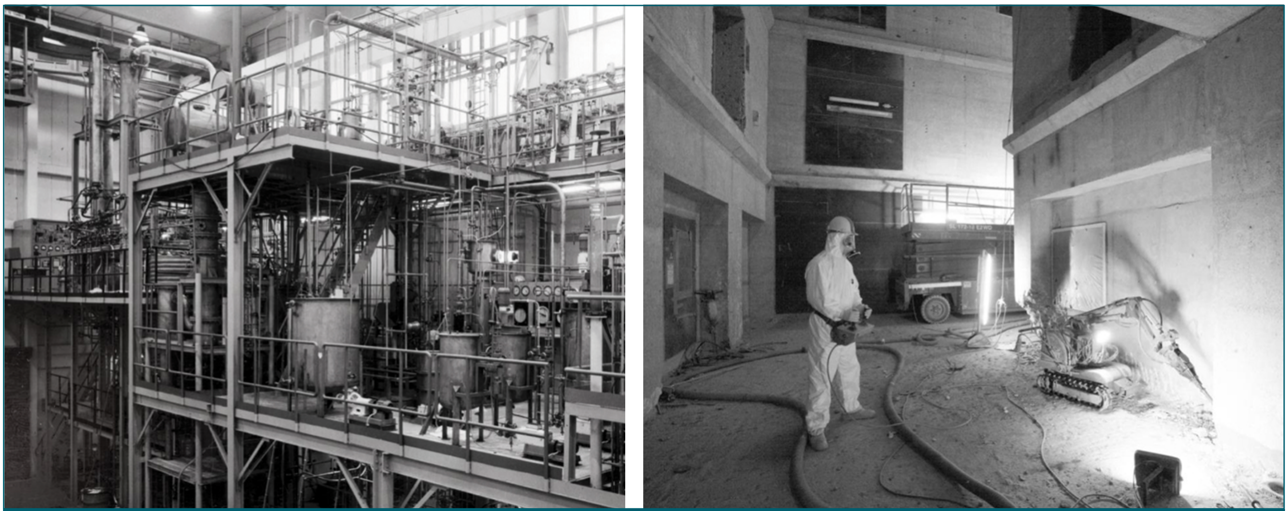

Figure 1. The challenges of decommissioning Eurochemic.

In order to achieve maximum decontamination of materials and installations, Belgoprocess invested substantially in research in new technologies. For example, Belgoprocess developed an innovative dry abrasive blasting installation that is based on the principle of impact of metal grit on concrete and metal surfaces to remove surface contamination.

What remained, was an empty room, every square inch of which was inspected for any remaining radioactive contamination. Once no contamination was detected anymore during these inspections, the cell was hermetically sealed and could be released for demolition. Samples of the demolished buildings were measured again before being released for re-use in the conventional industry or disposed of as conventional waste.

Today, Belgoprocess continues its decommissioning efforts at both sites and can free release 91% of its decontaminated material for reuse in the conventional industry.

In addition to dismantling its own obsolete waste treatment and storage installations, Belgoprocess dismantles nuclear installations elsewhere in Belgium and internationally. For example, Belgoprocess was an important player in the dismantling of Belgonucleaire, the former MOX plant in Dessel, and is currently participating in the dismantling of the cyclotron installation in Fleurus under the management of parent company ONDRAF/NIRAS. Together with Mourik, Belgoprocess also carried out the decommissioning of the Thetis research reactor at Ghent University and recently completed the decommissioning of the accelerator park (including a cyclotron) at Ghent university.

AN ESSENTIAL LINK IN THE NUCLEAR INDUSTRY

Belgoprocess is in charge of treating and temporarily storing the radioactive waste originating from nuclear power plants, hospitals, laboratories and industry in Belgium.

In order to choose the adequate treatment, the waste is classified in several categories, all related to a specific treatment and conditioning process. For each category, Belgoprocess has the appropriate installations and technologies. Among our main waste treatment facilities are the CILVA installation and PAMELA installation on site 1 and the facility for processing historical waste on site 2.

The **CILVA** facility is the treatment and conditioning facility for β and γ low-level (less than 2 mSv/h) and α-suspect waste. It can be used for sorting, cutting, incineration, precompaction, supercompaction (2000-ton) and cementation of solid and liquid low-level radioactive waste, including uncompacted and compacted solid waste, frozen animal carcasses, low-level ion exchange resins, organic liquids, aqueous liquids with or without sludges or complexing agents, as well as spent oil (Figure 2).

Based on a weekly production time of 100 hours, the capacity mounts to about 7.5 tonnes of solid waste and 1 to 5 tonnes of liquid waste a week or about 100 kg of waste per hour. The ashes are collected in 200-liter drums that are subsequently supercompacted and embedded in concrete in a 400-liter drum. The supercompactor is also capable of reducing the volume of most non-burnable waste with low activity placed in 200-liter drums.

The **PAMELA** installation is Belgoprocess' former vitrification facility that was transformed into an installation for processing alpha-contaminated and medium-level waste and is equipped with a 1000-ton supercompactor.

Figure 2. CILVA incinerator.

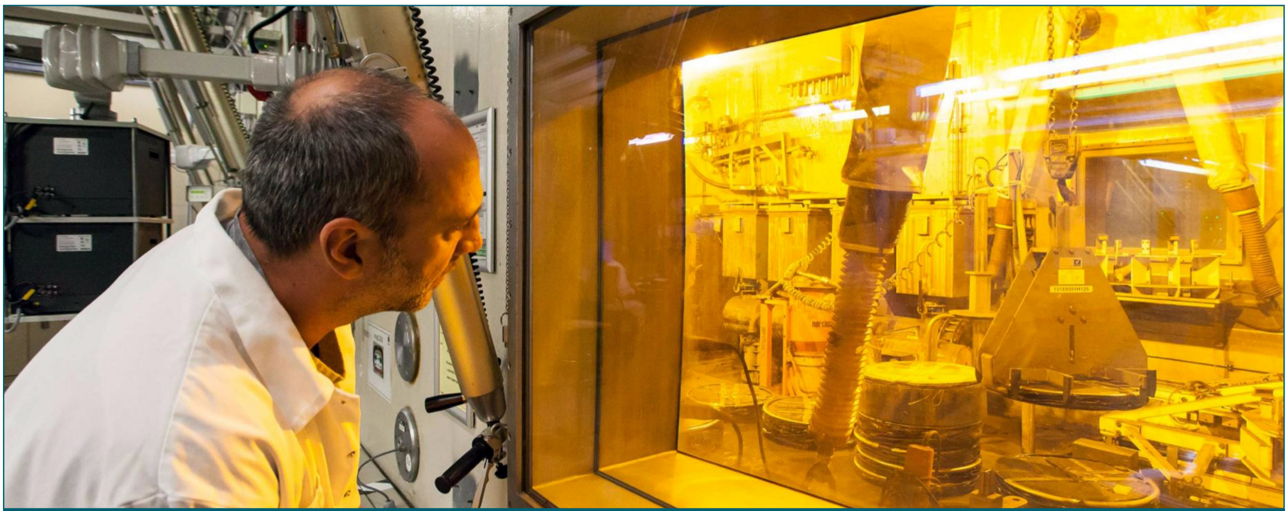

Figure 3. Treatment of alpha-bearing waste.

On Site 2, the focus is on eliminating historical waste batches and remediating and decommissioning the buildings and installations. Belgoprocess' long-term strategy for Site 2 is to gradually reduce it in size and turn it into a "radium site" with a limited number of existing facilities and access buildings.

One of the major challenges at this site has been the characterization, treatment and conditioning of approximately 200 m³ of medium level waste. Despite the limited volume, this historical waste consists of a great variation of waste characteristics and waste configurations. These approximately 4.000 waste packages had been produced in various research programs and reactor operations at SCK-CEN from the 1960's up to the 1980's and were stored in poor conditions in dry storage vaults (HRA) or concrete containers (Solarium).

Visual inspections and inventory checks made clear that the condition of some items has degraded significantly over time. Because of contamination issues and due to the high dose rates, the first aim of the project was to achieve acceptable storage conditions. The next step was to construct a specific facility for remediation purposes. This led to the construction of a roof cover for the "Solarium" and a confinement building over the "HRA pits".

Belgoprocess inventoried and categorized the waste and built a cover over the concrete containers as well as a new processing facility – building 280x – to allow safe transfer, handling, characterization and treatment of these packages. The sorting and processing of this waste started in 2004. The waste was divided into three main categories: non-radium containing waste, sodium and sodium potassium waste and radium-containing waste. Of these, the non-radium and non-sodium containing waste and the sodium and sodium potassium waste have been processed. The radium-containing waste is being processed today and will be completed by 2024 (Figure 3).

While awaiting final disposal, the conditioned radioactive waste is stored temporarily in storage buildings that provide radiation shielding. Belgoprocess has storage buildings for low-level conditioned waste, medium-level conditioned waste high-level vitrified waste, and alpha-contaminated waste. Currently, Belgoprocess is temporarily storing 300 m³ high-level conditioned waste, 4.000 m³ medium-level conditioned waste, and 20.000 m³ low-level conditioned waste (Figure 4).

Figure 4. Treatment of alpha-bearing waste.

INTERNATIONAL EXPERIENCE... A PIONEER IN THERMAL TREATMENT TECHNOLOGIES

Today, Belgoprocess is actively working at applying its operational expertise internationally. This has led to the establishment of various joint ventures and consortia and to a number of international contracts, ranging from treating foreign waste on site, to decommissioning obsolete nuclear facilities, to implementing our patented plasma thermal treatment technology and the patent-pending PRIME process.

Plasma technology

Low and intermediate level radioactive waste is often mixed with hazardous waste and various non-combustibles. Historically, these wastes have been treated by separating the combustibles from the non-combustibles and processing them separately through incineration, supercompaction, cementation and other encapsulating technologies. However, this approach is costly and increases the risk of personnel exposure.

Belgoprocess offers a proven, patented plasma treatment technology that uses a high-temperature plasma processing technique with operating features that eliminate the personnel exposure and costs associated with sorting, characterizing and handling this waste and gives a final product that meets most stringent acceptance criteria for final storage.

In addition, as plasma technology can recondition previously conditioned waste packages that no longer meet the present acceptance criteria for final disposal, it offers a solution to the growing demand for improved quality of final waste forms. Therefore, even historical conditioned waste in a bituminous or concrete matrix, which doesn't meet current acceptance criteria for conditioned waste can be retreated in a plasma facility, resulting in a conditioned product that does meet these criteria.

Plasma is a highly desirable heat source for treatment of problematic radioactive waste. Plasma treatment uses an electric arc to generate temperatures in the gas stream that can achieve several thousand degrees centigrade causing the rupture of molecular structures of materials into their constituent atoms. Its high temperature range of 5000 to 10 000 °C can treat the radioactive waste as it is. The non-combustible and other inorganic materials are melted into a glassy slag containing most of the radioactive isotopes, and subsequently transferred into an external drum and cooled. The organic materials are vaporized into a syngas and subsequently oxidized in an afterburner. The unwanted gaseous by-products of the combustion process are reduced to an acceptable level by using a proven off-gas system, based on that of the Belgoprocess CILVA incinerator for radioactive waste.

Plasma technology offers a number of benefits:

- applicable to solid organic and inorganic waste, including asbestos, and to other waste types such as drummed spent resins and liquid waste;
- one single process can treat the waste as generated – no prior treatment required resulting in less dose uptake and risk for contamination;
- a final waste form that is robust, free of organic material, and suitable for long-term storage and disposal;
- high volume reduction factor (VRF) that minimizes the overall costs of waste storage and final disposal (VRF~6 for waste containing mostly metals and debris, ~15 for drummed mixed waste and ~80 for primarily organic waste)

In addition, plasma technology has a wider range of applicability compared to conventional methods of incineration as illustrated by the table below.

TECHNOLOGY	Organic		Inorganic		Mixed organic-inorganic		Spent resins
	Liquids	Solids	Liquids	Solids	Liquids	Solids	
Calcination	NA	NA	A	NA	NA	NA	NA
High-temperature incineration	A	A	A	NA *	A	A *	A
Incineration	A	A	A	NA *	A	A *	A
Melting	NA	NA	NA	A	NA	NA	NA
Molten salt oxidation	A	A	NA	LA	LA	LA	A
Plasma	A	A	A	A	A	A	A
Pyrolysis	A	A **	NA	A **	A	A **	A
Synroc	NA	A	NA	A	NA	A	NA
Thermo-chemical treatment	NA	A	NA	A	NA	A	A
Vitrification	NA	A **	A	A **	NA	A **	A
Wet combustion	A	A	NA	NA	NA	NA	A ***

SOURCE IAEA TECDOC 1527

A: Technology is applicable to this type of waste
NA: Technology is not applicable to this type of waste
LA: Tecnology has limited applicability to this type of waste

* Small pieces of inorganic are acceptable without causing damage or plugging of the system
** Applicable only for the granular or powder form of this waste type
*** Applicable only to organic spent resins

Kozloduy Plasma Facility

The Joint Venture Iberdrola Ingeniería y Construcción - Belgoprocess built a full-scale plasma facility at the Kozloduy Nuclear Power Plant site in Bulgaria. This engineering, procurement and construction contract was co-financed through a grant by the Kozloduy International Decommissiong fund (KIDSF) administated by the European Bank for Reconstruction and Development, and through Bulgarian national funding. The KIDSF is funded by the Eurpean Union as well by the contributors to the KIDSF – Austria, Belgium, France, Grece, Ireland, The Netherlands, Spain, United Kingdom and Switserland. The plasma facility is operated by the State Enterprise of Radioactive Waste in Bulgaria.

The Kozloduy facility consists of a tilting plasma furnace equipped with a non-transferable torch of 500 kW as heat source and treats 250 tons per year, spread over 40 operational weeks. The tilting furnace developed by the JV has been designed to pour the slag in a controlled manner into a slag mould. This concept of the furnace with the fixed waste feeder, the off-gas equipment and the closed confinements around the slag pouring, prevents the release of radioactive or hazardous gasses and particles into the work area and into the atmosphere, thereby improving the safety features of the plasma facility.

The solid waste can consist of bags containing mainly organic waste, metallic 200-liter drums containing pre-compacted organic waste and metal particles or pucks up to 40 cm high, resulting from the supercompaction of metallic 200-liter drums containing mixtures of concrete, wood and other organic material. In addition, the facility can treat liquids and drummed spent ion exchange resins. Typical specific radioactivity of the waste is about 5E5 Bq/kg and contact dose rate is lower than 2mSv/h.

Figure 4. Plasma furnace with shredder.

The incoming waste is transferred to a shredder and from there to the feeder tube. Close to the furnace, the feeder tube has a rotating connection so that the feeder tube of the shredder is fixed-mounted in relation to the tilting furnace. On the opposite side of the furnace the contaminated hot gasses with a temperature of 1300°C are diverted to the afterburner chamber.

The system processes mixtures of organic waste such as plastic and celluloses, with inorganic waste such as concrete, mineral insulation, glass and metals. Depending on the incoming waste composition, a glassy-like slag or a metal-like slag is obtained. When about 200 litres of slag are produced, the slag is poured into the slag mould. After pouring, about 50 litres of slag remains in the furnace and it is used as a thermal flywheel for the next waste batch. The remaining slag also forms a protection for the refractory against the high temperature of the plasma flame.

The tapping of slag into the slag mould is carried out in a confinement in order to prevent spreading of contamination in the normal work area and into the environment. The Kozloduy plasma facility has been operating successfully since 2019.

PRIME, an innovative process to treat spent resins

Ion exchange resins are used by nuclear power plants for purification of the primary cooling water. Spent resins contain radioactive isotopes and must be treated as radioactive waste. Treatment of such spent resins must meet severe criteria for the organic waste content. Handling of this continuously generated waste stream of radioactively contaminated ion exchange resins remains a critical issue.

While various treatment installations are operational, a true mineralization (conversion to unreactive inorganic products) of spent ion exchange resins is not obvious due to the resins' activity and isotopic composition. However, mineralization is desirable, as stored and untreated spent resins may provoke chemical reactions from or between the organic resin, the container/drum, filler material and concrete, as well as radiolysis in the resin bed. A chemical reaction can affect the storage quality of the products and can compromise the container, resulting in leaking storage units. Treatment of the spent resins is therefore a necessity.

Belgoprocess and Montair developed the PRIME (Pyrolysis Resins In Mobile Electric) Installation, processing spent resins in one single reactor without pre-treatment and without intermixing of other waste, allowing for easy traceability and isotopic characterization of the end product. Both low level waste (LLW, < 2 mSv/h) and medium level waste (MLW, > 2 mSv/h) can be treated in the installation. The installation is designed to treat two batches of 100 liter of saturated ion exchange resins over a period of 24 hours (Figure 5).

The PRIME installation process starts with evaporation of the (transport) water, drying of the resins and finally pyrolysis in one single reactor. A dosing unit is used for feeding the saturated ion exchange resins to the pyrolysis reactor.

Pyrolysis treatment takes place from 300 up to 500 °C under inert conditions. The low temperature process results in low

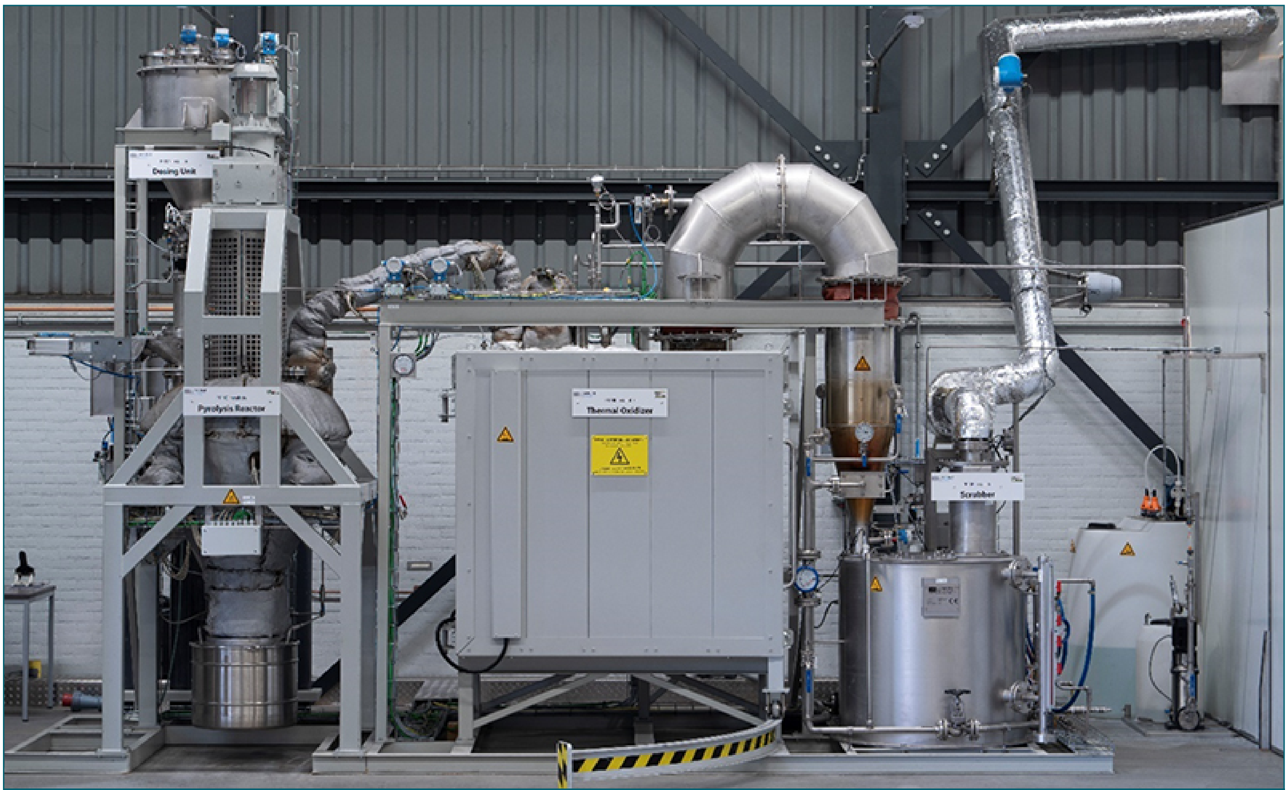

Figure 5. PRIME pilot installation - both pyrolysis reactor and oxidizer are patent pending.

carry-over of semi-volatile isotopes such as Caesium. Resins are converted into a dry, mineralized (inert) product with a VRF of 7 in case of a mixed bed (VRF 4 for cationic resins; VRF 10 for anionic resins).

The PRIME installation can process cationic or anionic resins or a mixed bed. The vast majority of the final product can be assigned to carbon (typically 80-90%). In addition, when cationic resins are involved, the material contains a fraction of the original sulfur content presumably present as sulfonyl and sulfur bridges. The residual fraction consists of metals such as Ca, Cr, etc. that were present in the spent resins.

The pyrolysis reactor contains a special design mechanical stirrer and can operate at a temperature of up to 600°C under inert conditions. As a result, the organic molecules will decompose at an accelerated rate until a carbonaceous material remains. XRF and SEM analysis on the residue shows that during the pyrolysis process almost all elements (H, N, O, S etc.) except carbon move towards the off-gas. The result is a significantly smaller resin bead which is almost entirely made up of carbon.

During the decomposition process, fraction of sulfur seems to create strong bonds with carbon. This phenomenon of cross-linking with sulfur introduces a high mechanical stability of the product and makes it very resistant to chemical attack. The lower temperature, the absence of oxygen as well as the design of the internals of the reactor to fluidize ion exchange resins at all times also prevent the clogging and breakdown of ion exchange resins into (powdery) ash, which is a considerable advantage during further handling.

In a completely new innovative design of the fully electrically operated oxidizer, the pyrolysis gases are treated at >850°C for a minimum of 2 seconds with a minimum oxygen volume of 6%. After oxidation, the hot off-gases are cooled down in the quench. Finally, sulphur dioxide is captured and neutralized in the wet gas scrubber. Additionally, the NOx is eliminated directly in the oxidizer. An extraction fan keeps the system under negative pressure to prevent the possibility of any off-gas leakage out of the system.

As the installation is fully electrically powered, no other secondary gas or fuel is needed, making it safe and simple to install and operate. The compact, skid-mounted design has a footprint that fits 20 ft ISO containers, which makes it a mobile installation. In addition, this simple and small installation, with local shielding for the spent resins, is designed conform the ALARA principle and greatly simplifies maintenance services.

Following successful tests with a first pilot installation between 2019 and 2021, Belgoprocess aims to have an industrial installation operational at its site by mid 2024.■