highlights

2018

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

2018

“ In tune with society ”

According to our mission SCK•CEN works on issues that are important to society, today and in the future: safety and efficiency of nuclear installations, solutions for the disposal of radioactive waste, protection of mankind and the environment against ionizing radiation, and sustainable development. In this way we contribute to a viable society, for ourselves and for the generations te come.

STUDIECENTRUM VOOR KERNENERGIE
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Highlights

The extra mile

DEAR READER,

Pioneering. The passion for pioneering is ingrained in the DNA of our research centre. Our research is not restricted by the boundaries of what we know. We explore. We stretch limits. We dare challenging ourselves and conquering uncharted territories. We always go the extra mile. In the preparation, implementation and completion.

The extra mile in preparation. Take the unique research installation that is MYRRHA, for example. In 2018, the Belgian government gave the first construction phase the green light – thanks to the detailed preparation by our colleagues, who submitted a comprehensive MYRRHA dossier to the government the year before. Meanwhile, we haven't stopped for a second. The particle accelerator that will power the research reactor has grown several metres. We subjected the lead-bismuth coolant to a whole range of simulation tests. In 2018, the first results of this large-scale experiment became available: cooling remains guaranteed.

The same dedication in preparation also resulted in a breakthrough in the RECUMO dossier. With RECUMO, our research centre offers a structural solution for the management of highly radioactive residues from the production of medical radioisotope, which are currently stored on the site of the National Institute for Radioelements in Fleurus. That is how this project contributes towards ensuring the supply of medical radioisotopes. Moreover, we strengthen Belgium's leading position in the production of medical radioisotopes.

The extra mile in implementation. Several research groups joined forced to set up NURA – a nuclear medical centre of excellence. With NURA, we will carry out ground-breaking research into radiopharmaceuticals for the treatment of different types of cancer, commissioned by clinical and industrial partners.

Eric van Walle
SCK•CEN
Director-General

The extra mile in completion. The year 2018 was also the final sprint towards finalising challenging projects. We did bring two challenging dismantling projects to a very successful end and completed the construction works of the EME building – with its high-tech gadgets and brand new emergency planning room.

The extra mile. Always with care for humans and the environment. Do read this annual report through and re-live this extra mile with us.

Enjoy the journey!

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Green light for MYRRHA

The world needs MYRRHA

Offering a technological solution to reduce nuclear waste and produce new, innovative, medical radioisotopes. That is the ambition of research installation MYRRHA. “This ambition now becomes a reality thanks to Belgian government funding”, beams Hamid Aït Abderrahim, Deputy Director-General at SCK•CEN and MYRRHA Project Manager. The government decision to support the project gave the construction of MYRRHA a sudden boost.

In September 2018, the Council of Ministers gave the green light for the innovative research reactor MYRRHA, the world’s first prototype of a nuclear reactor driven by a particle accelerator. Thanks to a financial injection of 558 million euros, SCK•CEN can launch its construction on its site in Mol. The research centre started with the particle accelerator and its irradiation stations for fundamental and applied research, as well as for medical application.

The Belgian government co-finances the construction of MYRRHA. A vote of confidence?

Hamid Aït Abderrahim: With MYRRHA, we want to demonstrate that transmutation at a semi-industrial scale is possible. Through nuclear fission, transmutation transforms long-lived, highly radiotoxic residue – the so-called minor actinides such as neptunium, americium and curium – into less radiotoxic elements, which also have a shorter half-life. As a result, the geological disposal period can be reduced from 300,000 to 300 years, and the volume can be reduced a hundredfold. This means transmutation offers new perspectives for geological disposal. Furthermore, MYRRHA will contribute to the production of innovative radioisotopes and the development of cancer therapies with fewer side effects. In short: a project with social value.

The Belgian Government acknowledges this and decided recently that it would not wait any longer for the input of foreign investors. It supports the MYRRHA project. This is a vote of confidence. A clear signal for us, but also aimed at our partners abroad. It will undoubtedly boost interest in participation in the project. Meanwhile, France, Japan, Sweden, the US and China have already expressed an interest. I am therefore very happy that Belgium made the first move.

This decision took a while, though, but you always kept faith.

Hamid Aït Abderrahim: Of course! I didn’t doubt for a second. The world needs MYRRHA: MYRRHA stands for medical diagnostics, better cancer treatment, ground-breaking research and processing of nuclear waste. Now, this becomes a reality.

Construction is now speeding up. When will MYRRHA be operational?

Hamid Aït Abderrahim: Rome wasn’t built in a day, and this project too requires time. The construction of MYRRHA happens in three phases. With the funding from the Belgian government, we can achieve phase 1 of MYRRHA.

What does this phase consist of?

Hamid Aït Abderrahim: In the first phase, we build MINERVA, the particle accelerator up to 100 MeV energy, and the related Proton Target Facility. MINERVA enables us to demonstrate the reliability of the linear accelerator. We aim at commissioning this modular installation in 2026. On the one hand, we will then be able to produce medical radioisotopes and, on the other, to carry out fundamental research in physics and material research. Since the government announced its decision, we have already made quite a lot of progress. The particle accelerator has grown several metres! [Read more on page 16]

“The government’s decision is a vote of confidence. A clear signal for us, but also aimed at our partners abroad.”

“With its range of innovative applications, MYRRHA becomes a magnet for international scientists, research centres and universities.”

Work doesn’t stop there.
Hamid Aït Abderrahim: Indeed. During the first phase we will also make all preparations to increase energy to 600 MeV (phase 2) and to link up the particle accelerator with the MYRRHA reactor (phase 3). Construction of the MYRRHA reactor is also included in phase 3. Completion is planned by 2033.

Once MYRRHA will be operational, SCK·CEN can start transmutation. How much Belgian nuclear waste would you process?
Hamid Aït Abderrahim: More than 5,000 tonnes spent fissile material from nuclear power stations are waiting. Let’s visual this amount for a second. After 40 years of operation, the nuclear waste of all Belgian nuclear power plants covers about the size of a football pitch, half a metre high. If we could process this waste, the height would be reduced to 5 mm.

WAVE OF RECRUITMENT

The construction of MYRRHA is gathering pace. “This has generated a strong wave of recruitment. Now, our team is 135 strong, in-house and outsourced staff. In 2019, we will recruit 81 workers, and in the coming years some forty more”, says Hamid Aït Abderrahim, Deputy Director-General at SCK•CEN and MYRRHA Director. Moreover, the MYRRHA project will boost employment with external suppliers. “Make sure you keep an eye on our vacancies page if you too want to make a difference.”

Why can’t existing, water-cooled reactors take care of this job?
Hamid Aït Abderrahim: For transmutation, we need fast neutrons. Water slows down and is therefore not suitable as coolant. In the design of MYRRHA, we opted for a mixture of lead and bismuth. This choice threw up quite a few questions. Which structural materials does this coolant need? Is cooling still guaranteed when the primary pumps are switched off? A whole range of experiments are currently ongoing, such as in E-SCAPE, a 1:6th scale model of MYRRHA. In 2018, the first results of the large-scale experiment in E-SCAPE rolled off the press, so to speak. The system works. Cooling remains guaranteed! [Read more on page 20]

MYRRHA is clearly exploring the boundaries of the unknown. Will MYRRHA become the international technological hub for the nuclear industry?
Hamid Aït Abderrahim: With its range of unique and innovative applications, MYRRHA will indeed become a magnet for international scientists, research centres and universities. A new generation of experts will also be trained here in the future. This reinforces SCK•CEN’s pioneering role that it has enjoyed since its creation. Belgian Reactor 1 (BR1) was the first research reactor on Belgian soil. Belgian Reactor 2 (BR2) is one of the most powerful and most flexible research reactors in the world. The dismantling of Belgian Reactor 3 (BR3) is a first in Europe. With MYRRHA, we forge ahead on this pioneering path and boost the development of innovative, safe and sustainable nuclear technology. Belgium too benefits from this: the nuclear know-how remains in the country.

MYRRHA is not only a technological, but also a socio-economic asset for the Kempen region, Flanders, Belgium and even Europe. How?
Hamid Aït Abderrahim: MYRRHA means employment opportunities. We need people to build the research reactor and later on to run it. I am talking of 700 people a year on average. Moreover, we will acquire new skills. And we can then valorise these skills via spin-offs. We will also continue exploring the boundaries, for example by focusing on the production of alpha isotopes or by developing new materials through research. All this will make the burgeoning of a new industrial cluster in the Mol region possible.

Pioneering also goes hand in hand with risk-taking. Is this new reactor concept safe?
Hamid Aït Abderrahim: Absolutely! If you switch off the accelerator, the reactor shuts down within a billionth of a second.

MINERVA accelerator has grown metres

At the Cyclotron Resource Centre in Louvain-la-Neuve, SCK•CEN is in the midst of building the first part of the particle accelerator that will drive the MYRRHA research reactor. This part (with an energy of up to 100 MeV), the corresponding injector and irradiation stations are a stand-alone project: MINERVA. With MINERVA, SCK•CEN can test the reliability of the particle accelerator, produce new medical radioisotopes and carry out fundamental research.

Thanks to a financial injection from the Belgian government, MYRRHA becomes a reality. MYRRHA is the world's first prototype of a reactor driven by a particle accelerator. The specificity of this configuration – Accelerator Driven System (ADS) – is the sub-critical core of the reactor. The core does not contain enough fissile material to sustain a spontaneous chain reaction and must therefore be fed continuously by an external source of neutrons. "This is where the particle accelerator comes in", explains Dirk Vandeplassche, physicist and specialist in particle accelerators.

"In the MYRRHA design, we opted for a linear accelerator (linac)", says Dirk. "This is to ensure the greatest reliability. Indeed, a linac produces fewer interruptions of the proton flow in the beam than a cyclotron." MYRRHA's particle accelerator consists of an injector with an ion source and a Radio Frequency Quadrupole (RFQ), and a chain of magnets and cavities. The proton beam will be accelerated in order to be fired at a spallation target at the heart of the reactor core. "Upon impact, neutrons are released, which will maintain the fission reaction", explains Dirk.

Accelerator bearing European colours

In 2018, MINERVA – the particle accelerator up to 100 MeV – took shape nicely. "Meanwhile, the first metres can be seen at the Cyclotron Resource Centre in Louvain-la-Neuve. The ion source and different components of this accelerator were first tested in Grenoble and have now been moved to Belgium. It doesn't stop at the Belgian border; it brings together several European partners and this accelerator therefore bears European colours", winks Dirk Vandeplassche. The accelerator team put the components back together and installed the complete wiring. Ultimately, the MINERVA accelerator will produce 100 MeV protons, but the installation in Louvain-la-Neuve is limited to 5.9 MeV. Dirk: "The low-energy part is extremely important and critical for the behaviour of the proton beam during the whole follow-up of the acceleration. Therefore, we are very focused on its extensive testing. We want to make as many proton beams as possible and characterise them." During the first half-year of 2019, high-performance tests will follow and the RFQ will be coupled to the accelerator. "This will be a magical, but exciting moment", exclaims Dirk. "Well, exciting… I would be surprised if it didn't work." The RFQ is a fundamental link in achieving the paramount reliability for MYRRHA.

Dirk Vandeplassche and **Jeroen Engelen,** collaborators for the particle accelerator

In a later phase of the MINERVA project, the capacity of the particle accelerator will be increased gradually up to an energy level of 100 MeV. In 2026, MINERVA will be brought on-line. From then on, the particle accelerator and its two corresponding irradiation stations will be used to produce medical radioisotopes and to carry out fundamental research in physics and material research – more specifically in the field of nuclear fusion. But first, the particle accelerator must be moved to Mol.

Transfer to Mol

Preparations for the building that will house MINERVA are in full swing. "The actual construction will start in 2022 and the buildings should be ready one and a half years later for the installation of the systems", explains Jeroen Engelen, who works at the Balance of Plant within SCK•CEN and is in charge of design and implementation. "We are talking about a 150-metre long tunnel for the accelerator and, parallel to this, a large technical hall. At the head of the accelerator, there will be a building housing workshops, offices and labs. Once the structural works are completed, we will start installing the particle accelerator and the ion source."

> *"Currently, we are building the first part of the particle accelerator in Louvain-la-Neuve for MINERVA and by extension therefore also MYRRHA."*

The last challenge is to crank up the energy level to 600 MeV. "This energy is required to carry out all the planned activities, in particular transmutation", says Jeroen. To reach that energy level, the accelerator must be extended by 250 metres. "Then, we extend the accelerator to the reactor building housing MYRRHA, which will also be built in the next phase." The total length of the setup – main building, injector, accelerator tunnel up to the impressive reactor building – will then be close to 500 metres. For the planned works, there will be a European tender procedure. "We appeal to all parties in Belgium and abroad to take part", concludes Jeroen. As regards employment opportunities – both in Mol and beyond – this can count. On average, around 700 people will work on MYRRHA each year, both during the construction phase and during the operational phase of the infrastructure.

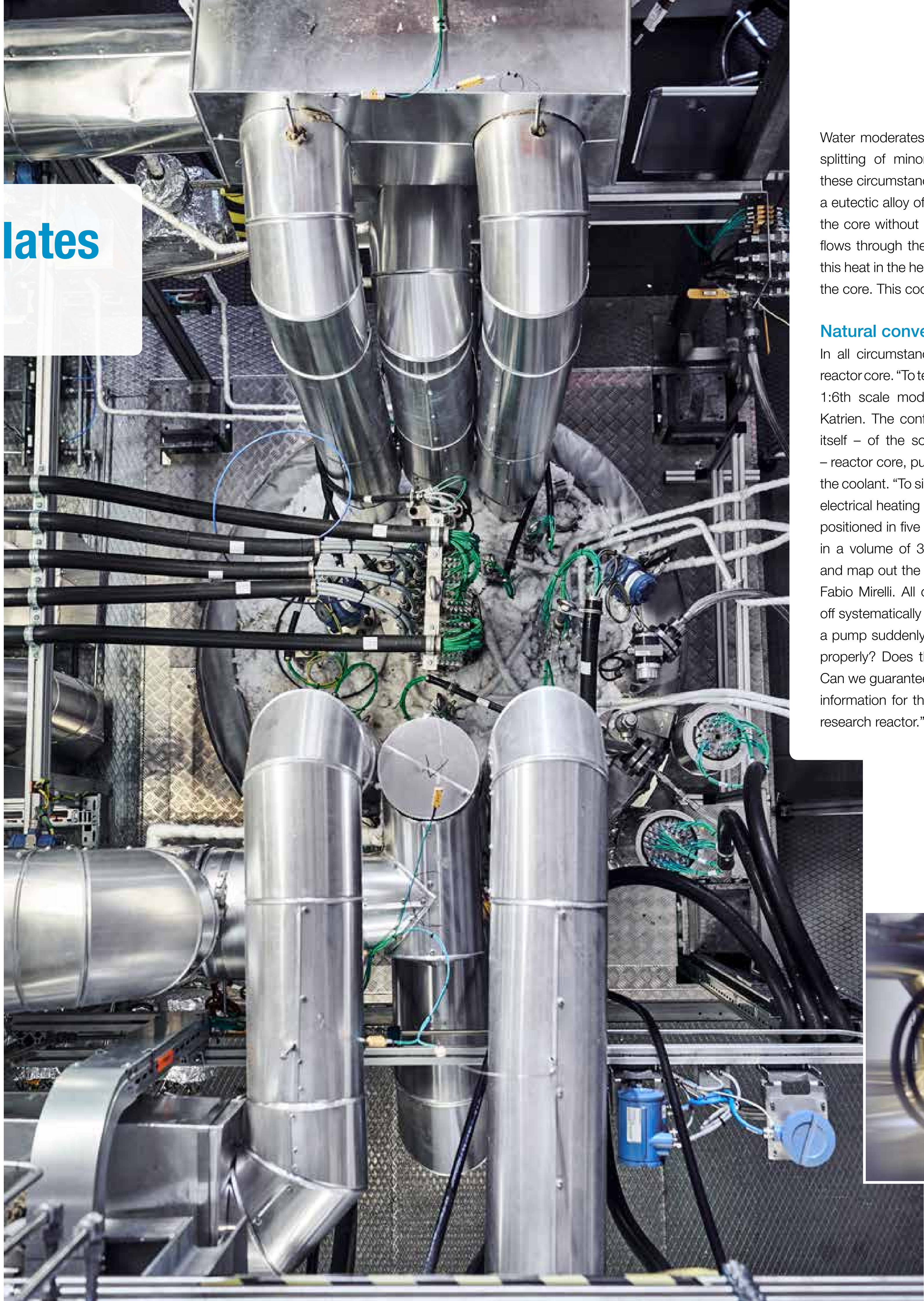
A COOL 2 KELVIN

Superconductivity is the phenomenon whereby the electrical resistance of certain materials disappears below a certain temperature. "The temperature we require is 2 Kelvin. This is close to the absolute zero, rather cool", winks Dirk Vandeplassche.

Mini-MYRRHA simulates cooling in reactor

In Mol, you will find the world's only complete scale model of a nuclear reactor cooled with a liquid lead-bismuth alloy: E-SCAPE. With the 1:6th scale model, researchers study the cooling of innovative research reactor MYRRHA. With positive results. Cooling remains guaranteed.

MYRRHA will produce medical radioisotopes, facilitate material research for fission and fusion reactors and take a big leap forward in closing the nuclear fuel cycle. For the latter, SCK•CEN implements the transmutation principle. "Through nuclear fission, transmutation transforms long-lived, highly radiotoxic residue – the so-called minor actinides such as neptunium, americium and curium – into less radiotoxic elements, which also have a shorter half-life", explains nuclear engineer Katrien Van Tichelen. As such, transmutation lightens the requirements for geological disposal, but it doesn't work in existing water-cooled reactors. In these reactors, the probability of absorption, whereby the atom absorbs the neutron and becomes heavier, exceeds the probability of fission for certain atoms. "It is precisely these heavier atoms that contribute most to the radiotoxicity of nuclear waste and have a longer lifecycle. Faster neutrons do manage to split those heavier nuclei", says Katrien.



Water moderates, slows down fast neutrons and hampers the splitting of minor actinides. "Transmutation cannot occur in these circumstances", explains Katrien. In the MYRRHA design, a eutectic alloy of lead (44.50%) and bismuth (55.50%) will cool the core without slowing down the fast neutrons. "The coolant flows through the reactor core, absorbs heat, rises and sheds this heat in the heat exchangers before dropping back down into the core. This cools the core."

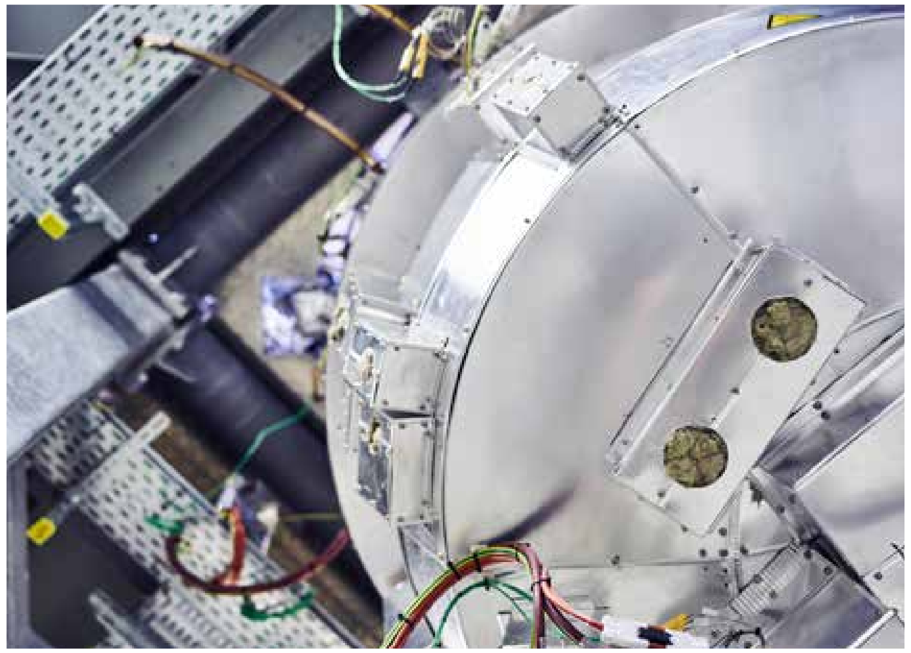
Natural convention cooling

In all circumstances, temperatures must be contained in the reactor core. "To test this, we designed E-SCAPE: an experimental 1:6th scale model of MYRRHA, a.k.a. mini-MYRRHA", says Katrien. The configuration of E-SCAPE is – just like MYRRHA itself – of the so-called pool type. This means that all parts – reactor core, pumps and heat exchangers – are submerged in the coolant. "To simulate the heat of the reactor core, we installed electrical heating elements in E-SCAPE. These heating units are positioned in five rings and have a total capacity of 100 kilowatt in a volume of 30 litres. With about 300 probes, we monitor and map out the temperatures in the tank", explains researcher Fabio Mirelli. All components of the scale model are switched off systematically to simulate accidental circumstances. "What if a pump suddenly fails? What if a heat exchanger doesn't work properly? Does the mechanism of natural convection kick in? Can we guarantee the cooling of the core? That is the important information for the design and safety analysis of the MYRRHA research reactor."

Fabio Mirelli, researcher at SCK•CEN

"Our experiments produce essential information for the design and safety analysis of MYRRHA."

Natural convection means the flow of a fluid that results from a difference in density caused by a difference in temperature. "A hot liquid has a lower density and floats upwards, while a cold liquid sinks because of its higher density", explains Katrien. In 2018, the first results of the large-scale experiment rolled off the press. "The system works. Natural convection cooling is more than enough to evacuate residual heat. Even when we switch off the pumps, cooling remains guaranteed". Both researchers are beaming. In the coming months, the research team will be scrutinising the results.



Katrien Van Tichelen, nuclear engineer at SCK•CEN

Reassuring noise

Last year, both researchers spent a lot of time near E-SCAPE. "In the summer, it is about 30 to 35°C in the room", says Fabio Mirelli knowingly. A sweltering temperature, accompanied by the uninterrupted droning of the pumps. "This humming sound becomes reassuring after a while. It is like the engine in your car. The noise tells you if everything is running smoothly. I really do want to hear the pump noises." Once the experiment is running, the researchers only need to keep an eye on things and analyse the recorded data. In order to have a better idea of the flow patterns of the lead-bismuth alloy, researchers are planning measurements with ultrasonic velocimeters in 2019. Longer-term, the researchers will also test the chemical conditions of the liquid alloy in E-SCAPE. "Then, we will have a wealth of information, essential data that will enable us to assess what to expect of the working of the MYRRHA research reactor", concludes Fabio.

Technology

Playing a pioneering role

SCK•CEN is home to technology and innovation. Thanks to our unique installations, we can conduct ground-breaking experiments and develop state-of-the-art technologies. However, innovation is not only the result of acquired knowledge or developed technologies. Innovation also relies on the creativity and motivation of our staff. They are paramount to inspire and create opportunities in order to develop efficient solutions for our society.

Marc Schyns
Institute Director
Advanced Nuclear Systems

02 Bringing knowledge to life

Structural solution for the management of highly radioactive residues

SCK•CEN and the National Institute for Radioelements (IRE) reach out to each other. The research centre offers a structural solution for the management of highly radioactive residues originating from the production of medical radioisotopes, which are currently stored at the IRE site in Fleurus. This project, called RECUMO, therefore contributes to the security of supply of medical radioisotopes.

"Thanks to the partnership, Belgium can anchor its nuclear knowledge."

Belgium is one of the five global actors in the production and distribution of medical radioisotopes. "Our research reactor BR2 is responsible for the first production phase of medical radioisotopes: irradiating targets. Then, the National Institute for Radioelements (IRE) processes these targets using a chemical process in order to produce medical radioisotopes and administer them to patients", explains Eric van Walle, director-general at SCK•CEN. This production leaves highly radioactive waste (i.e. highly contaminated uranium residues). The highly radioactive residues are stored on the IRE site in Fleurus, but in 2010, the Federal Agency for Nuclear Control (FANC) announced that the store was close to the acceptable storage threshold. "When the storage limit is reached, production and therefore security of supply cannot be guaranteed anymore. That could have a major impact on the medical sector. Indeed, almost 7 million patients worldwide rely on the Belgian production of molybdenum-99 for their medical examinations. Medical radioisotopes are indispensable in the fight against cancer", explains Eric van Walle (SCK•CEN). As a result, the IRE started looking for a structural solution. Several options were assessed, but late last year, the die was cast: SCK•CEN will purify the highly radioactive waste and the uranium it contains. "We will process both current and future residues that will be generated during production until 2038", says Eric about the private-public partnership between both parties.

Erich Kollegger, CEO of IRE, and **Eric van Walle**, SCK•CEN Director-General

The project, called RECUMO, reinforces the excellent relations SCK•CEN and IRE have been enjoying for many years. "Not only that", insists Erich Kollegger, director-general at IRE. "Thanks to this partnership, Belgium can firmly establish its extensive nuclear knowledge. We keep the necessary knowhow for the safe management of this nuclear heritage and reinforce our position as leader in the production of medical radioisotopes." Moreover, the project strengthens global non-proliferation. "In Mol, we will upgrade the residues and convert it into low-enriched uranium", adds Eric van Walle (SCK•CEN).

State-of-the-art technology

For the purification process, RECUMO implements state-of-the-art technology in radiochemistry. "It is not the first time that SCK•CEN implements this technique. In 1988, the technique had already been applied at lab scale. Very successfully! Now, we have refined, optimised and developed the technique so it can be implemented on a semi-industrial scale", explains Eric van Walle (SCK•CEN). To achieve this and turn the partnership into a success story, advanced infrastructures will be built on the site in Mol. The project creates jobs – both during the construction phase and for the running of the infrastructure.

STRONG TOGETHER

On 27 December 2018, SCK•CEN and IRE entered into a public-private partnership – one of the first in Belgium. "SCK•CEN and IRE are complementary in the story of medical radioisotopes. I am excited that we found each other again, because together, we stand strong. Joining forces is necessary to boost the fight against cancer", concludes Eric van Walle, director-general at SCK•CEN.

Cement recipe

At the same time, SCK•CEN – in cooperation with NIRAS – is working on a cement formula to condition the liquid waste flow after the upgrade process. "On the basis of desk research and our unique expertise, we were able to draw up a list of possible cement formulations and identify best candidates. Now, we examine the liquid waste, its stability and possible variations. This gives us a list of technical and chemical requirements. The cement will have to be suitable for all variations in this list", explains Eric van Walle (SCK•CEN). In a next step, the liquid waste will be mixed with the cement preparation and subjected to a series of tests. Eric van Walle: "Pressure tests, tensile tests, chemical test,… You name it. We must be sure that the cement is compatible with its environment."

Watchful eye

The RECUMO project is run in close cooperation with the Directorate-General Energy of the Federal Public Service Economy, SME, Middle Classes and Energy, under the supervision of the Federal Agency for Nuclear Control (FANC), Euratom and the United States. Eric: "They impose nuclear safety and security standards and monitor strict observance of these."

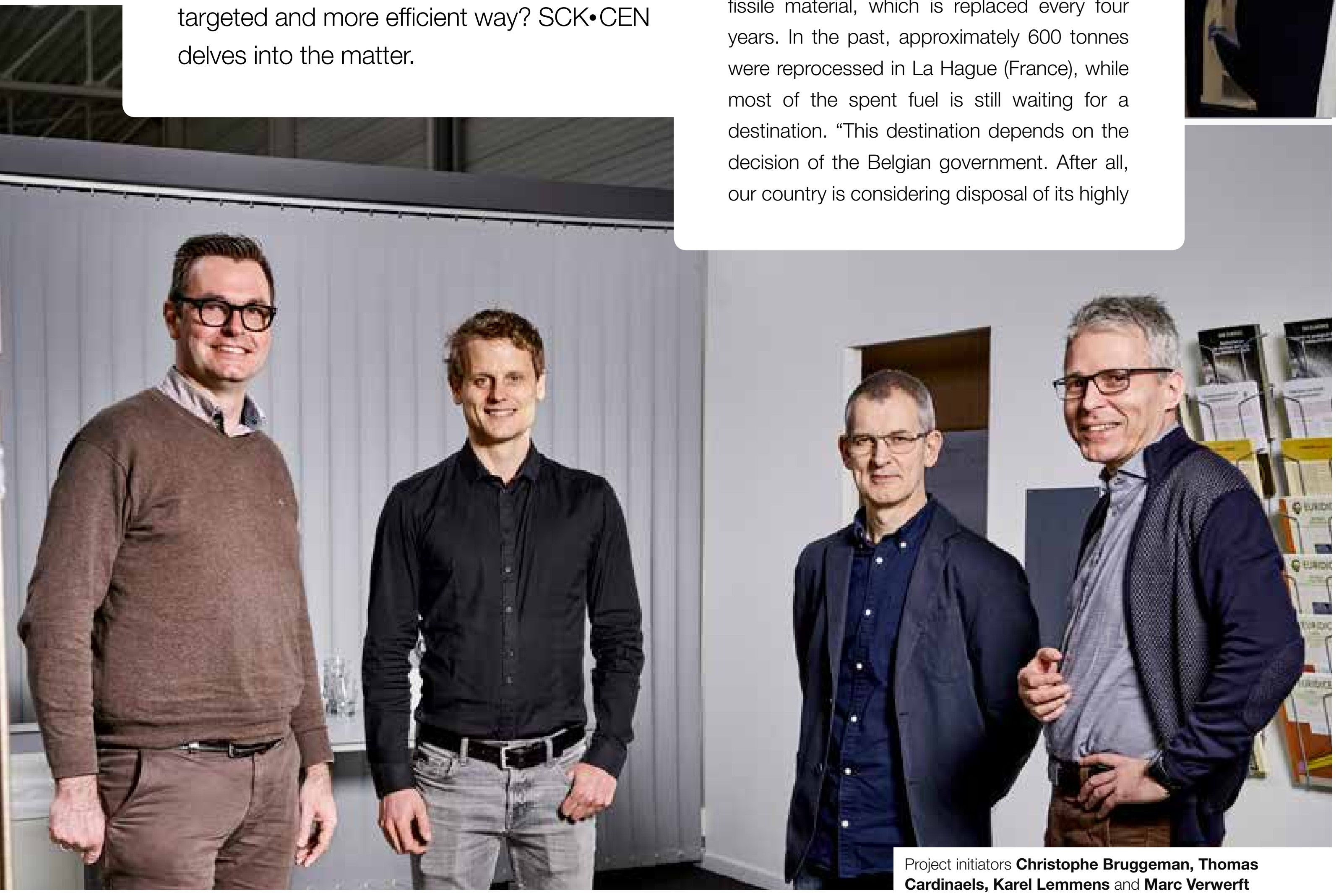
Meteoric developments

The RECUMO project set the tone. Indeed, both institutes do not exclude further cooperation. "The world of medical radioisotopes evolves at lightning speed and the importance of therapeutic radioisotopes is rising. Take lutetium-177 for example. That radioisotope is about to receive marketing authorisation by the European Union for the treatment of prostate cancer, the second most common form of cancer in men. We see demand growing exponentially, by a factor of ten. In the story of medical radioisotopes, SCK•CEN and IRE are complementary, and we therefore represent an added value for each other", says Eric van Walle (SCK•CEN). Erich Kollegger concurs: "Why wouldn't we join forces? RECUMO proves that it is possible. The information we gather from this project provides knowledge for both parties. We will therefore get more and more entangled."

"SCK•CEN and IRE represent an added value for each other. Why wouldn't we join forces?"

Caring for future generations

How does spent fissile material from nuclear reactors – so-called *spent fuel* – react with its environment, if we store it immediately underground? Can we separate the different radionuclides into different fractions, so that these fractions can be managed in a better targeted and more efficient way? SCK•CEN delves into the matter.



Project initiators **Christophe Bruggeman, Thomas Cardinaels, Karel Lemmens** and **Marc Verwerft**

In the 70's, Belgium started its own nuclear programme with the construction of four reactors in Doel and three reactors in Tihange. In 1975, the first ones went on-line. Since then, those seven reactors have been producing approximately 50% of the power supply in our country. The energy is generated by irradiating fissile material, which is replaced every four years. In the past, approximately 600 tonnes were reprocessed in La Hague (France), while most of the spent fuel is still waiting for a destination. "This destination depends on the decision of the Belgian government. After all, our country is considering disposal of its highly radioactive waste and spent nuclear fuel. Several options are available: the spent fuel may be stored directly and permanently in geological layers, but it may also be split up in fractions. By doing so, the total volume that must be stored can be reduced. SCK•CEN is exploring two possibilities in two multidisciplinary projects", explains Christophe Bruggeman, one of the project initiators. "Both projects have the same aim: reducing the load for future generations."

DIRECT STORAGE

SCK•CEN has been carrying out experiments for a while, commissioned by the National Institute for Radioactive Waste and Enriched Fissile Materials (NIRAS), which will support the safety studies concerning the possible direct geological disposal. "The SF-ALE project, which we run in cooperation with the German research centre Jülich (FZJ), is part of the NIRAS research programme", says Karel Lemmens, project manager at SCK•CEN. The project started in 2018 and tests one specific safety aspect of the current, proposed disposal concept.

Groundwater

"In the current design, the irradiated fissile elements are put in heavy, protective concrete containers. These containers slide into underground tunnels, which are also made of concrete. The irradiated fissile elements can enter into contact with groundwater seeping through the concrete and become alkaline as a result", explains Karel. "The groundwater then adopts the typical characteristics of cement pore water: high pH value and high concentration of alkali metals and calcium. What is the chemical stability of the 'spent fuel' in this environment? That is the main information on which the safety assessment of the disposal system is based."

To test the concept, SCK•CEN submerges representative nuclear fuel rods for at least eighteen months in cement water with a high pH. "The pH value of cement water is 13.5, while groundwater usually has a pH of around 7.4. The aim is to monitor the release of radionuclides over time", explains Karel.

Reproducing real-world conditions

In their experiments, researchers aim at imitating real-life circumstances of underground disposal as accurately as possible. “We have planned a long test period, because the release of radionuclides in these circumstances is expected to occur slowly. The experiment was launched in 2018, and the first phase runs until 2020. In this phase, we focus on the most soluble radionuclides found in the structures that are in direct contact with cement water”, says Gregory Leinders, who follows up cooperation with the German centre JFZ. “If the results are satisfactory and with the necessary funding, the tests will be extended in the period 2020-2021.”

BETTER MANAGEMENT

With the other multidisciplinary project ASOF, SCK•CEN investigates possible leads for a more optimal management of irradiated fissile material in Belgium. “ASOF stands for *Advanced Separation for Optimal management of spent nuclear Fuel*. You can guess from the name that this project focuses on the option of enhanced separation of the different radionuclides in irradiated fissile materials. The different resulting fractions can then be management in a more targeted and more efficient way. Compare this with household waste: before, everything was dumped in one big heap and then burnt, now we sort it. This offers the opportunity to follow the best way for the processing of each fraction”, illustrates Thomas Cardinaels, expert in radiochemistry.

> *“With the ASOF project, we are looking for an alternative scenario aimed at reducing the load and risks of geological disposal for future generations.”*

Separating more is disposing less

In this context, ASOF want to develop a method to separate americium. This element, in particular the Am-241 isotope, has a high radiotoxicity, a long half-life (432 years) and generates a lot of heat. “When we reprocess the separated americium into a target that can be irradiated in a reactor such as MYRRHA, it can be transformed into short-lived radionuclides”, explain Thomas Cardinaels and his project co-initiator Marc Verwerft. “We are also researching a method to separate fission products caesium-137 and strontium-90. These are short-lived and generate a lot of heat. By separating them and then conditioning them separately, we prevent this fraction from ending up with the highly radioactive waste.”

This means separation has an impact on the final disposal footprint. “In fact, our project is a search for an alternative scenario aimed at reducing the load and hazards for future generations”, concludes Thomas. The first results of this study are expected in five years’ time.

Knowledge

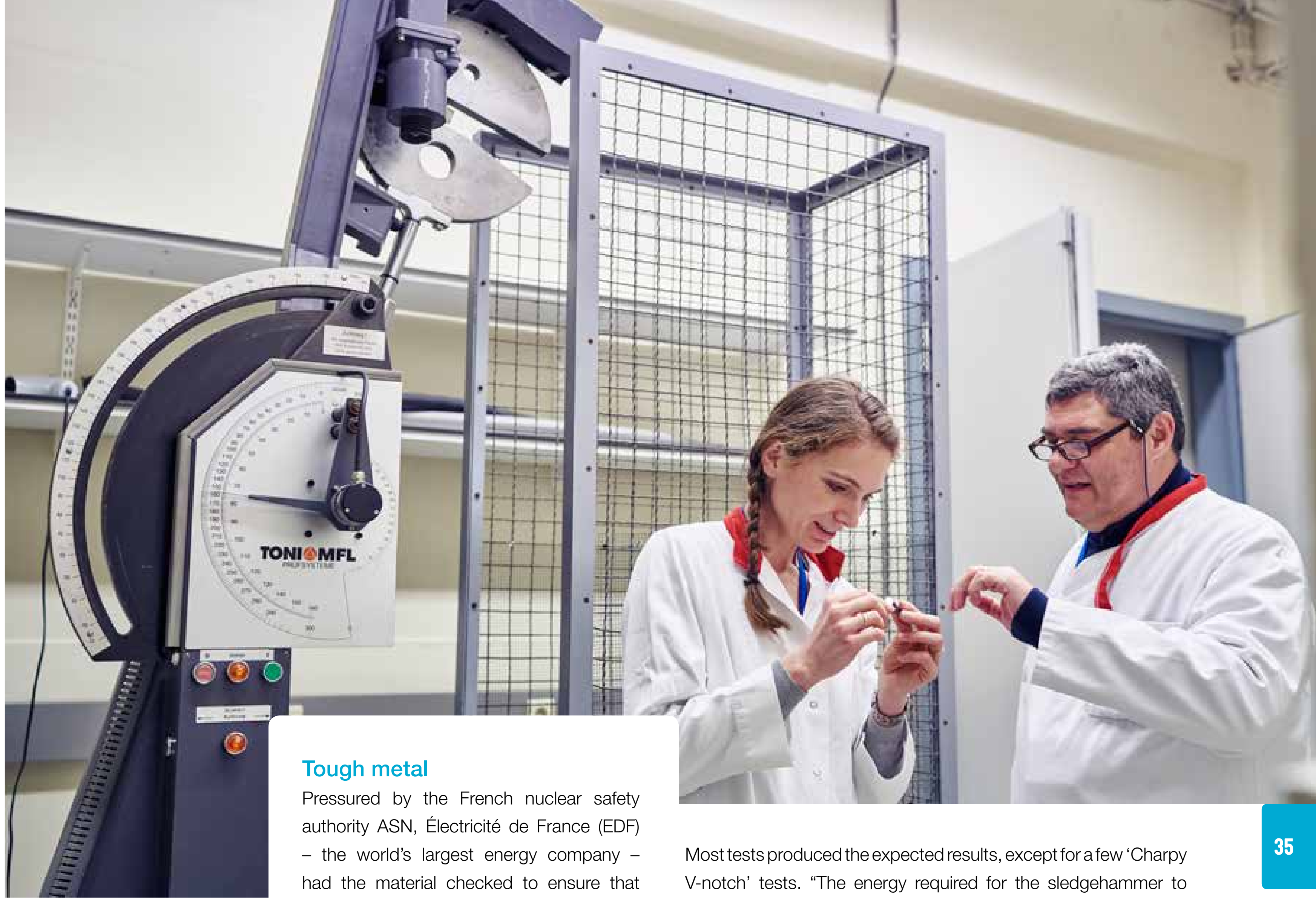
Keep investing

Even after an eventual closing of the power reactors in Belgium, we must keep investing in order to preserve and deepen our nuclear knowledge. This knowledge is useful to manage nuclear waste safely, dismantle nuclear power plants and ensure the production of theranostic radioisotopes (for therapeutic treatment or diagnostic research).

Sven Van den Berghe
Institute Director
Nuclear Materials Sciences

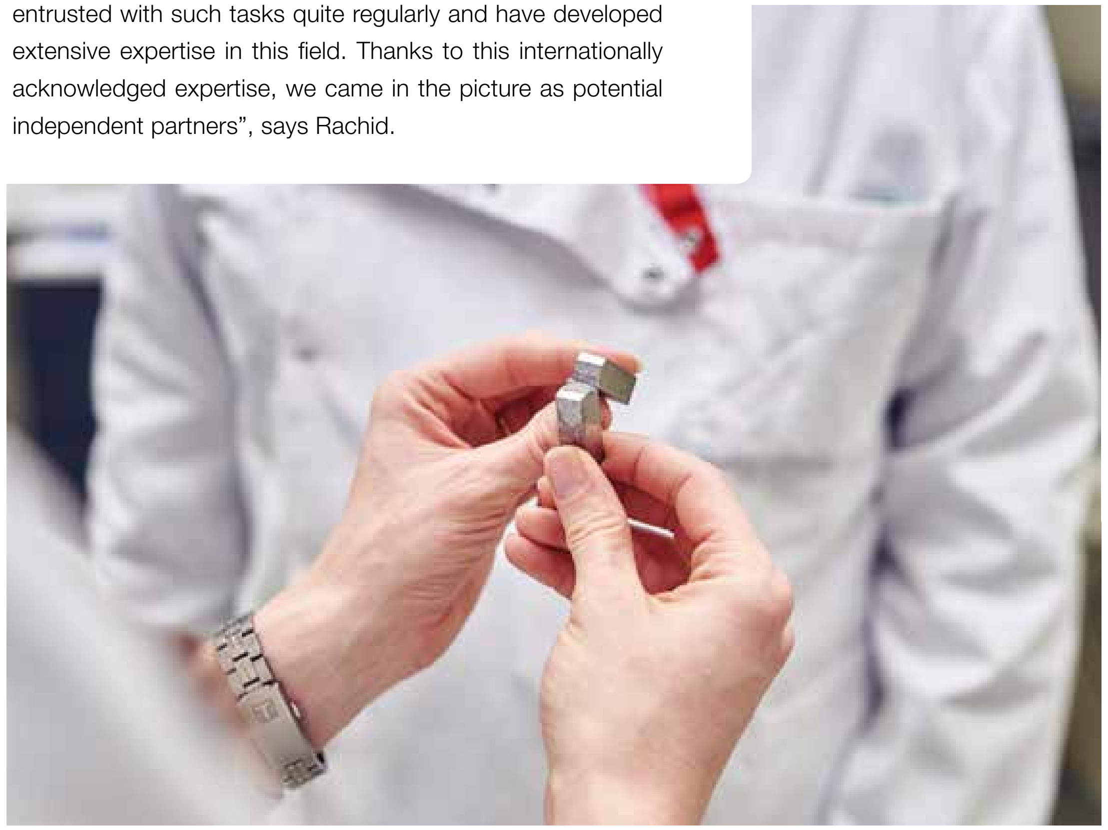
France orders material testing from SCK•CEN

In 2015, France found high carbon concentrations in the steel of power generators in its nuclear power plants. What is the effect of this ‘carbon segregation’ on the mechanical properties of the material? Contracted by the *Autorité de Sûreté Nucléaire* (ASN), the French counterpart of FANC, SCK•CEN took up the gauntlet to demonstrate safety. Literally.



In 2015, carbon segregations were discovered in the bottom and cover of the FA3 EPR (Flamanville’s European Pressurized Water Reactor). “Segregation occurs in the solidification process. The first element that crystallises when steel solidifies is the most common element, i.e. iron. The other elements, which are present in smaller amounts (such as carbon and sulphur), are trapped in the still molten areas and solidify last”, explains researcher Rachid Chaouadi. “The problem is that these so-called segregation areas are subject to increased brittleness.” After this discovery, the Autorité de Sûreté Nucléaire (ASN) ordered all operators to inspect other components. In total, high carbon concentrations were found in the steel of the primary base of power generators in 18 out of 58 French nuclear reactors. “In twelve reactors, the concentrations found were even ‘particularly high’”, says Rachid.

The discovery opened up a social debate about the safety of existing reactors. “What is the effect of carbon segregation on the properties of steel?”, explains Rachid. To clarify this question, France launched a research programme. Part of the tests were outsourced to SCK•CEN. “We are entrusted with such tasks quite regularly and have developed extensive expertise in this field. Thanks to this internationally acknowledged expertise, we came in the picture as potential independent partners”, says Rachid.



Tough metal

Pressured by the French nuclear safety authority ASN, Électricité de France (EDF) – the world’s largest energy company – had the material checked to ensure that it still met the standard requirements. The research at SCK•CEN was commissioned by Framatome, formerly Areva NP and now a member of EDF Group. “The divergent composition of the steel in the primary base of the power generators has an impact on the mechanical properties of the material”, says researcher Marlies Lambrecht. “We focused on this in our tests. The tests we carried out enabled us to determine the mechanical properties of the material, including the fracture toughness.” SCK•CEN started in March 2018 and, since then, has completed a few hundred tests. The approach with the ‘Charpy V-notch’ tests was not particularly soft. “This is an international standard test whereby researchers break up the test samples with a heavy sledgehammer”, explains Marlies. “The results we produce are used by EDF in their justification to keep the power generators running.”

Most tests produced the expected results, except for a few ‘Charpy V-notch’ tests. “The energy required for the sledgehammer to break the test samples was below the admissible values. Yet, our internal calculations demonstrate that the results are still within the statistical limits of fracture mechanics”, concludes Rachid Chaouadi.

To allow for a deeper analysis, the current contract was extended. Rachid: “These tests will take place in February or March 2019. We will forward the results directly to Framatome, who will use these results and other research to compile a dossier to be submitted to the French nuclear watchdog.”

> *“Thanks to our internationally acknowledged expertise, we came in the picture in France as potential independent partners to test the material.”*

Aiming at preserving nuclear knowhow

Discovering the nuclear sector while ‘playing’

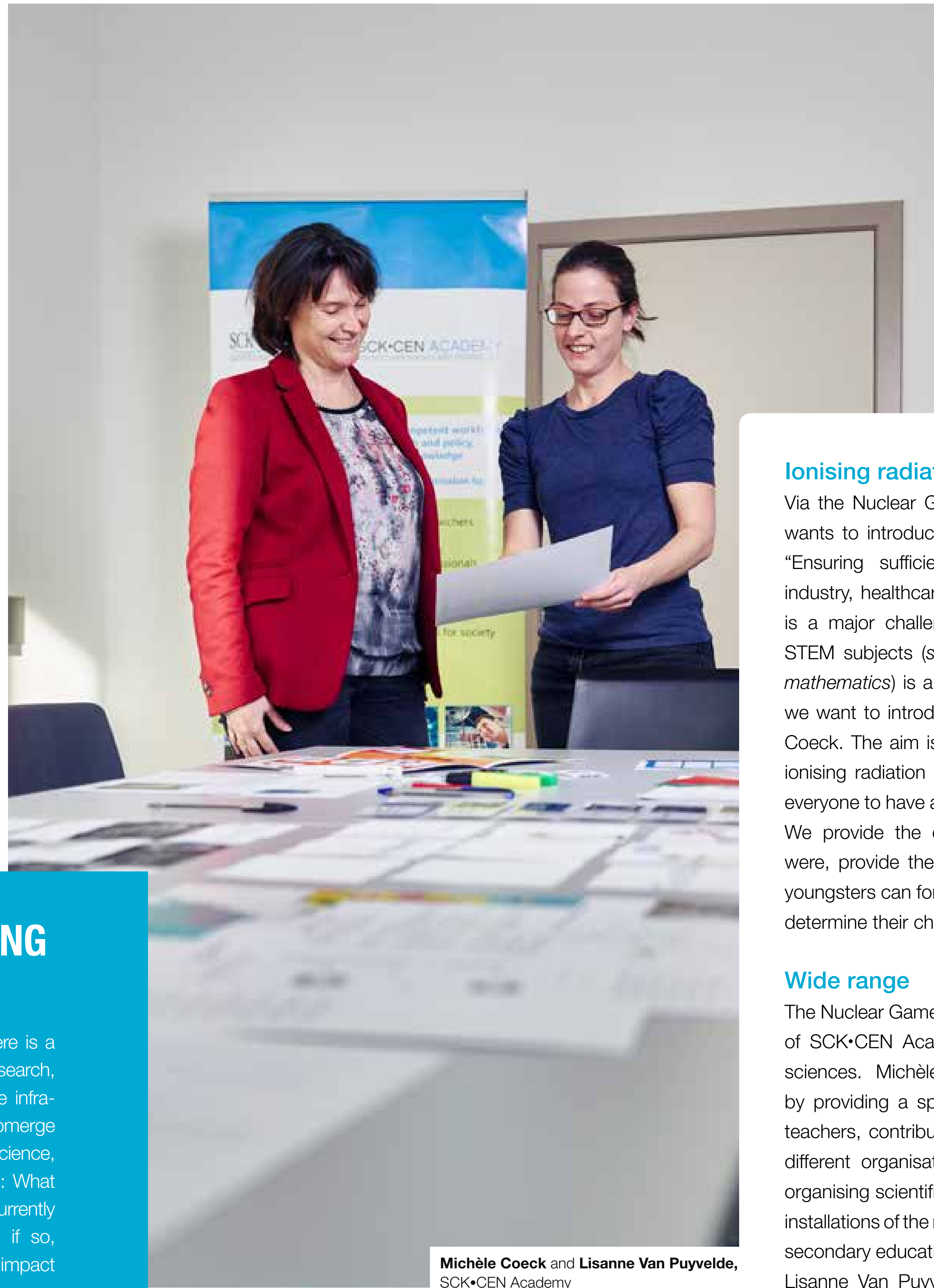
The SCK•CEN Academy wants to improve literacy about ionising radiation and its applications. Through in-depth training and education, inspiring company visits and fun scientific challenges such as the Nuclear Game Challenge. “Our task is to inform current and future generations and, as a result, preserve nuclear knowledge”, says Michèle Coeck, Head of SCK•CEN Academy.

In 2018, SCK•CEN in cooperation with the Joint Research Centre (EC-JRC), launched the very first edition of the Nuclear Game Challenge. “The Nuclear Game Challenge was a science contest for third-grade high school pupils. We challenged the youth to devise an interactive and educational game themed around nuclear sciences and applications”, explains Michèle Coeck, Head of SCK•CEN Academy. The science contest was a sure hit: no less than 100 pupils from 17 different schools registered. The competition started during a kick-off event at the Natural Science Museum in Brussels, where the pupils discovered different nuclear themes and gathered inspiration for their games. “Radioactivity, radiation protection, nuclear applications and nuclear research were tackled. Then, the pupils got going”, tells Lisanne Van Puyvelde, co-organiser of the contest. SCK•CEN Academy received 18 creative games in total. “A big thumbs up for all pupils, because they set the bar high. Amazing concepts, astonishing originality and detailed elaboration were the common thread throughout many of the games submitted”, says Lisanne.

The game Enrich U developed by team Nuclairons of the Brussels school Collège Jean XXIII was the ultimate winner. “An innovative and original game because of its diversity, its constructive level of difficulty, the different disciplines covered and the challenge to think strategically. Chance cards and other twists and turns keep you riveted right to the end. Excitement guaranteed”, says Michèle Coeck. The team also devised an extension to the game. “In the extended version, certain boxes were blocked because of so-called ‘gamma rays’, giving the game a whole new dimension. Other strategies are required to win.”

LEAVING A LASTING IMPRESSION

Behind the gate of SCK•CEN, there is a lot to discover: ground-breaking research, innovative technologies and unique infra-structures. “Our colleagues submerge visitors in the world of nuclear science, but the big question, of course, is: What impression do we leave? We are currently assessing whether or not – and if so, how – our school visits have an impact on the knowledge, perception and career intentions of young people. We are expecting the results next year”, concludes Michèle Coeck.



Michèle Coeck and **Lisanne Van Puyvelde,** SCK•CEN Academy

> *“With initiatives like this one, we want to improve scientific literacy among young people in the fields of ionising radiation and its applications.”*

Ionising radiation literacy

Via the Nuclear Game Challenge, SCK•CEN Academy wants to introduce youngsters to the nuclear industry. “Ensuring sufficient skilled workers in the nuclear industry, healthcare sector, public service and research is a major challenge these days. Attracting youth to STEM subjects (*science – technology – engineering – mathematics*) is a first step. With initiative like this one, we want to introduce them to these”, explains Michèle Coeck. The aim is to increase scientific literacy around ionising radiation and its applications. “This empowers everyone to have an informed involvement in the debate. We provide the correct facts and figures and, as it were, provide the scientific building blocks with which youngsters can form their own opinion and possibly also determine their choice of academic subject.”

Wide range

The Nuclear Game Challenge is only one of the initiatives of SCK•CEN Academy to enthuse youth for (nuclear) sciences. Michèle Coeck: “We also support STEM by providing a specific website for young people and teachers, contributing towards educational initiatives of different organisations (such as VONW, Vlajo,…) and organising scientific tours in the unique labs and nuclear installations of the research centre for third-grade pupils in secondary education.” Michèle Coeck and her colleague Lisanne Van Puyvelde experience a lot of interest for the initiatives they offer. “Because SCK•CEN is active in different fields, we can put forward a highly diverse offer. There is something for everyone”.

03 Holding back cancer

From cancer diagnostics to cancer therapy

SCK•CEN sets up NURA, a nuclear medical centre of excellence. “With NURA, we will carry out ground-breaking research into radiopharmaceuticals for the treatment of different types of cancer, commissioned by clinical and industrial partners”, announces project leader Dennis R. Elema. With the creation of NURA, SCK•CEN is shifting into high gear in the fight against cancer.

“Therapeutic radiopharmaceuticals are ‘the next big thing’ in the fight against cancer.”

Each year, more than 65,000 Belgians are diagnosed with cancer. This figure is expected to rise, and by 2025, the counter should reach almost 80,000 Belgians. Nuclear medicine has reached a tipping point. “So far, radioisotopes are used frequently in nuclear medicine for diagnostics purposes. The radioactive substance administered to the patient circulates with carrier molecules throughout the body and accumulates in diseased cells. The radioactive substance lights up under isotope scanning. This makes it possible to detect and locate aberrations. Over the past few years, we have been noticing that targeted treatments are on the rise and the need for therapeutic radioisotopes is therefore high”, explains project leader Dennis R. Elema.

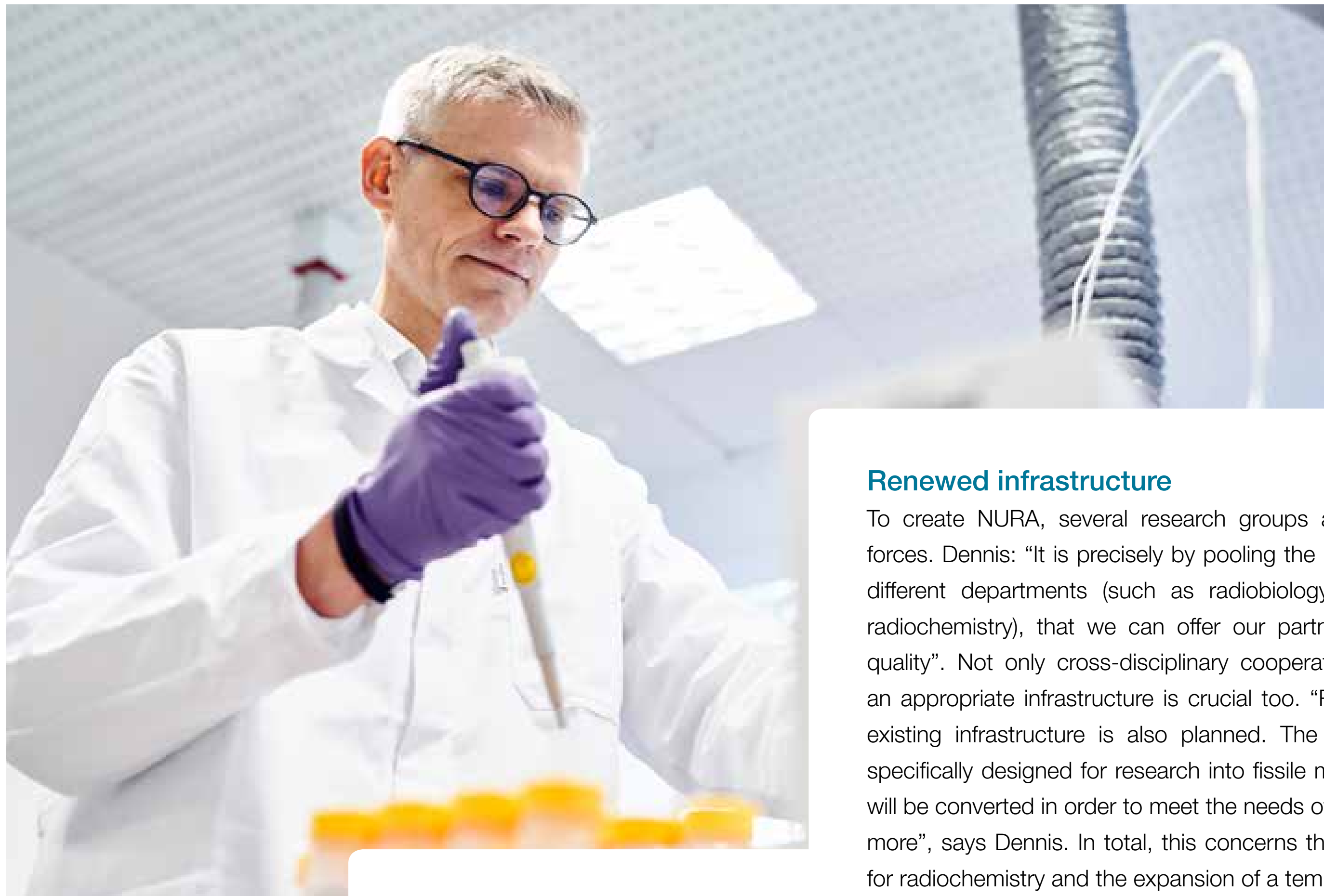
In targeted radionuclide therapy, a carrier molecule brings a radioactive isotope very accurately to the cancer cells. As soon as the molecule attaches to the cell, the radioactive isotope can irradiate the cancer cell. The aim is to reach and disrupt the cell’s DNA. “The tumour shrinks and will ultimately die”, explains Dennis R. Elema. The use of therapeutic radiopharmaceuticals is expected to grow. “It is the next big thing in the fight against cancer”, says Dennis. This represents an enormous growth potential for SCK•CEN, which has been contributing considerably to the fight against cancer for quite some time. “We have the knowledge, infrastructure and unique raw materials available to develop new radiopharmaceuticals. This means we have all the necessary assets in hand to reposition ourselves, target our efforts more on therapeutic radioisotopes and as a result increase our contribution in the fight against cancer. We want to help patients keep their illness under control and even heal”, says Dennis. Therefore, SCK•CEN is setting up NURA, which will enable it to grow into a nuclear medical centre of excellence.

Triple role

NURA has a threefold function. First of all, as a 'Contract Research Organization (CRO)', it will support clinical and pharmaceutical partners in the research into and development of promising radiopharmaceuticals for therapeutic purposes. "We focus on all stages prior to clinical trials and, as such, offer support in the first phases of the development chain", explains Dennis. "In a first phase, we mark a new candidate carrier molecule with a radioactive isotope. Then, we identify the most promising candidate and carry out several tests on this carrier molecule: in vitro tests whereby we let the carrier molecule and cancer cell interact in a test tube, as well as in vivo trials, whereby we test the behaviour of our radiopharmaceuticals. This research is necessary before we can start testing the pharmaceutical on humans."

In addition, NURA has the ambition to act as a 'Contract Manufacturing Organisation (CMO)'. "We want to become a stable supplier of therapeutic isotopes. Because everything happens in-house, we can offer our clinical partners and pharmaceutical companies a guaranteed superior quality of the development process", says Dennis R. Elema.

Finally, with NURA, SCK•CEN wants to strengthen research into medical applications of radioactivity in the existing research groups. Part of this research focuses on radiolabelling, whereby the radioactive nuclide is coupled to a carrier molecule with the purpose of imaging or attacking the tumour. "A one-size-fits-all approach does not work. Each type of cancerous cell has its own receptors, for which we must develop targeted carrier molecules", Dennis explains. In its research activities, SCK•CEN also focuses in particular on long-term effects of cancer treatment with therapeutic radiopharmaceuticals. The aim is to target the tumour specifically and reduce side-effects considerably – both short-term and long-term."



Less collateral damage

SCK•CEN puts its money where its mouth is. "In the BR2 research reactor, we are currently already irradiating targets for the production of lutetium-177. This beta-emitter is frequently used in hospitals for cancer treatment", says Dennis. "New treatments are also being developed. These treatments are based on the new, very promising, alpha-emitter Ac-225. NURA will also take care of its production", Dennis explains. SCK•CEN will subject the actinium-225 to very stringent quality tests, to make sure it meets the requirements of pharmaceutical partners. Radioisotopes such as rhenium-188 and terbium-161 are also promising. "This is the next generation of radioisotopes coming into the picture for production in the BR2 research reactor. With these isotopes, we can treat several types of cancer", explains Dennis.

Renewed infrastructure

To create NURA, several research groups at SCK•CEN join forces. Dennis: "It is precisely by pooling the knowledge of our different departments (such as radiobiology, dosimetry and radiochemistry), that we can offer our partners this superior quality". Not only cross-disciplinary cooperation is important, an appropriate infrastructure is crucial too. "Renovation of the existing infrastructure is also planned. The current labs are specifically designed for research into fissile materials and they will be converted in order to meet the needs of pharmaceuticals more", says Dennis. In total, this concerns three research labs for radiochemistry and the expansion of a temporary pre-clinical lab. "We will also build a large facility for pre-clinical trials. Construction for this building is planned in 2021. We will use it to conduct all in vitro and in vivo tests."

Job opportunities

The NURA project that is about to leave the starting blocks is a huge project. "A project of this magnitude also creates job opportunities", explains Dennis. "Everyone who joins the NURA team at SCK•CEN contributes to the fight against cancer. With the new generation of therapeutic radiopharmaceuticals we are currently developing, we want to improve and optimise treatment for cancer patients. Ever heard of a more noble cause?"

> *"Because everything happens in-house, we can offer our clinical partners and pharmaceutical companies guaranteed superior quality."*

SCK•CEN expands production of medical radioisotopes

To meet increased global demand for medical radio-isotopes and the need for less invasive cancer therapies, SCK•CEN expands its activities in nuclear medicine with the production of two new medical radioisotopes for the treatment of prostate cancer among other things: lutetium-177 "non carrier added" and actinium-225. For this, the research centre joins forces with IRE ELiT and Global Morpho Pharma.

Nuclear reactors are usually associated with the idea of nuclear energy. Incorrectly. On the SCK•CEN site there is a reactor that saves thousands of lives each year: the BR2 research reactor. The core of the research reactor produces more than a quarter of worldwide demand for molybdenum-99 (Mo-99), and when demand is strong even up to 65%. "Over the past few years, we have put a lot of effort into adapting the irradiation installations to make production possible of other medical radioisotopes. From 2019 on, we will be adding two new radioisotopes to the list: lutetium-177 non carrier added (nca Lu-177) and actinium-225 (Ac-225).

"Our cooperation with IRE ELiT and Global Morpho Pharma reinforces our pole position in nuclear medicine."

The radioisotope nca Lu-177 is an important ally in the fight against prostate cancer. "Prostate cancer is, bar one, the most common type of cancer in men and causes close to 90,000 deaths each year in Europe alone", says Richard Zimmerman, CEO at Global Morpho Pharma. "Due to its purity, the isotope introduces less radioactivity in the body when administered. This results in shorter hospital stays. Moreover, this new generation medical radioisotope can be coupled to a number of carrier molecules, which bind to targeted cancer cells and disrupt the DNA directly. This leaves healthy tissue virtually unaffected. Fewer side effects, another step towards developing personalised treatments."

In its pursuit of less invasive cancer therapies, SCK•CEN will also produce a second innovative radioisotope: actinium-225 (Ac-225). "Actinium-225 – also coupled to a carrier molecule – will release alpha particles that destroy cancer cells. The radioisotope makes it possible to tailor the treatment to the tumour, its size and location", explains Richard.

Strengthened cooperation with IRE ELiT

Just like for the production of molybdenum-99 (Mo-99), SCK•CEN relies on the National Institute for Radioelements (IRE) in Fleurus. “For the production of nca Lu-177, we partnered with IRE ELiT, an IRE subsidiary. This subsidiary specialises in the production of radiopharmaceuticals used in the treatment of different types of cancer and in palliative care. This cooperation with IRE ELiT enables us to aim for outstanding quality. Quality that follows the rules of Good Manufacturing Practices (GMP) and meets the expectations of GMP”, explains Koen Hasaers, Head Commercial and Marketing about the cooperation. SCK•CEN takes care of the total production of Ac-225.

Koen Hasaers, Head Commercial and Marketing

RACE AGAINST TIME

Lutetium and actinium decay rapidly. As a result, the radioactive substances must be administered to the patient within six days. This short period includes: 16h cooling down after production in Mol, transport to Fleurus (Belgium) or Petten (Netherlands) for the chemical treatment of the irradiated targets, encapsulation in the diagnostic tool and worldwide distribution to hospitals. “There, doctors and patient are already waiting. Seamless logistics is therefore crucial. Thanks to cooperation with Global Morpho Pharma, we reinforce the worldwide network and strengthen our position as reliable suppliers”, explains Koen Hasaers, Head Commercial and Marketing.

Worldwide distribution

For the distribution of this new generation of medical radioisotopes, SCK•CEN and IRE ELiT join forces with Global Morpho Pharma. “A golden team”, says Koen Hasaers. SCK•CEN has extensive knowhow and unique infrastructures in the nuclear field. IRE ELiT put their weight on the scales by making available their outstanding expertise in the radiopharmaceutical sector. Global Morpho Pharma have the necessary expertise and network to reach the market. Indeed, the business manages a production and distribution network for therapeutic radioisotopes and will take care of distribution in Europe and North America. “With this double partnership, we strengthen the position occupied by SCK•CEN worldwide as major player in the production of medical radioisotopes. Not only that, we reinforce our pole position in nuclear medicine, concludes Koen.

Cooperation

Join forces
to make a difference

SCK•CEN embraces the challenges of targeted radionuclide therapy. To succeed, SCK•CEN works in close cooperation, internally and externally. Internal cooperation through the pooling and broadening of expertise in the production of innovative radioisotopes, radiobiology and dosimetry and radio-pharmacy. External cooperation by joining forces with clinical and pharmaceutical partners. In this respect, our research forms the backbone for continuous improvement and innovation in healthcare.

Hildegarde Vandenhove
Institute Director
Environment, Health and Safety

04 A heart for both man and environment

State-of-the-art housing for humans and the environment

“In fact, we made three buildings in one.”

In 2018, SCK•CEN completed the construction of the EME building. “EME is short for EMergency MEdical & Measurement”, says building coordinator Davy Dehaen. The new, state-of-the-art building offers a better home for three departments: the medical department, the low radioactivity monitoring department and the emergency planning room. “Better housing for humans and the environment.”

The new EME building is crowned with a kind of white ball of ice cream, housing Snow White: an early warning system for low radioactivity contamination – the only one in Belgium. “You could say it’s like a gigantic vacuum cleaner that draws in huge amounts of air and pushes it through a filter”, explains Freddy Verrezen, researcher in low radioactivity monitoring. “High doses of radioactivity can be detected easily. We don’t need advanced technologies for that, but we do for low doses. It is important to invest in instruments that can measure low doses. Indeed, they can reveal a latent issue, such as a hidden leak.”

We will have to wait until 2019 for Snow White to be operational, but researchers are already itching to have the system up and running. “With this investment, we can surpass our current air quality monitoring capacity. So far, air monitoring was done via small funnels. These funnels collected a lot less dust per air intake unit than Snow White. And it is precisely this dust that we need to measure low doses. We test which radioactivity concentration it contains”, explains Freddy Verrezen.

Snow White is only one of the technological marvels to be discovered in the new energy-efficient building. Davy Dehaen, who coordinated the project, explains: “In fact, we created three buildings in one. We christened it ‘EME’. EME stands for EMergency MEdical & MEasurement. A reference to the three departments housed inside.” For this building project, SCK•CEN did not want to make hasty decisions. “In 2012, we started inventorying all needs and expectations of the different departments. This inventory would shape our initial renovation plans for the current building, but we quickly abandoned this idea. New build was a better solution for the dire lack of space on the one hand, and the need for more up-to-date installations on the other”, says Davy Dehaen. In 2018 construction was completed, and the three departments could move in.

Building coordinator **Davy Dehaen** (centre) with his colleagues **Daniëlle Cremers** and **Lode Hoeyberghs**

Mini hospital

The first department to be housed in the EME building was the medical department. This department takes care of the periodic medical monitoring of all staff at SCK•CEN, VITO and Belgoprocess. "We are also entrusted with the monitoring of outsourced personnel who work at SCK•CEN and Belgoprocess temporarily", explains occupational physician Luc Holmstock. "All in-house and outsourced workers that we examine periodically - approximately 1700 in total – undergo an extensive check-up. Each year, we must also issue approximately the same number of certificates of medical fitness for outsourced workers who come and work in controlled zones for a while. We have our own clinical lab to carry out a whole range of blood and urine tests, equipment to test eye, ear and lung function and an X-ray department, as well as fully fitted infirmary to administer appropriate care in the event of industrial accidents. Combined with a comfortable waiting room, the medical department has the atmosphere of a modern, run-of-the-mill hospital."

Lab division

The second department to move in is the Low Radioactivity Monitoring (LRM) department. Among other things, it keeps a watchful eye on possible radioactive contamination from industrial activities near nuclear facilities and Flemish hospitals. It also carries out bioanalyses for staff. "This is mainly done through urine sampling, because radioactivity is excreted for 80% via urine", explains Freddy Verrezen (LRM). To make work easier, the lab was given new equipment. "The installation was adapted to the process flow: from sampling to analysis. We also paid extra attention to the continuous monitoring of certain parameters such as oxygen, temperature, humidity and explosive atmosphere." The integrated monitoring network is not only located in the new lab, but in all rooms of the building. "We can set threshold within this network. As soon as certain values exceed the threshold, alarms are generated. This enables us to take timely action", building coordinator Davy Dehaen explains.

Fernand Vermeersch, Luc Holmstock and **Freddy Verrezen** helped develop the building.

"The new emergency planning room is partitioned into different rooms. This enables the members of the crisis cell to focus better, while still being close enough for easy consultation."

Emergency planning room

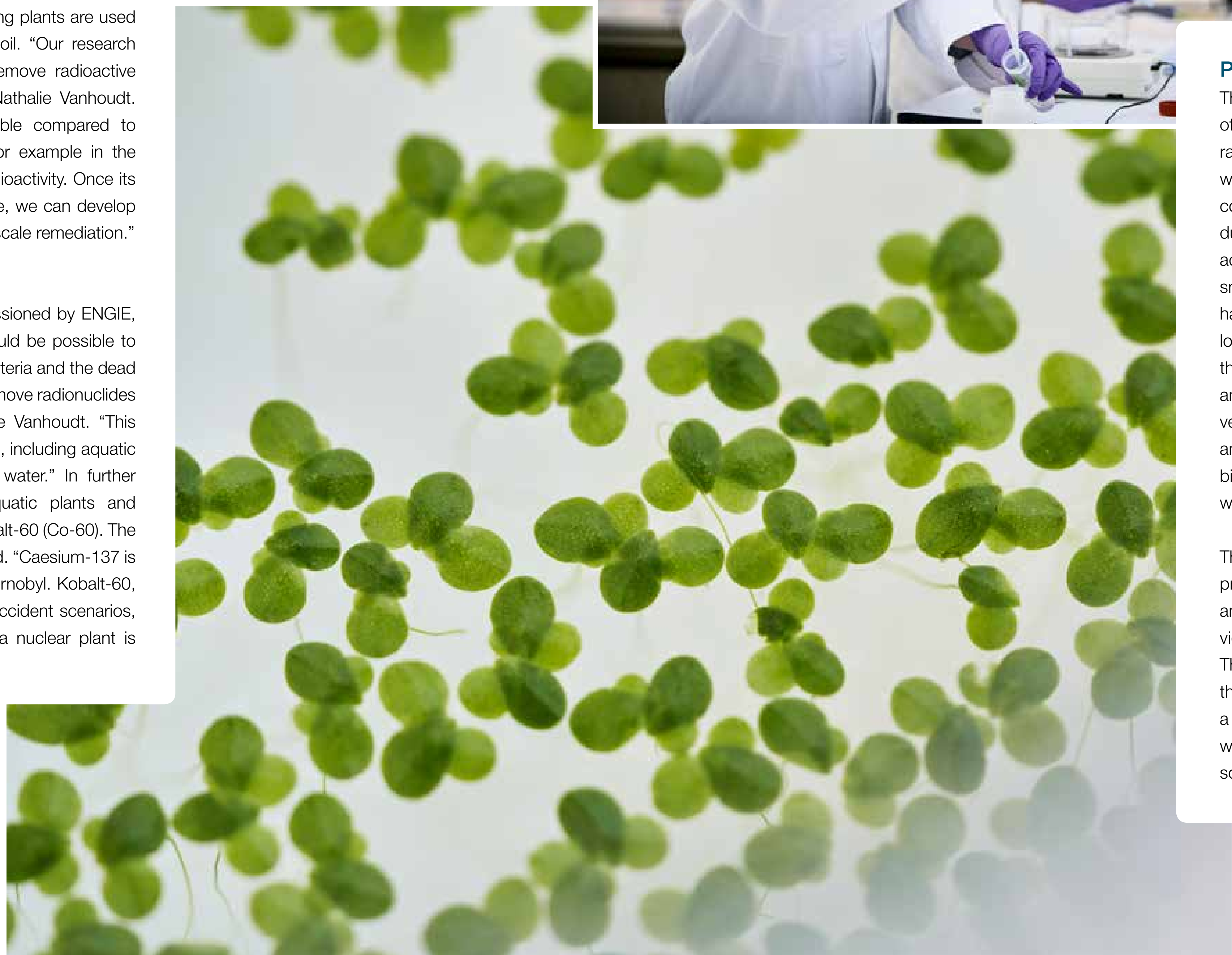
However, the showpiece of the EME building is the emergency planning room. "All stakeholders gather in the emergency planning room – in the event of an incident – to consult quickly, take action and communicate. The periodic safety evaluation revealed that the existing emergency planning room needed renovating", says Fernand Vermeersch, Head of the Internal Department for Prevention and Protection at Work. Unlike the current emergency planning room, the members of the crisis cell don't sit in one big room anymore. The new emergency planning room is divided into different, partitioned rooms. "This enables the members of the crisis cell to focus better, but they are still close enough to each other for quick consultation." The uniqueness of the room is mainly its ventilation. Fernand: "It works in over-pressure and the air is filtered via a HEPA filter system. This prevents contamination from coming in from outside." SCK•CEN organises regular drills in the emergency planning room.

Duckweed as radioactive sponge

The green carpet of plants that grows on canals and ponds in the summer is duckweed. This little plant not only tinges the water green, it also has the property to filter radionuclides out of contaminated water.

"Our research shows that duckweed is very suitable to remove radionuclides from water."

Phytoremediation is the process whereby living plants are used for the decontamination of water, air and soil. "Our research focuses on the use of aquatic plants to remove radioactive particles from water", explains researcher Nathalie Vanhoudt. "In certain situations, this can be preferable compared to conventional water treatment techniques, for example in the event of contamination with low doses of radioactivity. Once its use has been demonstrated on a small scale, we can develop a method to deploy aquatic plants for larger-scale remediation."



Potential of aquatic plants

The project was launched in 2014. "Commissioned by ENGIE, we did desktop research into whether it would be possible to use plants, macro and micro algae, cyanobacteria and the dead matter originating from these organisms to remove radionuclides from contaminated water", explains Nathalie Vanhoudt. "This research showed that a number of organisms, including aquatic plants, can potentially purify contaminated water." In further research, the researchers focused on aquatic plants and radionuclides caesium-137 (Cs-137) and cobalt-60 (Co-60). The choice of these radionuclides is not haphazard. "Caesium-137 is released in serious nuclear disasters like Chernobyl. Kobalt-60, on the other hand, is rather found in other accident scenarios, for example whereby the cooling water of a nuclear plant is contaminated", explains Nathalie.

Promising plant

This follow-up study show that three types of aquatic plants are suitable to remove radionuclides from water: water-lettuce, water hyacinth and duckweed, in this case common duckweed (*Lemna minor*). "Common duckweed was found to be the most promising aquatic plant in our tests", says Nathalie. The small aquatic plant floats on the water and has 3 to 4 leaf blades, each maximum 5 mm long, from which a thin root reaches down in the water. "The little plants can remove a large amount of Cs-137 and Co-60 from the water very quickly. They also store a relatively large amount of these radionuclide per gram of biomass, whereby the amount of radioactive waste produced is minimised."

Then the question arises: how does *Lemna minor* do that precisely? "Duckweed has tiny roots. The leaves grow quickly and have a large contact area. After shaking it a few times vigorously, you shake off a lot of the caesium or cobalt present. Therefore, we presume that it has mainly to do with adherence of these radionuclides to the plant, but further research will give us a better insight. How does the mechanism fit together? Does it work via active absorption via the root and leaves? Or is it mainly sorption?", muses Nathalie.

Higher uptake

In this study, researchers at SCK•CEN compared living *Lemna minor* plants with their dead biomass. "According to scientific literature, dead *Lemna minor* biomass can remove radionuclides from contaminated water just as well, but that's not what we have been observing so far in our research", explains Nathalie. "Meanwhile, we have tweaked our test rig several times, but we still have no confirmation that dead biomass works as well." However, Nathalie and her researcher colleagues could demonstrate that living biomass can remove a lot more cobalt than similar amounts of dead biomass. "For dead biomass, we reach 20 percent, for living plants 97 percent."

The 'Biosphere Impact Studies' research group, of which Nathalie is a member, will expand this research to other radionuclides and mixtures of radionuclides and heavy metals. "We also want to develop a model that would enable us to predict the performance of *Lemna minor*", concludes Nathalie.

> *"Lemna minor is already being used for the remediation of waste water."*

Practical applications

So, there is a lot going on as far as research is concerned, but what about practical applications? "Hopefully, we will be able to use *Lemna minor* to remove radionuclides from surface water following accidental scenarios and/or historical contamination on the one hand, and to remove them from waste water produced by industrial processes on the other hand. But first, you need to know and be able to predict the result of deploying such a plant for different scenarios", says Nathalie Vanhoudt knowingly. "Otherwise, businesses can't assess the potential of this water decontamination method. Moreover, *Lemna minor* is a very handy plant to work with: its amount doubles every two days and there are already duckweed harvesters on the market, because duckweed is already being used for the purification of normal waste water."

Dedication

Our expertise for the benefit of humans and the environment

Our actions are based on Care and Respect. We invest in innovation and quality improvement to face the challenges for humans and the environment. This mindset is embedded in our DNA, flows through our veins. It is tightly interwoven in every single project we undertake. The constant guiding principle is that everything is based on our nuclear expertise.

Peter Baeten
Deputy Director-General

Dismantling hot cells provides a heap of experience

Such complex challenges also require involvement, personal input and proactivity from all operators. This has strengthened our team spirit enormously.

Together with their passionate team, engineers Michel Estas and Luc Ooms accomplished two large-scale, difficult dismantling projects in 2018. The experience gained increased greatly SCK•CEN's expertise, which they can use in-house for the dismantling of installations and provides added value outside.

SCK•CEN has a unique expertise, developed by the centre thanks to the dismantling of BR3. Recently the research centre dismantled two hot cells on their site, whereby it could deepen and widen its know-how. "We make this knowledge available on a national and international level", says Michel Estas, engineer at SCK•CEN.

HOT CELL M2: TABULA RASA

'A screened off, ventilated room where specialists can handle radioactive substances and materials contaminated with radiation remotely using manipulators', is a comprehensive definition of a 'hot cell'. The term 'bunker' is also an apt description for hot cell M2. Indeed, the hot cell has 1-metre thick concrete walls and is lined inside with a 1-centimetre thick stainless-steel jacket. The concrete will prevent radiation from the objects handled to leave the hot cell, while the stainless steel prevents contamination from spreading.

Extreme peak values

The M2 hot cell located in the Lab for High and Medium-high Activity (LHMA), became operational in 1977. The hot cell was used for many years to carry out destructive mechanical operations on spent fuel from nuclear reactors. "This explains the extremely high beta-gamma and alpha contamination values measured. The radiation of some elements in the hot cell was comparable to the radiation in a nuclear reactor", explains engineer Michel Estas. At the start of the project, the dismantling team even measured a peak value of 3000 Sievert per hour. Compare that to the natural background radiation to which we are exposed on a daily basis, which is 70 nanoSievert per hour (1 Sv = 1,000,000,000 nanoSv). Even once these highly radioactive components were removed, the dismantling team – a group of operators, mechanics, electricians and engineers – could still not enter M2. "The radiation level was too high. Moreover, many tools available in the hot cell had reached the end of their life cycle. On the one hand, this is due to degradation over time, but on the other also to the constant bombardment with radiation", says Michel. A blocked access door, stuck worktops and faulty lighting are just a few examples of the obstacles which the team were facing. "The only access we had to the cell was the materials access: an 18-cm opening."

In addition, like all installations in the past, the cell was not designed to be dismantled. Michel explains: "This means, from the outset of our mission in 2010, we had to tackle this extreme situation in a creative manner. For this, our team deployed its experience, chose the appropriate techniques and established the most efficient sequence of operations."

Psychological threshold

The team built a copy of M2 – a so-called 'mock-up' – to be able to practice all actions. "Above the materials access of the hot cell, we built an intervention space, in which we planned airlocks to remove material from the hot cell remotely. Afterwards, we use manipulators to decontaminate the bunker with chemicals", explains engineer Luc Ooms. Accessing the hot cell – with masks and in positive pressure suits – only happened five years later. "You still have to conquer a psychological threshold to enter the hot cell", Luc goes on. "Therefore, we deemed it important that the engineers would also enter in positive pressure suits. We wanted to give the team confidence in the safety of the situation, and we got a personal feeling for the terrain."

Factor 1 million

Now, M2 is being kitted out again for future use, for experiments with nuclear fuel. In the end, 6.4 tonnes of high and medium-high radioactive material were removed from the hot cell and transferred to Belgoprocess. The radiation level dropped by a factor 2000 and the contamination level by a factor 1 million.

HOT CELL 11: UNIQUE TO INTERNATIONAL STANDARDS

In the same building, the next project was already waiting for them: hot cell 11, in which tensile and pressure mechanics tests on reactor vessel steel and irradiated materials from nuclear power plants had been ongoing since 1974. "Hot cell 11 did not meet the current precision standard requirements anymore and had to go", explains Michel Estas. The team had two options: either dismantle it in situ or remove the whole lot to the BR3 installation and cut it up manually over there. "We chose the second option to reduce the hinder of dismantling on the activities of LHMA to a minimum."

"The dismantling of the hot cells produced knowhow that SCK•CEN can use in-house and represents added value outside."

Diamond cable

The hot cell was anchored in a massive concrete slab. As a result, the hot cell weighed 14 tonnes. However, the bridge to be used to lift the whole was only designed for maximum 10 tonnes. "We had to saw the slab through horizontally. We carried out a whole range of analyses to establish the height of the cut, because we needed to find a balance between load, on the one hand, and stability of the offcut on the other. If the concrete layer were too thick, we would overload the bridge. If it were too thin, the concrete would break, and the nuclear material would be scattered all over the room. Solid calculation was therefore necessary to make it possible to go on dismantling the hot cell in BR3 safely. Once we had cut through the slab with a diamond cable, we jacked up the hot cell using a custom designed lifting system. Then, it was transferred to the cutting workshop in BR3 to cut it up further", Luc Ooms explains. "A one-off, also to international standards." Only 2% of the materials were removed as nuclear waste after processing.

New in-house knowledge

Both engineers highlight that they acquired a lot of expertise with both operations. This knowhow can be used in-house by SCK•CEN and represents added value outside. "Such complex challenges also require involvement, personal input and proactivity from all operators. This has strengthened our team spirit enormously", concludes Michel Estas.

Green accents increase workers' wellbeing

On 20 September 2018, Peter Baeten, Deputy Director-General at SCK•CEN, signed the Green Deal 'Business & Biodiversity'. By signing this Green Deal, the research centre makes the commitment to have an eco-friendlier management of its grounds. A win-win situation for nature and staff.

The SCK•CEN site covers 371 hectares. "That is 917 hectares of unique fauna and flora", says Staf Bosch, head groundskeeper at SCK•CEN. The strawberry spider, grey-backed mining bee, doodle bug and megarhyssa – which uses its long ovipositor to hunt for larvae of wood-boring wasps in the bark of birch trees – are thriving here. The common redstart nests here. Twittering siskins look for food on alder catkins. In spring, may lily blooms; this is a plant that can only be found in very old woodland. "Woods that have been in existence continuously since 1780", explains Staf. "As the temperature rises, other rare spring flowers sprout up here and there: spotted orchid, greater yellow rattle and marsh gentian. So, quite a few gems of nature can be discovered on our grounds." To keep vegetation in check, SCK•CEN uses Scottish highland cattle. "These impressive horned bovines take care of natural grazing of grassland, giving these spring flowers the opportunity to reveal themselves."

SCK•CEN has always been dedicated to a natural management of its grounds, but by signing the Green Deal 'Business & Biodiversity' on 20th September 2018, the research centre goes one step further. "The aim is to create a beautiful Kempen landscape by stimulating native fauna and flora in a natural manner and, as a result, increase biodiversity", says Staf. From now on, we leave nature even more to do its own thing, and this is also noticeable in a changed management approach. "Routine mowing and trimming make way for extensive nature management. Environmental management where human intervention is reduced. For example, before, we removed dead wood from our woodland and cut down broken trees. Now, they can stay, provided they are safe. Indeed, parts of the grounds are open for ramblers."

Staf Bosch, manager of SCK•CEN's domain

Step by step

Rome wasn't built in a day, and this project too requires time. "We are very busy now developing a roadmap. An environmental management plan is submitted for a 27-year period. This means you need to know what you are dealing with and where you want it to go", explains Staf Bosch. SCK•CEN will therefore first carry out a baseline study and map out the current situation on the ground. "We check which plants are growing and which animals or insects are already living there. Then, a study will establish how we can increase biodiversity, with as many native and landscape-specific vegetation. We want to create an environment where humans and animals feel at home."

THE SECOND LARGEST BUSINESS

This Green Deal is an initiative of former Flemish Minister for the Environment Joke Schauvliege, aimed at turning businesses and industries greener, with a view to the preservation of local fauna and flora. On 20th September 2018, SCK•CEN and 110 other companies signed the Green Deal. At that time, SCK•CEN and its 371 ha was the second largest business, after Brussels Airport, to accept the challenge. Meanwhile, more companies and organisations made the commitment.

To put this plan into practice, Central Technical Services (CTS) count on the input of different stakeholders. “A few motivated colleagues also set up a ‘Nature’ working group eighteen months ago. We will consult regularly with members of this working group about how to approach the Green Deal. All input is welcome.” In 2019, SCK•CEN will also develop a masterplan in which the research centre will be screening its complete infrastructure from a technical point of view – ranging from buildings and traffic to (nature) experience. “Our commitment is therefore not an empty promise; it is reinforced in our operational management.”

“Why not have walking meetings instead of gathering in a conference room for the umpteenth meeting?”

Surplus for staff

One of the action points which certainly can’t be left out is heather restoration. “Sheep are considered for grazing. We also want to transform coniferous woods gradually into mixed woodland”, explains Staf. SCK•CEN will also take the opportunity to make ‘small’ corners green. “Think of bug hotels, which we can build with our own wood store. And why not have walking meetings instead of gathering in a conference room for the umpteenth meeting? This initiative is therefore not only a good thing for nature, all staff and visitors will have the opportunity to enjoy all that green too.”

Growth chart

Planned and cost-effective spending

Setting objectives. Planning. It’s essential for any organisation, for both project outcomes and financial results. In 2018, we all worked very hard to achieve this. With success! By being proactive, planning and budgeting, we were able to achieve more in 2018. The achievement level – financial growth chart – reached a better result than ever before. To carry on this growth and build a great future for SCK•CEN, this remains an important focus.

Kathleen Overmeer
Institute Director
General Services and Administration

05 Key figures

837 EMPLOYEES

214 ♀ | 623 ♂

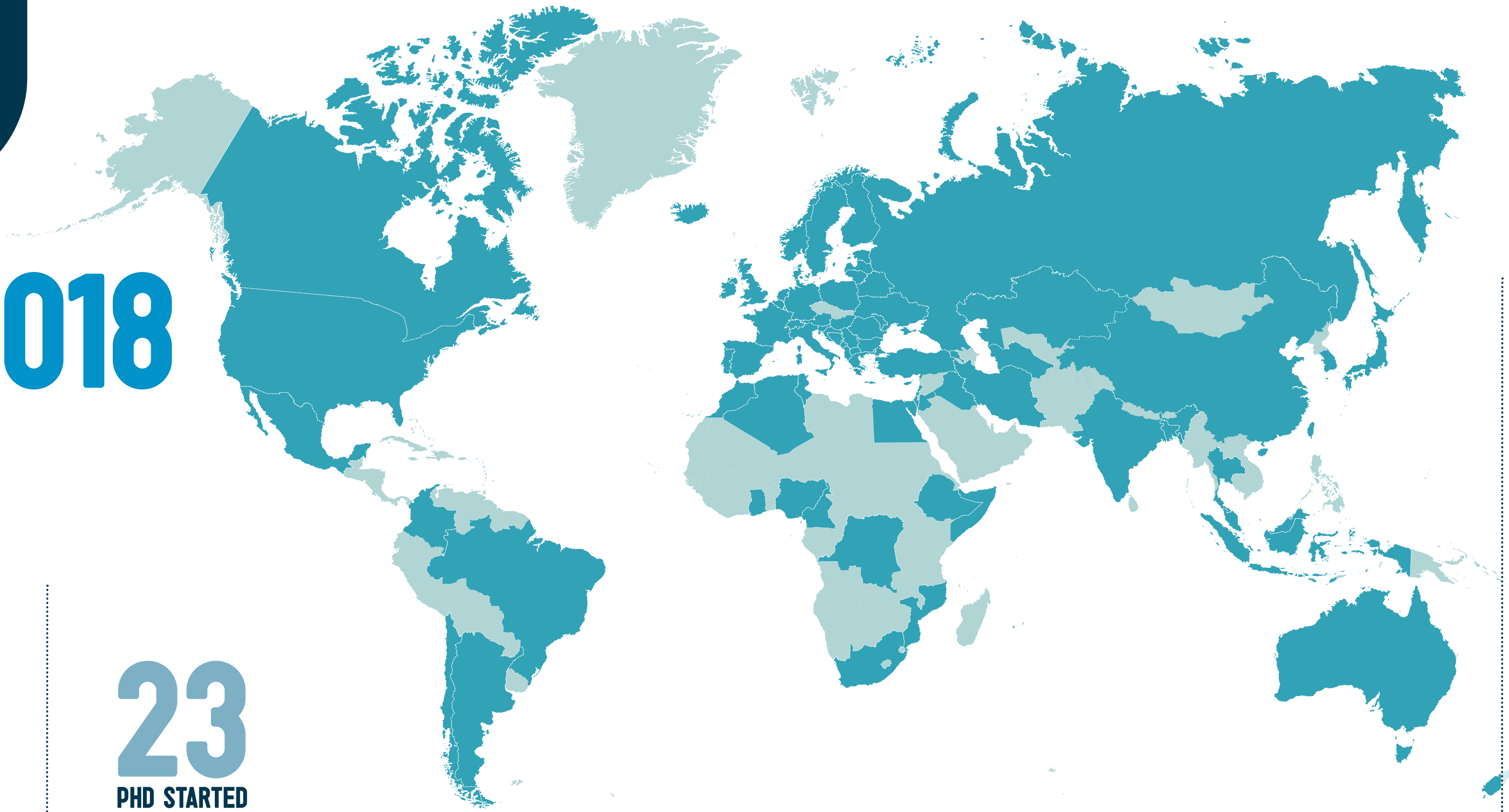
37% WITH AN ACADEMIC DEGREE

13,77 AVERAGE YEARS OF SERVICE

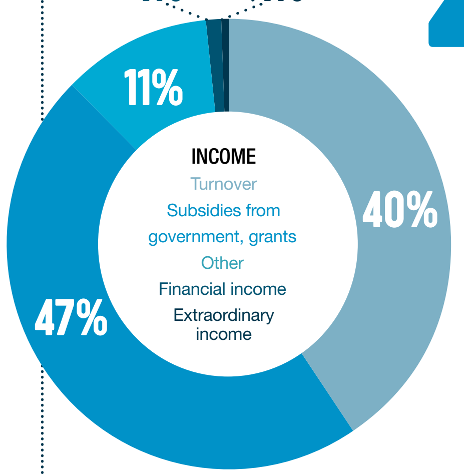
86 PHD STUDENTS

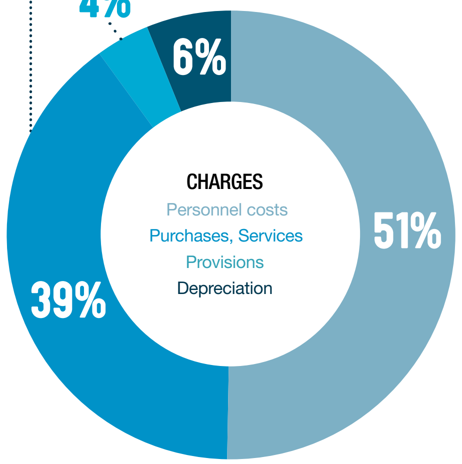
45 NATIONALITIES

ACTIVE IN 79 COUNTRIES



2018

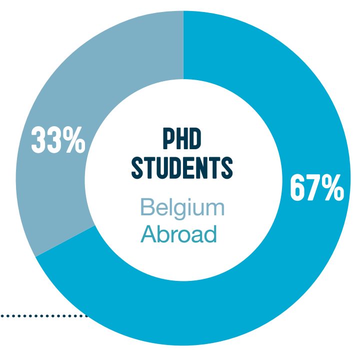




23 PHD STARTED

81 TRAINING FOR THIRD PARTIES

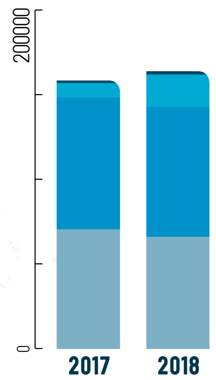
1218 PARTICIPANTS



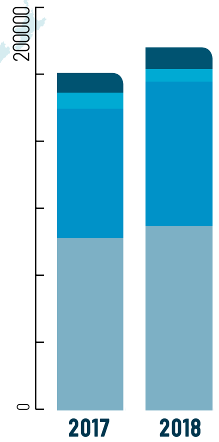
503 SCIENTIFIC PUBLICATIONS & PRESENTATIONS

2017-2018

BUDGET EVALUATION (kEUR)



INCOME	2017	2018
Turnover	70573	66256
Subsidies from government, grants	77859	76897
Other	8554	18745
Financial income	1107	1196
Extraordinary income	11	156
Total	158105	163250



CHARGES	2017	2018
Personnel costs	77129	82686
Purchases,Services	57873	64434
Provisions	7255	5762
Depreciations	8867	9726
Total	151125	162608

SCK•CEN

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Highlights
2018

Belgian Nuclear Research Centre
SCK•CEN is a foundation of public utility, with a legal status according to private law, that operates under the tutorship of the Belgian Minister of Energy.

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SCK•CEN

Belgian Nuclear Research Centre

65 years of experience in nuclear science and technology

As a research centre dealing with peaceful applications of radioactivity, SCK•CEN is an indispensable part of our society. We perform forward-looking research and develop sustainable technology. In addition, we organise training courses, we offer specialist services and we act as a consultancy. With more than 750 employees, SCK•CEN is one of the largest research centres in Belgium.

Throughout all of our work, there are three research topics that receive particular attention:

- Safety of nuclear installations
- Well-thought-out management of radioactive waste
- Human and environmental protection against ionizing radiation

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