sck cen

Highlights 2020

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Whether it is about the development of better cancer treatments, the safety of nuclear reactors, radioactivity measurements, particle accelerators or nuclear fusion, SCK CEN contributes to the future of our society through its scientific research.

"Breaking patterns enables innovation"

A few words of thanks from Eric van Walle, Director-General of SCK CEN

Dear reader,

As soon as these words appear on paper, the reality hits me even harder. I had hoped to write that we were able to put a challenging year behind us, that we had navigated the turbulent waters that coronavirus created for us, and that the country has now returned to normality. Unfortunately, the reality is different. We're still in the middle of it. Coronavirus still has the world in its grip and is constantly challenging us to question existing systems and patterns. However, that's not necessarily a bad thing. In fact, that's precisely where the seeds of innovation lie.

And that comes as no surprise to us, as scientists. Breaking patterns enables innovation. That is why we constantly question ourselves. We dare to let go of what we already know and we dare to redraw what we had already designed.

And in 2020 – the year we also reflected on the essence of life as individuals – we were all the more aware of this. Many of our studies and projects are shaking up standards, including our own, and we therefore want to share them with you.

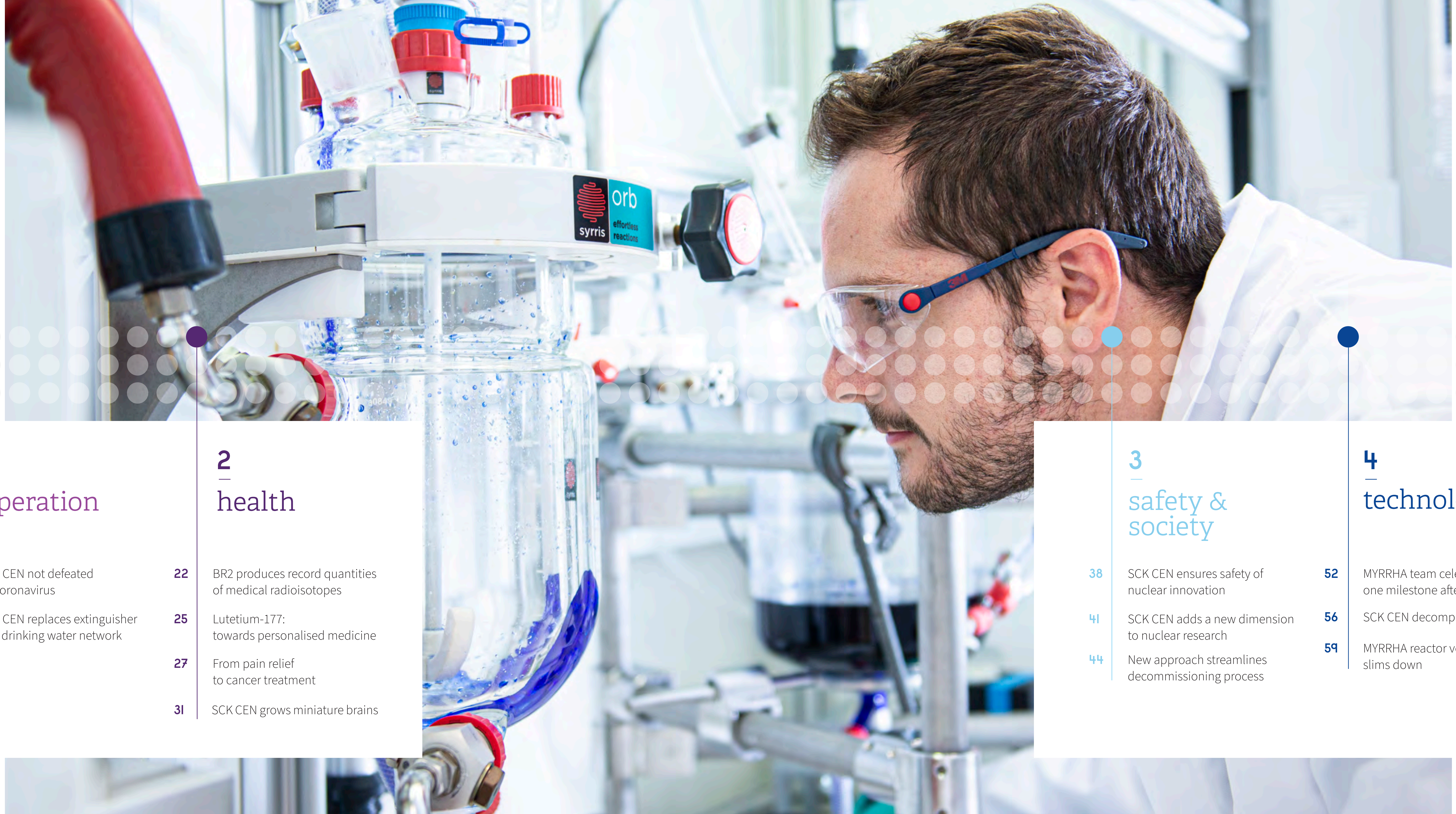
This annual report compiles the 'seeds of innovation' that we planted in 2020 or that thoroughly 'took root' in that same year. Consider, for example, the increased number of operating days of the BR2 research reactor, which enabled us to help a record number of patients, even during a pandemic year; the brand new installation that allows to carry out far-reaching testing of fissile materials, and the newly built lasers, which we will use to isolate innovative radioisotopes in the MYRRHA research reactor. And not to forget the existing infrastructures that we renovated from top to bottom.

A word of thanks is in order. On the one hand to our employees: They continued to give their all in this time of crisis. Thanks to their unwavering commitment, we have been able get through a lot of work and, more importantly, fulfil our duty to the global community. As one of the world leaders, we will not let our nuclear medicine colleagues down! On the other hand, I want to thank our partners, clients and guardians, who have placed their full trust in us.

I invite you to have a browse through this annual report and discover the potential of breaking patterns.

I hope you enjoy reading it!

Eric van Walle
Director-General of SCK CEN



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key figures

Several research fields, a clear focus

Projects as a strategic guide

SCK CEN was founded in the 1950s to study the applications of nuclear energy, but we have since expanded our knowledge into a wide range of research fields and projects. Each field has a strong future-oriented and international focus. MYRRHA, NURA and RECUMO are the largest projects of SCK CEN, with which we want to make a significant difference in the near and distant future. It is high time to review the status of these projects.

NURA

Expertise: check! Equipment: Double-check!

Currently, a quarter of all the world's medical radioisotopes start their journey at SCK CEN. This figure will increase significantly in the future, as SCK CEN ramps up the fight against cancer with NURA – the dedicated cancer research programme founded in 2018. "With NURA, we want to discover the untapped potential of radioisotopes, both independently and as a Contract Research Organisation (CRO)," explains project manager Dennis Elema. These radioisotopes include actinium-225, terbium-161 and samarium-153 [read more on page 27]. To realise this ambition, the right equipment is at least as important as knowledge and expertise. Since 2020, SCK CEN has had a MILabs U-SPECT CT scanner. Its installation marks another milestone in the NURA project. "Now our cancer research can truly get started. This scanner enables us to map the impact and path of promising radioisotopes, and thus continually improve our knowledge of radiopharmaceutical processes."

MYRRHA

One MYRRHA first after another: Full speed ahead into the new development phase

SCK CEN is currently working hard on the construction of MYRRHA, the world's first particle accelerator-powered research reactor. The construction of MYRRHA is taking place in several phases. In phase 1, we are building MINERVA, the particle accelerator with energy of up to 100 megaelectron volts (MeV). This phase progressed at lightning speed in 2020: in the summer, our researchers succeeded in accelerating a proton beam for the first time in the newly connected Radio Frequency Quadrupole (RFQ). Just six months later, they took that result to the next level. For the first time, the RFQ produced a proton beam at the exact conditions required to power the particle accelerator [read more on page 52]. "A milestone we have been working towards for six years, a breakthrough that is the result of international collaborations," says Hamid Aït Abderrahim, Director of MYRRHA and Deputy Director-General of SCK CEN.

RECUMO

Construction of the RECUMO plant now one step closer

In 2020, SCK CEN submitted an application to expand an existing nuclear installation on its site. That expansion is necessary in order to carry out the RECUMO project. This project forms a continuation of the long-standing partnership between SCK CEN and its sister company, the Institut National des Radioéléments (Institute for Radio Elements (IRE)). SCK CEN will convert the radioactive residues that remain after the production process of medical radioisotopes into low enriched uranium and purify it. "The high-quality material we recover can be reused as fuel for research reactors or as targets for radioisotope production. This will enable us to ensure the security of material supply," says Eric van Walle, Director-General of SCK CEN. This year, in 2021, the Federal Agency for Nuclear Control (FANC) will issue its decision on the operating license, while the Flemish Region will do so regarding the environmental license. "Once we've got the green light, we can get started!"

operation

Breaking patterns by

rethinking operations. On the one hand, we have no choice but to achieve our goals in these coronavirus times, on the other hand, we take the initiative to proactively improve our operations.

operation

SCK CEN not defeated by coronavirus

SCK CEN remained 100% operational thanks to the flexibility and dedication of employees

The coronavirus unexpectedly pushed the pause button on our world, but thankfully not on medical radioisotope production. As one of the world leaders in production of these products, SCK CEN continued to operate at full capacity. Remaining operational requires a strict coronavirus policy. "We had to rethink and reorganise ourselves in no time at all," notes Kathleen Overmeer, Director of General Services and Administration. Here, she looks back on the pandemic, its impact, and the resilience to come out of it together.

On Wednesday, 12 March 2020, the World Health Organization (WHO) officially declared the outbreak of the virus SARS-CoV-2 a pandemic. In order to limit the further spread of coronavirus, contact had to be restricted as a preventative measure. Many firms therefore shut down completely, but SCK CEN did not. The research centre continued to operate at full capacity – under numerous COVID-19 measures.

Kathleen Overmeer: "The production of medical radioisotopes cannot be allowed to cease under any circumstances. Cancer patients need them for their diagnosis or treatment. And that was something the federal government recognised as well, designating the production of medical radioisotopes and other nuclear and radiological activities as an essential service."

Did that recognition from the federal government come as a surprise?
Kathleen Overmeer: "No, people's lives depend on it. There is no available alternative to our BR2 research reactor to provide half of the necessary supply. We know that our service is essential and we put everything in place from the start so that we could continue to provide that service – under a strict set of coronavirus measures. In March, we published on our website: 'You can count on us'. One year later, I am proud to say we have delivered on that promise. We owe this to the dedication and flexibility of all of our employees. They applied the coronavirus policy in the workplace day in and day out. A policy is only as successful as its implementation."

'You can count on us'. We delivered on that promise.

Kathleen Overmeer

The pandemic, on the other hand, came as a big surprise. How did SCK CEN keep it under control?
Kathleen Overmeer: "As a nuclear institution, we have emergency plans in place for a wide range of accident scenarios, but they don't include a scenario for a pandemic. No one has a plan for that scenario up their sleeve."

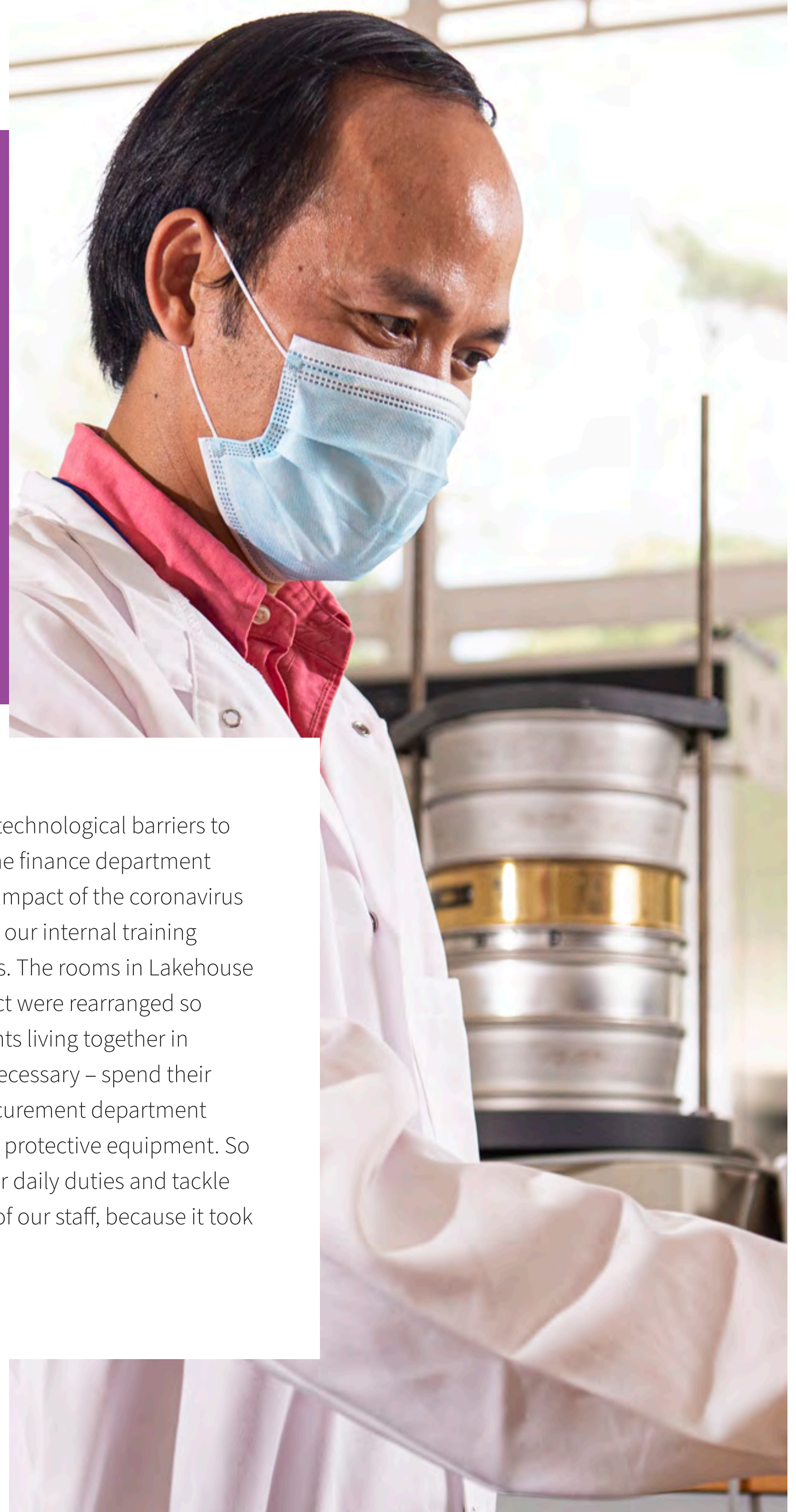
Yet SCK CEN has not been resting on its laurels, I assume?
Kathleen Overmeer: "No, we set up a crisis team almost immediately. This crisis team met daily to monitor the situation in brief. It's important that we protect our employees from the virus, but at the same time it's important we get through the crisis with as many opportunities as possible. In that crisis team, we allocated six roles: one for general management, one for the medical service, one for the safety service, one for the Committee for Prevention and Protection at Work, one for the communications service and one for HR."

Why were these roles chosen?
Kathleen Overmeer: "There are several parameters in the balance, which the crisis team needs to take into account: our responsibility towards our employees, their well-being, our social responsibility, our business continuity, and our long-term future. Choosing different roles and therefore perspectives enables us to maintain a balance. We closely monitored developments on the shop floor and beyond: How is the pandemic evolving? What policy decisions is the federal government making?"

Has SCK CEN been able to apply the government measures one-to-one on the work floor? Or did it sometimes mean finding a custom solution?
Kathleen Overmeer: "Translating federal policy to the work floor in practice requires some creativity, certainly for the HR department. Take, for example, the 'coronavirus parental leave' or the 'coronavirus time credit'. What does that involve? How do you apply for it? Can you combine it with the parental leave you are already taking? And so on. Our HR department looked for a suitable answer to each question. If a solution was not immediately at hand, our HR colleagues were there to listen. And the latter is invaluable in these times when our mental well-being is being tested."

Collective commitment

The research centre SCK CEN has also made its expertise and infrastructure available to wider society. "We donated disposable latex gloves to the hospital in Mol, computers to the youth welfare organisation Tonuso vzw in Brussels, and our qPCR machine to the task force. With the latter, we helped – together with other players in the sector – to increase the number of coronavirus tests in Belgium from 2,000 to 10,000 per day," explains Kathleen Overmeer. SCK CEN also offered to sterilise masks with hydrogen peroxide when hospitals were facing shortages.



The HR department was undoubtedly not the only department to provide custom solutions.
Kathleen Overmeer: "No, absolutely not, and there are a few examples that show that. When certain products were found to have run out, other colleagues came to the rescue by sewing masks themselves or producing their own hand sanitiser. And we showed our collective commitment beyond that too [see text box]. The cleaning service increased the cleaning frequency and was called in to thoroughly disinfect offices in the event of confirmed infections. The technical services provided strict supervision for contractors so that the reopening of the sites and the works themselves could proceed in a Corona-safe manner. In no time at all, the ICT service rolled out a digital environment to remove possible technological barriers to teleworking and collaboration. The finance department closely monitored the budgetary impact of the coronavirus crisis. The SCK CEN Academy and our internal training service switched to online courses. The rooms in Lakehouse and a villa in the residential district were rearranged so that international staff and students living together in the residential district could – if necessary – spend their quarantine period there. The procurement department moved heaven and earth to order protective equipment. So we were able to both carry out our daily duties and tackle additional challenges. I'm proud of our staff, because it took a lot of resilience and flexibility."

SCK CEN replaces extinguisher and drinking water network

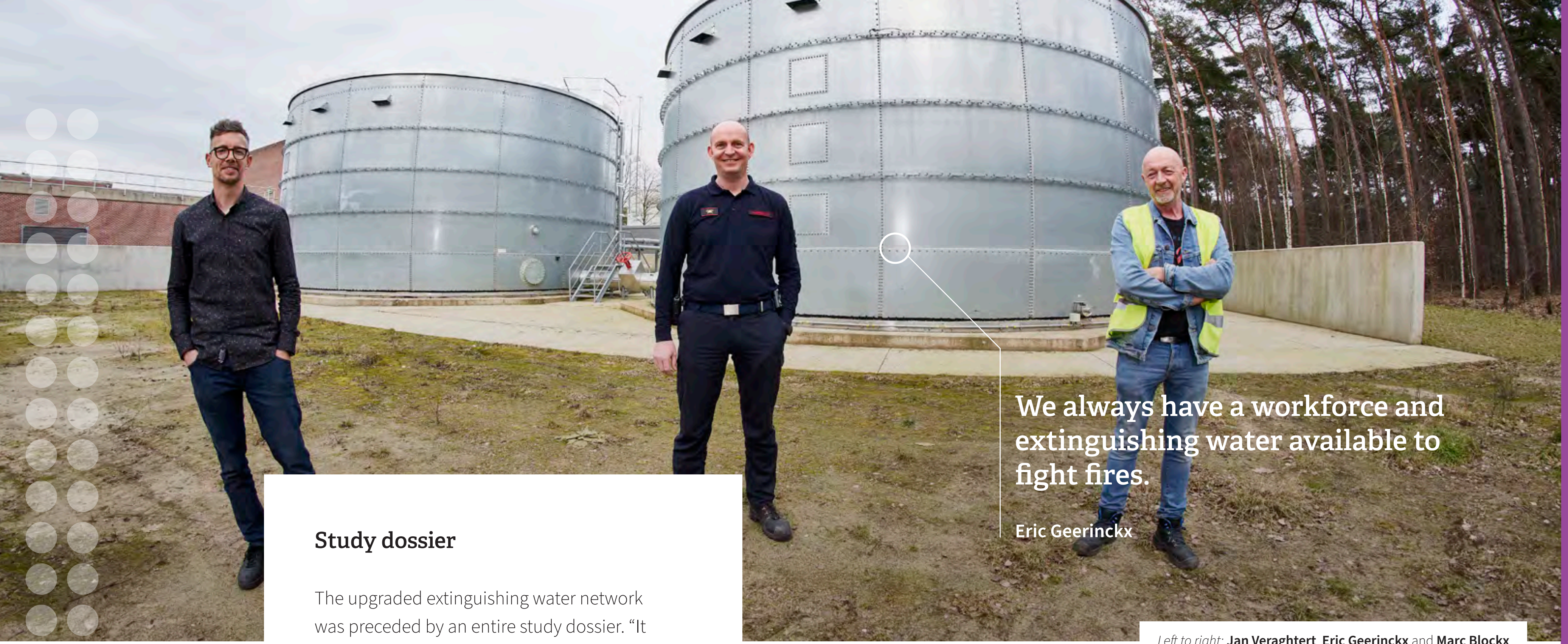
Brand new fire extinguisher water network facilitates more efficient firefighting

Underneath the technical site of SCK CEN lies over 10 kilometres of new extinguisher water pipes. Water flows out of the 110 fire hydrants connected to it at a rate of 2,000 litres per minute. "That's more than twice our former capacity. The commissioning of this extinguishing water network therefore marks a remarkable step-up in our fire safety and firefighting," notes Eric Geerinckx, manager of the company fire brigade.

Numerous safety mechanisms are built into all nuclear facilities that SCK CEN operates or designs, and these safety mechanisms serve to prevent incidents. SCK CEN has also shaped its fire safety and firefighting strategy with the same philosophy in mind. It is impossible to eliminate fires completely, however, and that's where being prepared comes in. In a fire, every second counts.

The SCK CEN company fire brigade is on standby 24/7 to respond immediately in the event of an alarm. "The faster we get to the scene, the more quickly we can put out the fire," says Eric Geerinckx. And fast they are, the 29 enthusiastic and motivated firefighters of SCK CEN, who are mainly volunteers. It takes no more than 15 minutes for them to arrive at the scene. However, short intervention times are not the only factor that matters. The team must also have the appropriate materials and equipment. "That equipment must allow us to put out the fire or to keep the fire under control while waiting for the public fire brigade," states Geerinckx. SCK CEN has no need for concern about suitable resources. After all, in 2020 it commissioned **a brand new fire extinguishing water network.**

This extensive network of water pipes provides the company fire brigade with extinguishing water. The water is drawn from four water tanks, spread over two locations. The tanks are each five metres high with a diameter of 13 metres, and their size allows each of them to hold 700,000 litres of water. Each location has two diesel-powered pumps, which pump the water from the tank into the network at 11,600 litres per minute. With this capacity, SCK CEN can now comfortably bridge the time until the public fire brigade is able to make the tertiary extinguishing water supply operational. "A tertiary fire extinguishing water supply is a virtually unlimited water supply that may be located a great distance away," Geerinckx explains.



We always have a workforce and extinguishing water available to fight fires.

Eric Geerinckx

Left to right: **Jan Veraghtert**, **Eric Geerinckx** and **Marc Blockx**

Study dossier

The upgraded extinguishing water network was preceded by an entire study dossier. “It began with a comparative study,” says project coordinator Jan Veraghtert. SCK CEN visited nuclear institutions, petrochemical companies, and SMEs. “We compared the different fire extinguishing water networks, and we soon came to the conclusion that they have doubled the extinguishing water and drinking water network, that they keep a buffer supply of water, and work with above-ground fire hydrants. Above-ground fire hydrants have a larger capacity, and require less set-up time, than the underground variants, which we were using at the time. The firms face similar risks, so we had to implement a similar system.”

Then came the technical puzzle. Where should the technicians fit the fire hydrants? This is important in order to avoid the company fire brigade having to unroll several fire hoses to be able to connect to the water supply. How long does it take to refill the water tanks? What if one of the tanks is suddenly breached? This would release 1,400,000 litres of water from each, forming a ‘mini-tsunami’, and this ‘mini-tsunami’ should not cause other problems. “On top of that, we had to incorporate into the design the other recommendations that arose from the stress tests at the time. Specifically, we had to provide a backup system for each system. For example, we have spread four tanks over two locations, so that if a plane were to crash at one of the locations, we still have a buffer supply available. Then we started work in 2018 and completed it in 2020,” says Marc Blockx, who has been closely monitoring the site. “So we always have a workforce and extinguishing water available to fight fires,” Geerinckx summarises.

Detailed study for two networks

Following the Fukushima accident in 2011, the European Council imposed stress tests on all active nuclear reactors within the European Union. These tests must demonstrate the extent to which the nuclear reactors can withstand extreme natural phenomena such as flooding and earthquakes. The analysis of these tests was carried out in the period 2011-2013. The recommendations were incorporated into the design of the extinguisher water network. The design proposed in 2015 was updated on the basis of a detailed study, which was developed by VK Engineering. This detailed study zoomed in on two networks: the extinguisher water network on the one hand, and the drinking water network on the other. SCK CEN received feedback from both internal and external experts, including FANC, Bel V, and the public fire brigade. A final design was ready in 2018. Work began shortly afterwards and was delivered two years later by the contractor DENYS.

Emergency planning drills

In order to be able to act quickly in the event of a fire, the company fire brigade must be familiar with all the actions it needs to carry out. “In crisis situations, there’s no time to wonder how the firefighting equipment works or what deployment methods to use. That knowledge needs to be ready when needed, and at that time you have to perform those actions without thinking. Your focus must be on the fire, not the actions. And that’s why we hold drills frequently,” explains Geerinckx. SCK CEN holds fire drills every fortnight, provides special training for its drivers, and organises one large-scale joint exercise with the public fire brigade each year. These drills are not only a practical must, but also a statutory requirement. This is contained in Article 17 of the ‘Belgian Royal Decree on safety requirements for nuclear installations’: ‘For each location where a fire could affect equipment that is most essential for nuclear safety, or where radioactive materials are present, a fire-fighting strategy must be developed that is kept up-to-date and is the subject of a training programme.’ “Double-check,” Geerinckx concludes.

Nuclear and petrochemical firms face similar risks, so we had to implement a similar system.

Jan Veraghtert

2

health

Breaking patterns by

expanding production, research methods and existing partnerships. This expansion leaves room for progress towards more personalised medicine, more efficient cancer treatment and better understanding of radiation effects.

2

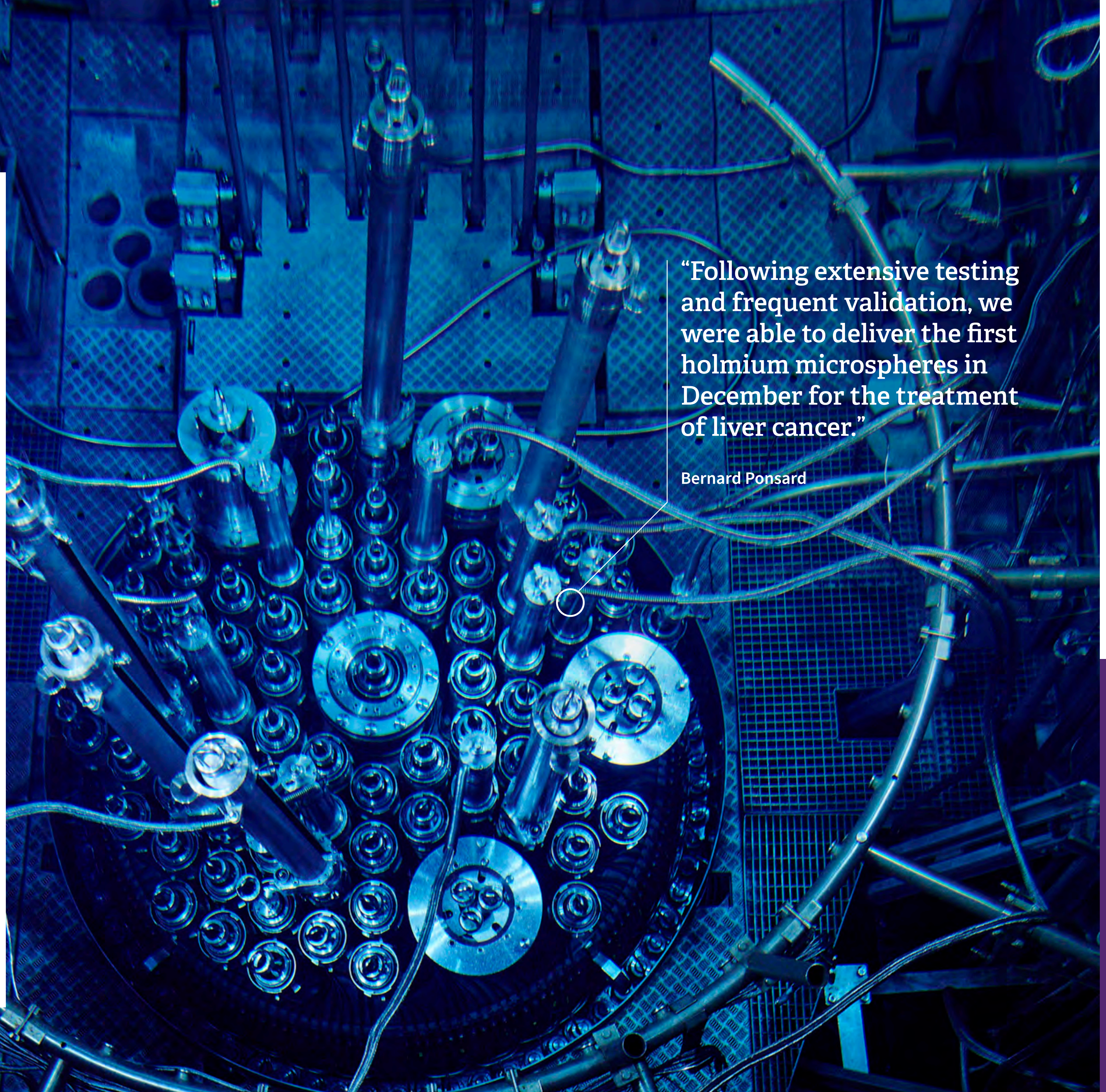
health

BR2 produces record quantities of medical radioisotopes

More than 12 million patients have been helped thanks to this production

More than 12 million patients have been helped by the production of medical radioisotopes in the BR2 research reactor. "That's five million more patients than our previous average," SCK CEN is proud to report. A change in the number of operating days is the reason behind these positive figures.

"Never before in the history of the BR2 research reactor have we racked up such figures," enthuses Steven Van Dyck, Reactor Manager at SCK CEN. Anyone looking at the figures would immediately share Van Dyck's enthusiasm. Typically, SCK CEN produces ten to fifteen different radioisotopes per reactor cycle. Two radioisotopes accounted for most of the production: molybdenum-99, the source of the most important diagnostic radioisotope technetium-99m, and lutetium-177, a radioisotope that is actively used in the battle against prostate cancer. Production of molybdenum-99 increased by a 25%, while lutetium-177 production saw an unprecedented increase of 75%. In total, more than 12 million diagnoses and 25,000 treatments were made possible thanks to Belgian production.



"Following extensive testing and frequent validation, we were able to deliver the first holmium microspheres in December for the treatment of liver cancer."

Bernard Ponsard

More operating days

These great figures are the logical consequence of the decision to **increase the number of operating days from 160 to over 210 per year.** This decision was taken in order to ensure a continuous supply of medical radioisotopes. "Half of the supply has to come from our research reactor, there is no alternative anywhere in the world. This underlines the vital contribution we make and must continue to make in the future. After all, the number of cancer patients continues to rise year after year, and demand increases proportionately," says Steven Van Dyck.

When SCK CEN made that decision, nobody could have foreseen that a pandemic could potentially shut down production. "We were worried when the coronavirus arrived in Europe. But we managed to secure that increased, essential production, even in a time of crisis. And this is all thanks to the unseen dedication of our employees. So it was an exceptional year, in an exceptional year," concludes Steven.

Repeat record-breakers

SCK CEN not only produced a record quantity of medical radioisotopes. At the same time, the number of metric tonnes of doped silicon produced also skyrocketed. "Silicon is by far the most widely used semiconductor. Semiconductors are the basic material for the electronic components of systems for solar and wind energy, hybrid cars, and high-speed trains, for example. Last year, orders flooded in from Japan, China and other corners of the world. In total we produced 36 metric tonnes – double the amount of previous years," explains Steven Van Dyck.

Holmium spheres

And as if 2020 was not exceptional enough, the research centre also expanded its portfolio of radioisotopes that same year. A new addition to the list is the therapeutic radioisotope holmium-166, a better alternative to yttrium-90, which is currently the standard in selective internal radiation (SIRT). An SIRT treatment is initiated for patients with liver cancer for whom surgery is not an option. In this type of treatment, small spheres – with a diameter no larger than a human hair – are injected into the hepatic artery. They accumulate in the tiniest capillaries of the liver tumours and locally emit their radiation there. The tumours shrink or disappear, while the surrounding healthy liver tissue is spared. "Unlike yttrium-90, holmium microspheres are visible on MRI and SPECT CT scans. This allows doctors to tailor the dose individually to the patient. We worked hard to get the challenging irradiation conditions for holmium-166 right. Following extensive testing and frequent validation, we were able to deliver the first holmium microspheres in December. Next year, in 2021, we will start commercial production of these microspheres to treat patients," explains Bernard Ponsard, stakeholder manager for radioisotope and doped silicon production.

And personalised treatment is more than welcome. In 2020, over 905,000 people across the world were diagnosed with liver cancer. In the same year, 830,180 liver cancer patients lost their lives. This makes it the seventh most common and third most deadly cancer in the world.

Ensuring operation until 2036

Nuclear medicine can count on our BR2 research reactor. In the last 45 years, it has not missed a single announced cycle completely. This is thanks to our thorough preventative maintenance, which also remains a priority in a ramped-up operating regime. This is why we began the preparations for the ten-year safety review with full confidence. With this report, we are asking the Belgian authorities for permission to ensure the continued operation of the reactor until at least 2036.

Sven Van den Berghe
Nuclear material sciences

Lutetium-177: towards personalised medicine

IRE and SCK CEN conclude a partnership for the production of lutetium-177 and other radioisotopes

For many years, the Institute for Radioelements (IRE) and SCK CEN have been working closely together on the production of radioisotopes for use in medicine. In 2020, the two partners signed a second public-public partnership that gives fresh impetus to their long-standing collaboration, with a focus on both diagnosis and treatment.

December 2018: the nuclear research centre SCK CEN and its sister company Institut National des Radioéléments (IRE) sign the public-public partnership RECUMO. The ink is not even dry before both partners are already talking about their next collaboration, this time in the field of medical radioisotopes. "In the history of medical radioisotopes, SCK CEN and IRE are complementary partners and provide added value to each other. Why shouldn't we join forces?" it was announced shortly after the signing. And so they did.

In 2020, the two partners signed a second public-public partnership that **gives fresh impetus to their long-standing collaboration in the field of nuclear medicine.** "For decades, the focus of our production was on two specific radioisotopes: molybdenum-99 for diagnosis on the one hand, and iodine-131 for the treatment of thyroid cancer on the other. Meanwhile, scientific research is enabling incredibly rapid advances in nuclear medicine. Radioisotopes can make the difference not only in medical imaging but also in targeted treatments. As global players in their production, we must keep an eye on these dynamics and enable further development of emerging therapeutic radioisotopes," clarifies Erich Kollegger, CEO of IRE.

Therapeutic radioisotopes: a definition

Therapeutic radioisotopes are an indispensable component of targeted cancer treatments. In this kind of treatment, a carrier molecule delivers a radioisotope very precisely to the cancer cells. Once the carrier molecule is attached to or absorbed into the cell, the radioisotope can irradiate the cancer cells without affecting healthy tissue. The cancer cells are damaged, causing them to die off and the tumour itself eventually shrinks.

RECUMO

It is already the second time that both partners have signed on the dotted line to make their close cooperation official. In December 2018, IRE and SCK CEN concluded their first public-public partnership for the RECUMO (Recovery of valuable Uranium residues of ^{99}Mo-based radio-pharma in Belgium) project. This project offers a systematic solution for the management of all highly radioactive residues resulting from the production of medical radioisotopes and currently stored on the IRE site in Fleurus.

Range of radioisotopes

The production of lutetium-177 is the first specific project within the framework of this collaboration and other radioisotopes will follow in the coming years. Lutetium-177 is currently being used in hospitals to treat neuroendocrine tumours. Neuroendocrine cells are mainly located in the organs of the digestive system, including the stomach, pancreas, and intestines. However, this radioisotope is very promising for the treatment of prostate cancer, which is responsible for 90,000 deaths in Europe every year. It is used in combination with gallium-68 (^{68}Ga), and the latter enables doctors to map the size of the prostate tumour and adjust the dose of lutetium-177 that the patient should receive during treatment accordingly. "You could call it personalised medicine. We expect global demand to triple in the coming years," adds Eric van Walle, Director-General of SCK CEN. "If pharmaceutical companies want to market lutetium-177 as a treatment for prostate cancer, supply must be able to meet that demand. With this partnership, we will facilitate access to these and other innovative radioisotopes. By working together, we can also make Belgium a key player in the production and distribution of radioisotopes for nuclear medicine."

Complementary roles

The partnership means an altered form of cooperation, but an unchanged division of roles, one which has existed between the two partners since the outset. "Our BR2 research reactor is responsible for the first stage of medical radioisotope production, namely irradiating targets. Then IRE treats these targets through a chemical process in order to obtain medical radioisotopes which are administered to patients. We coordinate our work very closely, the partnership runs like a well-oiled machine," explains Eric van Walle (SCK CEN). Erich Kollegger (IRE) agrees: "This public-public partnership makes full use of these complementary skills. That's what makes this partnership so valuable."

From pain relief to cancer treatment

SCK CEN conducts research on samarium-153 as a theranostic radioisotope

For more than 20 years, the nuclear research centre SCK CEN has been producing samarium-153, a radioisotope that is often used in palliative care. Last year, SCK CEN radiochemists developed a technique to further purify the radioisotope. "Thanks to this technique, we can treat cancer instead of just alleviating its symptoms," says radiochemist Michiel Van de Voorde. The first preclinical tests have already been completed.

Some cancers such as breast, prostate and lung cancer spread to the bones, and these metastases can cause severe pain. To reduce this pain (temporarily), patients are often given treatment with samarium-153. This radioisotope, which behaves like calcium in the body, is largely absorbed into the skeleton. It irradiates very locally in the places where the bone is affected. Palliative treatment is usually non-curative, and only relieves pain.

The nuclear research centre SCK CEN – in cooperation with CERN in Geneva, Switzerland, and the Institute for Nuclear and Radiation Physics of KU Leuven – is working to change this. "The samarium that is currently used in palliative cancer therapy is, in fact, a mixture of non-radioactive samarium-152 and radioactive samarium-153. Until now, it has been impossible to separate these two radioisotopes. The consequence of this is that an excess of samarium-152 blocks the uptake of samarium-153 in a cancer cell, which inhibits its therapeutic power," explains Michiel Van de Voorde, radiochemist at SCK CEN.

SCK CEN has developed a separation technique to obtain pure samarium-153. “Thanks to this technique, we can **treat cancer instead of just alleviating its symptoms,**” says Michiel. So what does the new production process look like? What additional steps are taken to obtain pure samarium-153? To obtain radioactive samarium-153, capsules of highly enriched samarium-152 are first irradiated in the BR2 research reactor. After irradiation, the capsules are taken to a radiochemistry laboratory on our site in Mol. “That’s where we prepare the irradiated material to be transported to CERN-MEDICIS. There, samarium with an atomic mass of 153 is isolated and collected by means of mass separation in an ISOL facility. Once back in Mol, we continue to purify the captured samarium-153 through a radiochemical process, so that we can study its therapeutic effect further,” explains radiochemist Andrew Burgoyne.

Thanks to this technique, we can treat cancer instead of just alleviating its symptoms.

Michiel Van de Voorde

Left to right: **Maarten Ooms**, **Michiel Van de Voorde** and **Andrew Burgoyne**

Staggered doses

Theoretically, further research is already worth the effort. “The radioisotope has a half-life of barely two days. Thanks to this short half-life, doctors are able to divide the dose into fractions and therefore administer several injections. This way, the patient is burdened with fewer high doses per treatment,” says Maarten Ooms, radiopharmacist at SCK CEN. Another great advantage lies in the decay of the radioisotope. “Samarium-153 decays by emitting a beta particle. It also emits photons, which are packages of radiant energy that allow the body to be photographed internally, as it were. This makes samarium-153 the perfect theranostic radioisotope. It allows us to treat cancer while closely monitoring the effect of that treatment.”

Before that happens, though, it needs to be tested in practice. The first preclinical tests have already been completed. “We bound samarium-153 to a carrier molecule, tested the stability of that bond, and followed the path it takes in the body. Does the carrier molecule take the radioisotope to the target organs? It certainly did,” continues Maarten. In a next step, the researchers will conduct experiments with cancer models and test medical imaging using samarium-153. SCK CEN then intends to scale up production as part of the NURA project in order to enable further research into this promising radioisotope. This project carries out game-changing research into radiopharmaceuticals for treating different types of cancer in collaboration with clinical and industrial partners.

Mass separator

At present, CERN-MEDICIS takes care of the physical selection based on mass, but in the future, the research infrastructure ISOL@MYRRHA will take on this role. "It's a race against time to get the medical radioisotopes to the patient in time. Every minute counts. So every time we don't have to change location, we save time for the benefit of the patient. And that's not all. By taking care of all the steps internally, we can guarantee the excellent quality of the development process," concludes Maarten. The construction of ISOL@MYRRHA is increasingly taking shape [read more on page 56].

"Samarium-153 is the perfect theranostic radioisotope that allows us to treat cancer while closely monitoring the effect of that treatment."

Maarten Ooms

What are targeted treatments?

Targeted cancer treatment involves the very precise delivery of a therapeutic radioisotope to cancer cells using a carrier molecule. Once the carrier molecule is bound to or absorbed into the cell, the radioisotope can irradiate the cancer cells without affecting healthy tissue. The cancer cells are damaged, causing them to die off and the tumour itself eventually shrinks.

SCK CEN grows miniature brains

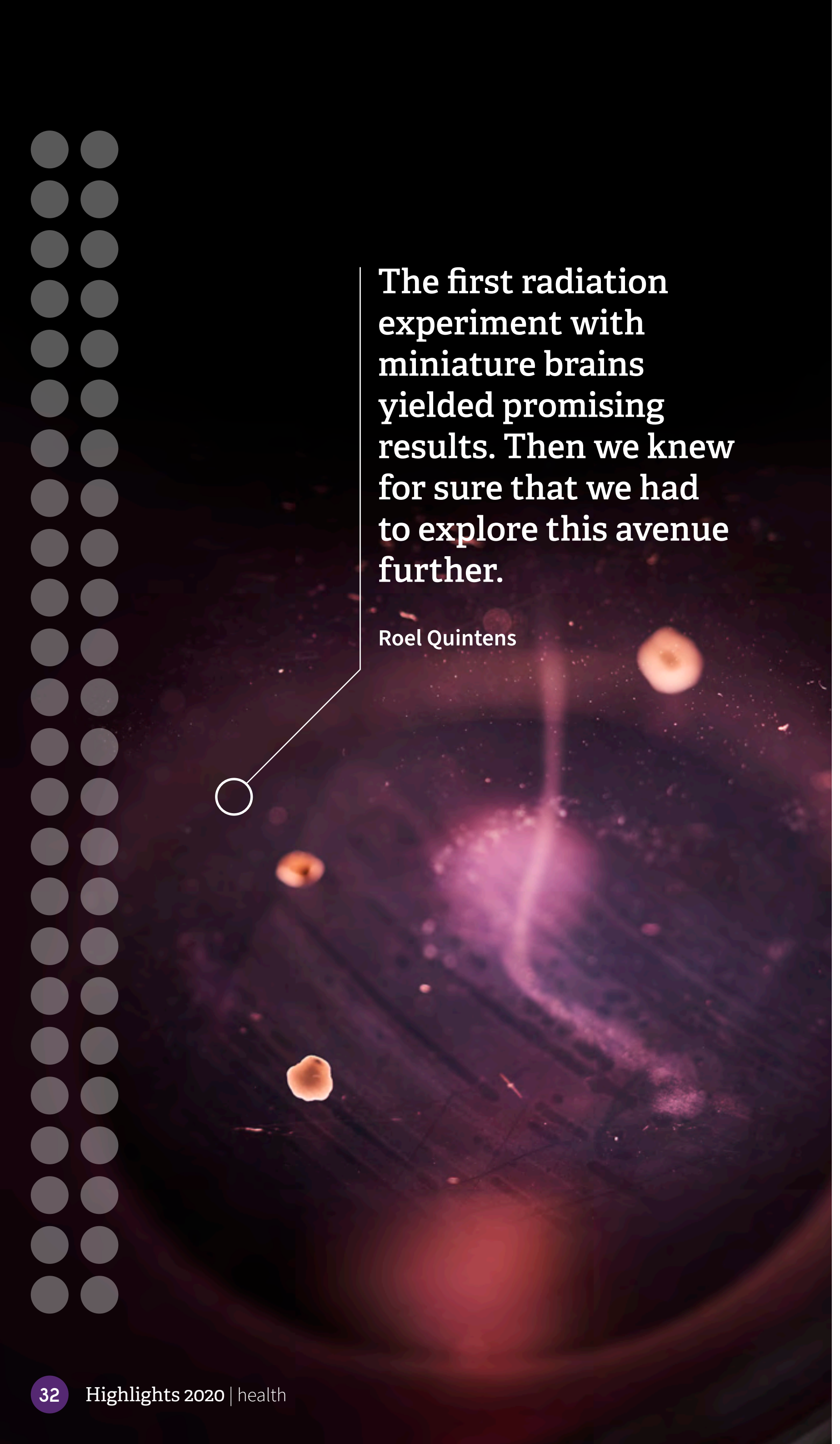
Miniature brains may lead to increased understanding of the effects of radiation

Scientists at SCK CEN are growing artificial brains in a petri dish. The miniature brains, which are barely the size of a hailstone, are very similar to the human brain in some respects. The innovative technique enables more effective investigation of all kinds of radiation effects.

Sharing knowledge is key to achieving scientific progress. If our predecessors had not bothered to share their knowledge, science would never have reached this point. This is why scientists delve into the literature or scour conferences, though not during this pandemic. Sometimes they stumble upon some amazing results or techniques, which provide them with a fresh perspective in their own research. The same happened with neurological research at SCK CEN.

"We discovered that Jay Gopalakrishnan, a professor at the University of Düsseldorf, uses brain organoids – artificially cultured brains – as a model to study Zika virus-induced microcephaly. In microcephaly, the brain does not fully develop: children are born with a skull that is too small and a mental disability," explains Roel Quintens, radiobiologist at SCK CEN. "We are studying microcephaly that can manifest in an embryonic stage after radiation exposure."

The nuclear research centre could use **this technique to improve its pre-existing knowledge of the impact of ionising radiation on brain development.** "Compared to adults, the brain of a developing fetus is extremely sensitive to radiation. Due to uncertainty, pregnant women are currently advised against having a scan or undergoing radiotherapy. For the mother herself, however, a delayed diagnosis or treatment may have more serious consequences than any radiation effects on the fetus. That's why these insights are so crucial," adds Mieke Verslegers, radiobiologist at SCK CEN.



> The first radiation experiment with miniature brains yielded promising results. Then we knew for sure that we had to explore this avenue further.
>
> **Roel Quintens**

Improved understanding

The scientists at SCK CEN are convinced that the brain organoids can help them to fully understand the effects of radiation. “In collaboration with Professor Gopalakrishnan from Düsseldorf, we conducted an initial radiation experiment, and the results were promising. The miniature brains that were irradiated grew more slowly than their non-irradiated counterparts. The effect was dose-dependent: the higher the radiation dose, the smaller the miniature brains. Then we knew for sure that we had to explore this avenue further,” says Roel Quintens (SCK CEN). This is the subject of further research by Jessica Ribeiro, who is devoting her doctorate to this subject. “In 2020, we perfected the cultivation process. Next, we will initially expose the artificial brains to high doses of radiation so that we can observe clear effects. That will give us a frame of reference when we come to systematically reduce the dose and study the effects of those doses,” she clarifies.

Culturing process

The miniature brains are made using stem cells, which can develop into any possible cell in the body. Jessica Ribeiro (SCK CEN): “To make them grow into brain cells, we have to make them believe that they are such cells. So we need to fool the stem cells and we do that by giving them just the right nutrients. Then the cells begin to divide, interconnect and therefore organise themselves into a developing human brain. In twenty days, we have a mini-brain, which we can run tests on.” The embryonic mini-brain is no bigger than a hailstone, but in some respects it closely resembles the structure of a human brain. This will enable scientists to study the human brain more closely and test possible drugs that suppress the signalling pathways involved in microcephaly.

Radiobiologists **Mieke Verslegers** and **Roel Quintens**

> A delayed diagnosis or treatment may have more serious consequences for the mother than any radiation effects on the fetus.
>
> **Mieke Verslegers**

Follow-on research

SCK CEN will also be using the miniature brains in other brain research. For example, the next PhD looks at using brain organoids to investigate glioblastoma, the deadliest form of brain cancer, which often comes back after treatment. On average, patients live less than fifteen months after diagnosis. Only a few survive in the longer term: twenty-five percent of patients survive for two years and less than ten percent for five years.

Neurological research at SCK CEN

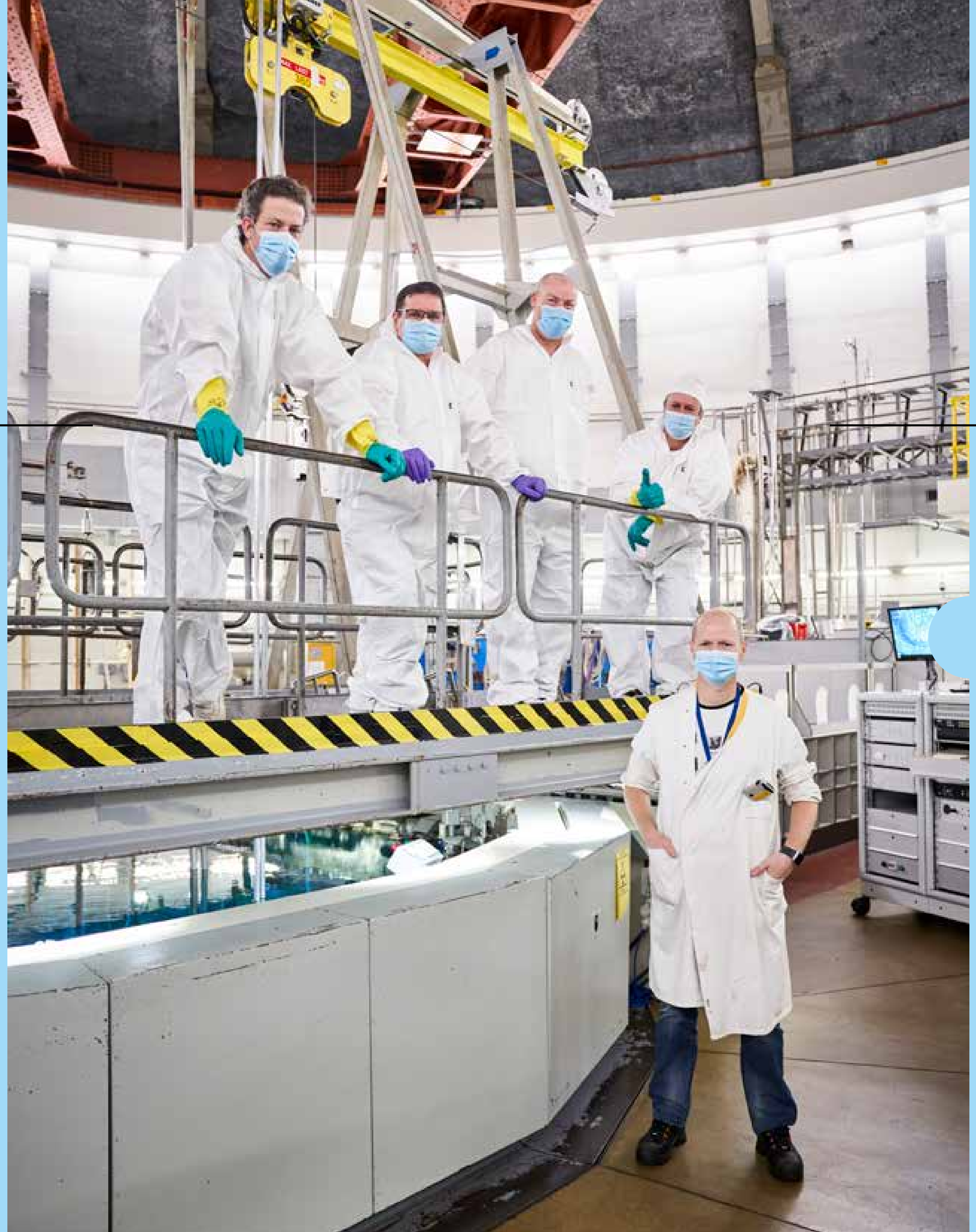
This innovative project forms part of broader neurological research at SCK CEN. This research focuses on the impact of ionising radiation on the brain development of embryos and children with brain tumours, who have to undergo radiation treatment at a young age. The researchers at SCK CEN are studying how radiation is linked to cognitive decline and changes in behaviour. “Is that a root cause of premature aging and Alzheimer’s disease? Or are they at higher risk of developing epilepsy? Which cell types are involved? We are trying to formulate an answer to these questions,” concludes Mieke Verslegers.

3

safety & society

Breaking patterns by

starting from a different perspective. When putting on new glasses, you see another reality. A better reality. One that thoroughly tests the safety of nuclear innovations, that provides innovations to end-users and that reduces the volume of waste.



SCK CEN ensures safety of nuclear innovation

SCK CEN installation puts fuel rods to the test

SCK CEN has been testing newly developed nuclear fuel rods as far back as 1976. These tests are the final part of a new fuel's safety file. Last year, the research centre replaced its installation, which it is now using to carry out these tests – the only one of its kind in Europe. "What was supposed to be a copy of the previous version became an installation with more features and more measurement instrumentation," says project manager Brian Boer.

A car hitting a lamppost, overturning or colliding head-on: no model of car is permitted to come to market without passing a crash test. "A crash test evaluates the impact of an accident and therefore the safety. The equivalent for nuclear fuels is the transient test," says Marc Verwerft, nuclear fuel expert at SCK CEN. A transient test simulates a sudden power increase in a reactor. The aim is to test what power increase will cause the cladding – the first physical barrier of the uranium fuel – to fail.

Transient tests are essential for ensuring the safety of nuclear power plants. The BR2 research reactor at SCK CEN is the only one in Europe that is capable of performing such necessary tests. "We've been providing this service since 1976, but recently we commissioned an upgraded facility," Verwerft explains. That installation is called PWC7. PWC stands for Pressurised Water Capsule, while the number indicates it is the seventh generation of it. **"What was supposed to be a copy of the previous version became an installation with more features and more measurement instrumentation,"** says project manager Brian Boer.

> We've been providing this service since 1976, but recently we commissioned an upgraded facility.
>
> **Marc Verwerft**

Highest accuracy

The measurement instrumentation allows more factors to be mapped: What is the water temperature in the capsule in which the researchers placed the fuel pin? How hot does the fuel cladding get? How does the pin expand during irradiation? Does the diameter of the cladding change? What neutron and gamma flux are we obtaining? What internal pressure is exerted on the fuel pin? All of these things are determined with the highest accuracy. Marc Verwerft explains: "In order to confirm our repeatability and accuracy, we have performed numerous qualification tests over the past two years: both with dummy fuel pins and with real fuel rods. The upgraded installation meets all high quality and safety requirements. So it's is ready for the next step: the first commercial, nuclear transient test. That's scheduled for the second half of 2021."

Test procedure

Then comes the question: what happens in a transient test? How does SCK CEN imitate a commercial nuclear power plant 'going through its transient'? The fuel pins the research centre receives have been previously irradiated for several years under normal conditions. Fuel pins in a commercial power plant are four-metre long tubes into which uranium fuel is stacked in the form of ceramic pellets – cylindrical tablets about 1 cm high. "For our transient test, we take a half-metre-long sample, load it into a PWC water capsule, and position it in the reactor core of BR2," says Brian Boer.

This position has been accurately calculated to simulate an accident. The reactor runs at low power for a day, after which the reactor operators double the power in under two minutes. This increase causes the temperature of the test pin to rise. The outside temperature remains at the normal operating temperature, but in the fuel core the temperature doubles to well over 2000 °C. As the temperature rises, the fuel expands and exerts pressure on the cladding. "If we see activity in the water of the PWC, then the cladding has failed; the test is stopped and the damage examined. If there's no activity, we maintain that power for twelve hours and then examine the pin for damage. This could be small cracks that you can't see with the naked eye, for example."

The results generated by the transient test are used to validate computer codes, which can then be used to perform dozens or hundreds of simulations. "A transient test pushes the safety margins of nuclear fuel and forms the final part of a licence dossier. With our experiments, we enable the industry to introduce innovations in a safe way," concludes project manager Brian Boer.

Increased capacity

The PWC7 can – in addition to the transient test – also be used for other purposes. First, customers can ask us to look at how fissile materials react when nuclear power plants respond more to energy peaks and troughs and when power output fluctuates more frequently. Second, they can ask us to test burnup limits, and third, they can put new materials to the test. SCK CEN is already considering a PWC8 and PWC9 to increase capacity.

> With our experiments we enable the industry to safely implement innovations.
>
> Brian Boer

SCK CEN adds a new dimension to nuclear research

Impactful science is shaped by, and for, people

The nuclear research centre SCK CEN is a pioneer in the integration of societal and ethical aspects in nuclear research. It set up its own research programme in this area in the 1990s. From this perspective as a pioneer, SCK CEN has successfully sparked the debate in Europe, and its efforts have been rewarded. From 2020 onwards, social sciences are becoming a focus for research into radiation protection. “By actively involving people from the start, we can increase the impact of research,” says Catrinel Turcanu, Expert in Social Sciences at SCK CEN.

More than 30 project partners have joined forces over the past five years to guide future research on radiation protection in Europe. The H2020 project was named ‘CONCERT’ and came to an end last year, though that end rather **marked the beginning of nuclear research with a new dimension.** “Innovation is the work of people, and that’s why scientists need to step into the shoes of their end-users. By doing this, they can tailor solutions to specific needs and expectations,” says Tanja Perko, an expert in crisis communication and risk perception. As an illustration, an eye lens dosimeter that is uncomfortable will not be worn by a user.

The nuclear research centre has been aware for some time that there is added value in tailoring research to societal needs and concerns. SCK CEN has been integrating social and human sciences into its research for over twenty years, but it recognised CONCERT as the ideal pilot project to introduce this critical self-reflection at a European level. “It was a success,” notes Catrinel Turcanu. “Social sciences will be one of the focal points in future research.”

Left to right: **Gaston Meskens, Catrinel Turcanu** and **Tanja Perko**

Europe is therefore advocating greater integration of societal and ethical aspects in research on radiation protection – a recommendation that it also takes to heart. Four CONCERT-funded subprojects with a societal focus have already been completed, including CONFIDENCE. This extensive project identified uncertainties in crisis situations and discussed how those uncertainties can affect outlined contingency planning. "Policymakers base their policies on assumptions. Take, for example, a provincial governor publishing the provincial emergency plan and advising people to take shelter. It's safer to stay indoors, but how will people react if their children are still at school? Will they leave the children at school and stay indoors? Or do they drive straight over there to pick them up? In crisis situations, everyone is their own policymaker. Often, assumptions deviate from actual behaviour," says Catrinel. Understanding 'how' and 'why' people behave in specific situations can increase the effectiveness of policy measures. SCK CEN made a significant contribution towards these subprojects through social-scientific research.

> It is important that we continue to hold up a mirror to ourselves and continue to encourage integration. This is the only way we can close the gap between science and wider society.
>
> **Catrinel Turcanu**

Practicability and trust

In order to map this behaviour, and the factors that influence it, the project partners used every possible method. They analysed the content of media articles, organised a large-scale survey in three European countries, and observed eleven nuclear crisis drills. It emerged from this research that each individual goes through various stages of uncertainty. "In the first stage, we ask ourselves if we can trust the information that we are given. We find out further information and listen to the advice of the competent authority. Then comes the moment when we have to decide: do we follow that advice? Or not? If we want to follow the advice, is it practicable in that situation? Do I have iodine pills at home that I can take? Am I mobile enough to evacuate the building by myself? Policies that are easy to apply are more likely to be complied with. Finally, we evaluate whether the measure – for us personally – has had the desired effect. After this evaluation, the cycle starts again," Tanja Perko explains. Besides practicality, trust is one of the most influential factors. "We are more likely to follow the advice of official bodies that we trust."

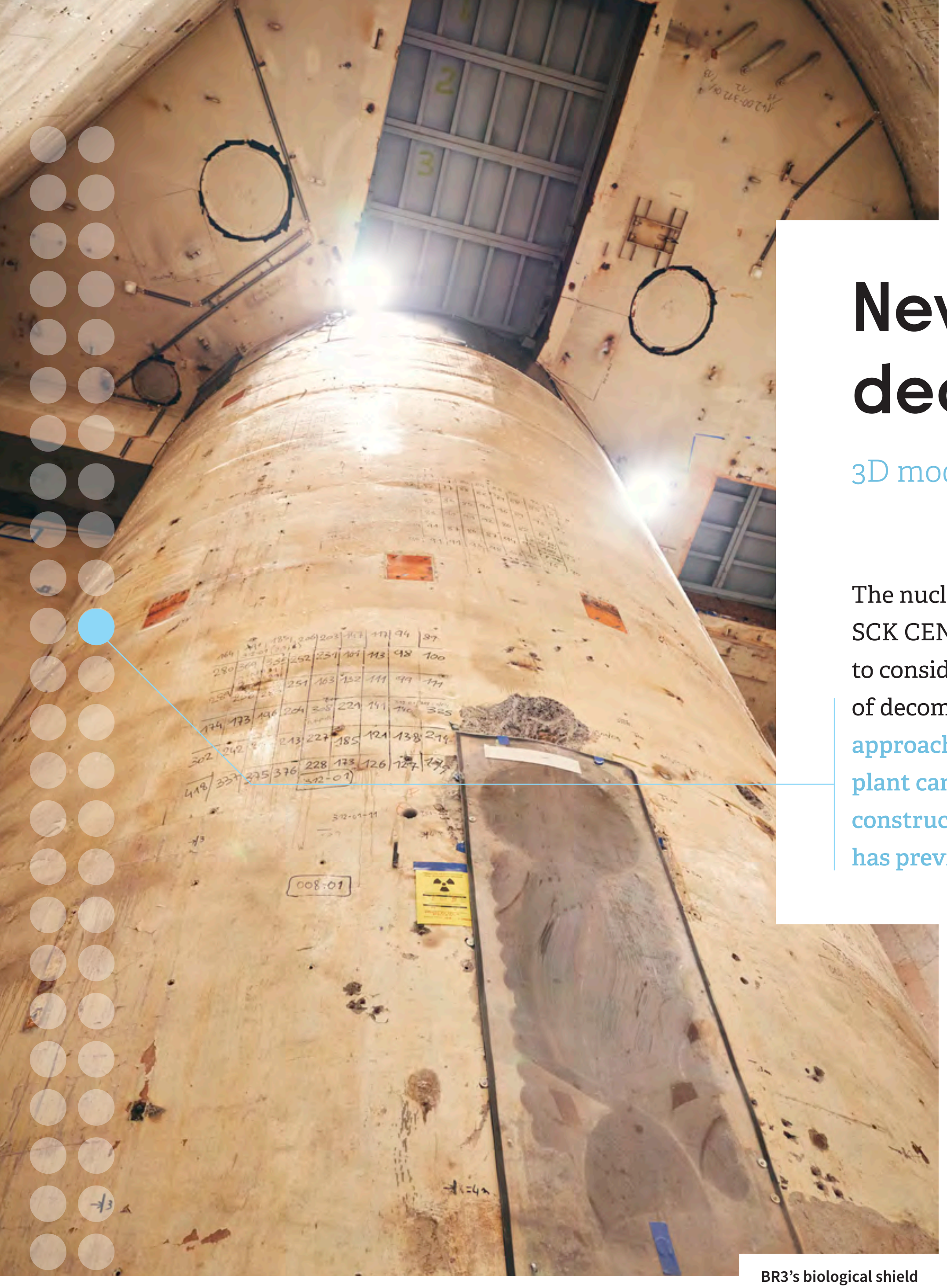
Trend

The project partners formulated a set of practical recommendations to help policymakers to make the right assumptions and to assist actors in the field to ensure that an intervention does not run into societal barriers. "Thanks to CONCERT and its subprojects, we have taken a great leap forward. It is important that we continue to hold up a mirror to ourselves, keep the discussion open, and continue to encourage integration. This is the only way we can close the gap between science and wider society," concludes Catrinel.

Science-technology-society: an exciting triangle

As scientists, we first analyse previous studies to grasp the broad context, assess them with a critical eye and formulate objectives to fill the gaps. We engage in dialogue with peers, including during implementation and analysis. To increase the effectiveness of research, it is advisable to involve experts from other fields, as they offer a different perspective on the matter and enrich our understanding. The involvement of human and social scientists who can help us to understand societal needs and human behaviour is a prime example of this.

Hildegarde Vandenhove
Environment, Health and Safety



BR3's biological shield

New approach streamlines decommissioning process

3D model maps radioactivity more accurately

The nuclear research centre SCK CEN has developed a 3D model to considerably reduce the footprint of decommissioning. With this new approach, used concrete from a nuclear plant can be given a second life in the construction sector, more often than has previously been the case.

Each reactor vessel of a pressurised water reactor is surrounded by reinforced concrete. The purpose of this concrete wall – known as the biological shield – is to block radiation. "When decommissioning commercial nuclear power stations, the biological shield forms the largest part of short-lived and low- and inter-mediate-level radioactive waste," explains Sven Boden, decommissioning expert at SCK CEN. The shield of the dismantled BR3 pressurised water reactor is 15 metres high and is 1.20 metres thick. That is enough for 2,200 metric tonnes of reinforced concrete – or the loading capacity of 100 trucks. "It is not the intention to dispose of 100 trucks' worth of concrete at the available, equipped disposal sites. The golden rule in any decommissioning project is to minimise the amount of radioactive and conventional waste in a cost-effective way."

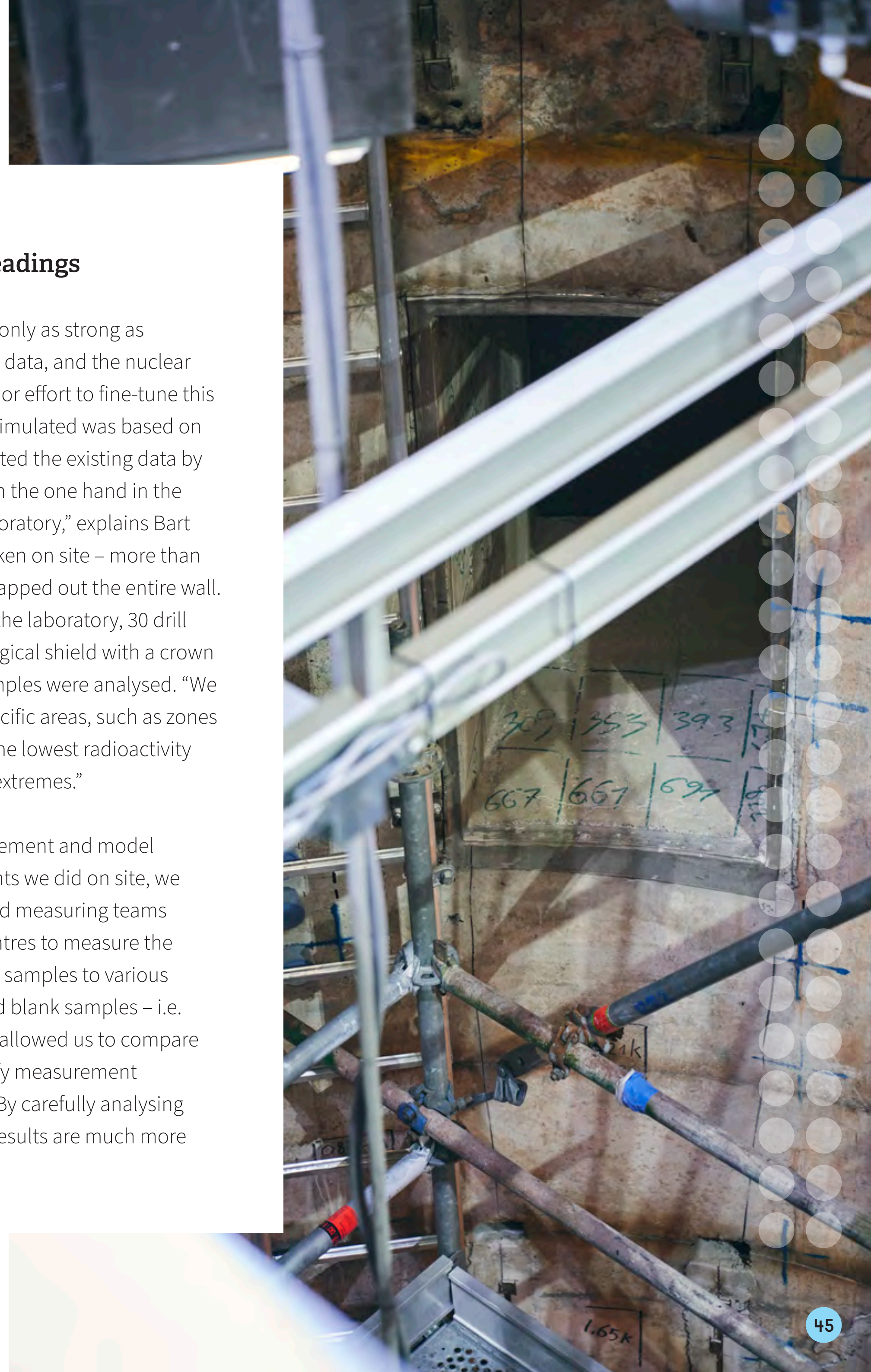
To succeed in doing this, the concrete has to be removed in layers by means of scabbling, using a jackhammer or wire sawing. Each layer has a different destination. The concrete that is released, after the necessary readings have been taken, is returned to general use, and is recycled in the construction sector. The other concrete layers are sent to a category 1 landfill site, where hazardous waste, such as asbestos, is deposited. This project, which is intended to give a second life to as much concrete as possible, promotes a circular economy.

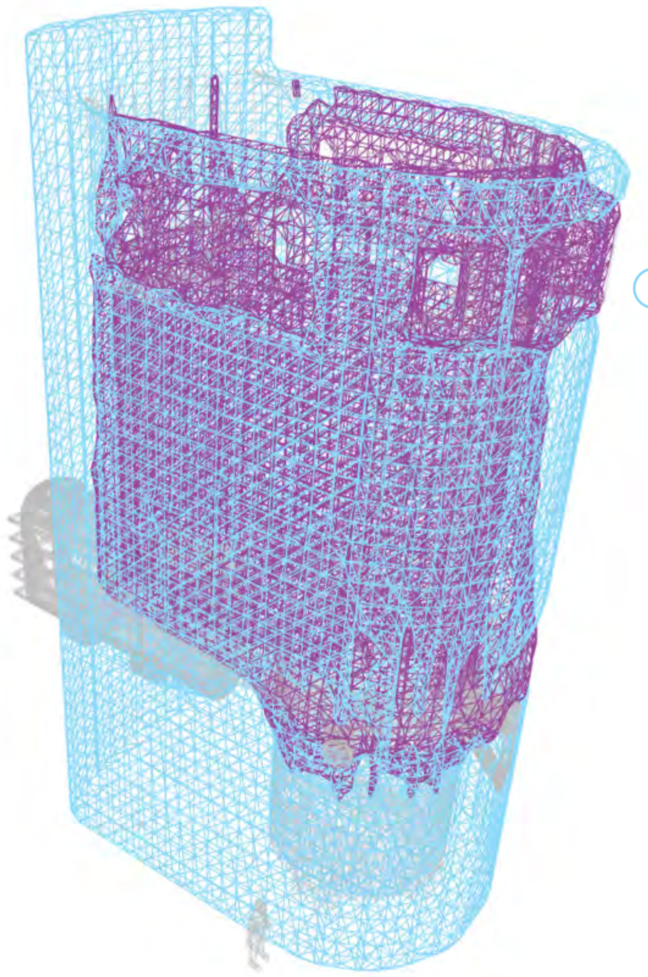
The question then arises: at what depth are the values sufficiently low to allow the concrete to be released? How do you determine how many centimetres to remove? Should readings be taken as each layer of concrete is worked through? The nuclear research centre SCK CEN realised there is a smoother, more efficient way of doing this tedious task. It developed a 3D model that mapped radiation levels in the biological shield down to the decimetre. "That model takes into account several different parameters, including the distance from the former reactor core and the depth in the concrete. The closer it was to the core, the more the concrete was exposed to radiation and therefore the thicker the layer that needs to be removed," explains Bart Rogiers, data scientist at SCK CEN and the driving force behind the 3D model.

Historical data and new readings

However, a mathematical model is only as strong as concrete if it is fed enough accurate data, and the nuclear research centre has spared no time or effort to fine-tune this input. "The very first 3D model we simulated was based on historical data. We then supplemented the existing data by carrying out new measurements: on the one hand in the field and on the other hand in a laboratory," explains Bart Rogiers. With the measurements taken on site – more than 400 in total – the research centre mapped out the entire wall. For the analyses that took place in the laboratory, 30 drill cores were extracted from the biological shield with a crown drill, from which more than 200 samples were analysed. "We also took additional samples in specific areas, such as zones where we expected the highest or the lowest radioactivity levels. That tells us a lot about the extremes."

SCK CEN took into account measurement and model uncertainties. "For the measurements we did on site, we used different types of detectors and measuring teams from several European research centres to measure the same locations. We then sent some samples to various European laboratories and included blank samples – i.e. samples without radioactivity. This allowed us to compare all measurement results and identify measurement uncertainties as much as possible. By carefully analysing these and other uncertainties, the results are much more reliable," clarifies Bart Rogiers.





- Volume that can be recycled
- Volume that has to be disposed of

> The 3D model combines safety for people and the environment with economic feasibility.
>
> Sven Boden

Dismantling strategy

SCK CEN has further outlined its dismantling strategy based on this 3D model. The separation works will start in 2021. "Thanks to this model, we were able to greatly reduce the amount of waste that cannot be recycled and therefore must be disposed of at a Category 1 landfill site. In addition, we ensure that no radioactive waste enters the surface disposal site. This means we are reducing the burden on future generations, while incurring minimal cost for measurements and still getting maximum certainty about the distribution of radioactivity in the wall. The 3D model combines safety for people and the environment with economic feasibility," says Sven Boden enthusiastically. For precisely this reason, the pilot project is proving its worth for the future dismantling of nuclear reactors in Belgium and other countries. The implementation of this new approach forms a part of the European research project 'INSIDER'.

Public-public collaboration agreement with ONDRAF/NIRAS

This research fits in seamlessly with the public-public collaboration agreement signed by SCK CEN and ONDRAF/NIRAS. Both partners have committed to continue working together for research over the next 25 years. Research will focus on surface disposal and geological disposal of radioactive waste. This includes waste characterisation – more specifically, the development of techniques to subject waste to additional analyses before it goes to the repository.

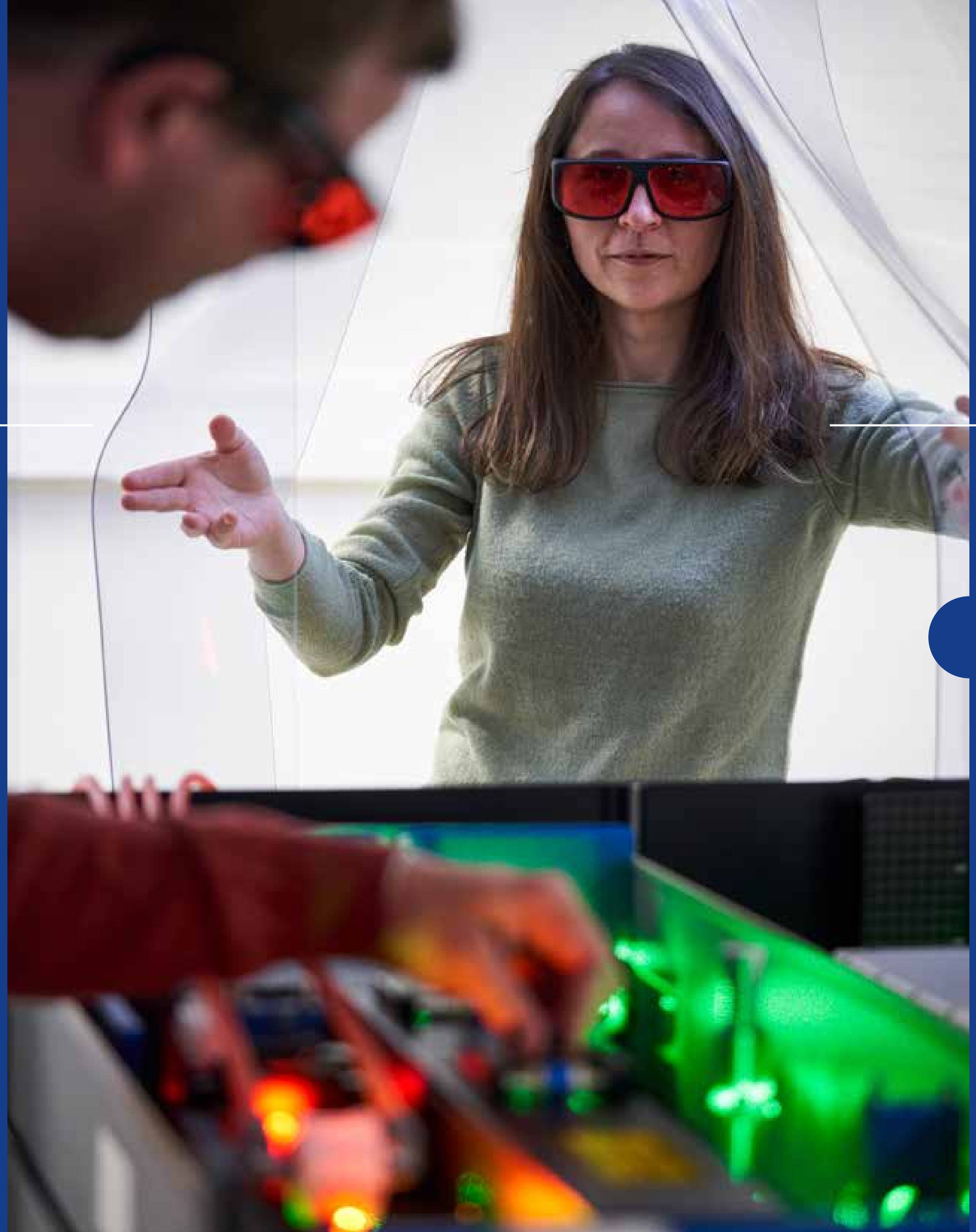
> By carefully analysing uncertainties, the results are much more reliable.
>
> Bart Rogiers

4

technology

Breaking patterns by

introducing new technologies. These technologies are still in their design or construction phase. Once they are up and running, they will make a world of difference. In the fight against cancer, in the management of nuclear waste, etc.



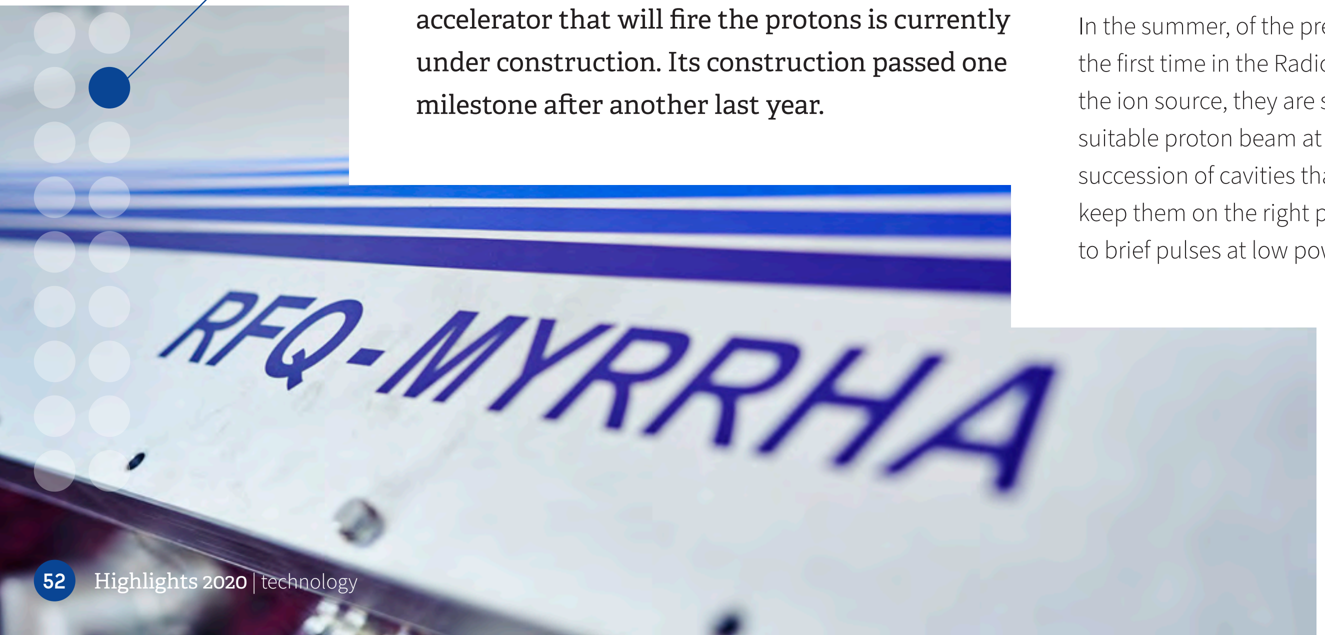
MYRRHA team celebrates one milestone after another

Acceleration of MYRRHA protons is a success

From 2027, SCK CEN will be making a crucial contribution to the development and production of a new generation of medical radioisotopes. The nuclear research centre will do this **by bombarding 'targets' with protons instead of neutrons.** The MYRRHA particle accelerator that will fire the protons is currently under construction. Its construction passed one milestone after another last year.

In 2019, the eyes of SCK CEN scientists lit up with delight when the very first protons effortlessly rolled out of the ion source. "The ion source is the first link in MYRRHA's particle accelerator [see text box] from where the protons are emitted," explains Dirk Vandeplassche, physicist at SCK CEN and specialist in particle accelerators. In 2020, barely a year later, those same scientists can again clap their hands with joy. And not once, but twice.

In the summer, of the previous year, they successfully accelerated a proton beam for the first time in the Radio Frequency Quadrupole (RFQ). "Once the protons have left the ion source, they are sent into the RFQ, and this part accelerates them to deliver a suitable proton beam at the other end. The energy from this beam is then increased by a succession of cavities that give each the protons an accelerating push, and magnets that keep them on the right path," Dirk Vandeplassche explains. The summer test was limited to brief pulses at low power, but it already showed that the system works flawlessly.



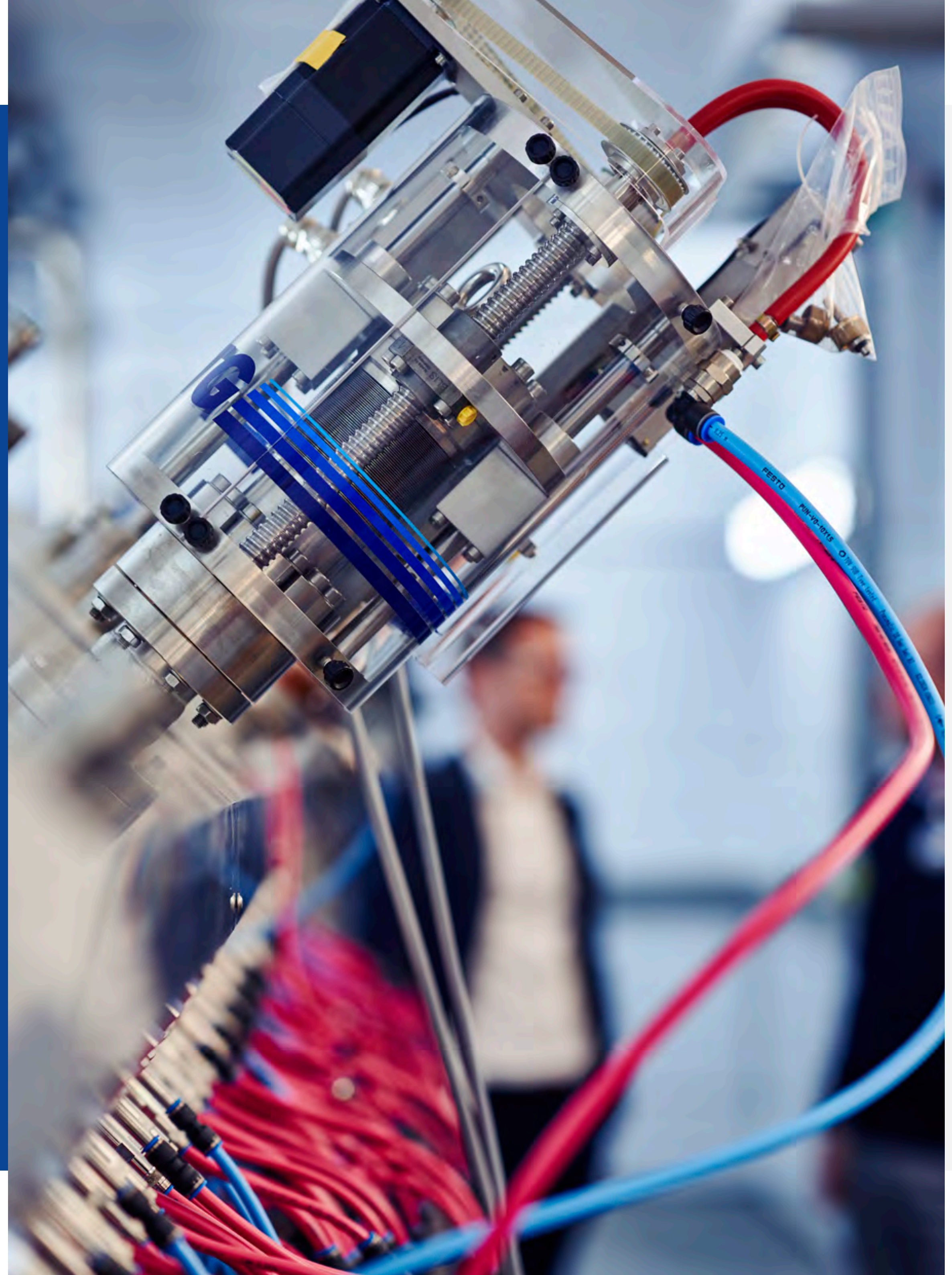
In the autumn, the scientists went a considerable step further by putting the Radio Frequency Quadrupole to the test for several hours. Can the RFQ produce a proton beam to the exact requirements to power MYRRHA's particle accelerator? "It does it brilliantly! At 100% power and without any interruption for several hours, we firmly established the nominal proton beam," says Vandeplassche proudly. This is great news, because the entire low-energy section – starting from the ion source to the RFQ – largely determines the reliability of the accelerator. This reliability is important in order to realise the intended applications in MYRRHA.

Joined forces

The scientists spent six years waiting for this moment. "This milestone that we've been working towards for 6 years is the result of international collaborations," says Hamid Aït Abderrahim, Director of MYRRHA and Deputy Director-General of SCK CEN. The Institute of Applied Physics (IAP) at Goethe University Frankfurt in Germany helped to design the RFQ, while the German engineering firm NTG was involved in its construction. The powerful RF amplifiers that provide the right power for acceleration are, in fact, produced by the Belgian company IBA. The French National Institute of Nuclear and Particle Physics (IN2P3) – a department of the French National Centre for Scientific Research (CNRS) – provided the link between the ion source on the one hand and the RFQ on the other, and RF regulation at low level. "Seeing the assembly at work at full power makes us proud, and it makes all the more eager to achieve more," concludes Vandeplassche. Next steps include the extensive measurements of the characteristics of the proton beam, the challenging reliability tests, and the experiments with the CH cavities.

MYRRHA: three construction phases

SCK CEN is currently working intensively on the construction of MYRRHA, the world's first research reactor driven by a particle accelerator. MYRRHA paves the way for countless promising technologies and applications, for example to optimise the management of nuclear waste and to produce new medical radioisotopes. The construction of MYRRHA is taking place in several phases. In phase 1, SCK CEN is building MINERVA, the particle accelerator with energy of up to 100 megaelectron volts (MeV). In a subsequent phase, the research centre will increase the energy level to 600 MeV. This energy is needed to carry out all planned activities in the MYRRHA research reactor, and especially the demonstration of the transmutation of nuclear waste. The actual subcritical research reactor will be built in the third and final phase, which runs until 2036.



A detailed project plan engages people

It's all hands on deck when it comes to achieving an ambitious goal. Each of us has his or her expertise and ideas, but also the drive to create one successful team with others. This is where a detailed project plan provides clarity. It creates confidence in the strategy that we are following and the contribution that each of us can make to that strategy. It also allows us to tick off milestones, track project progress, and learn as we go along.

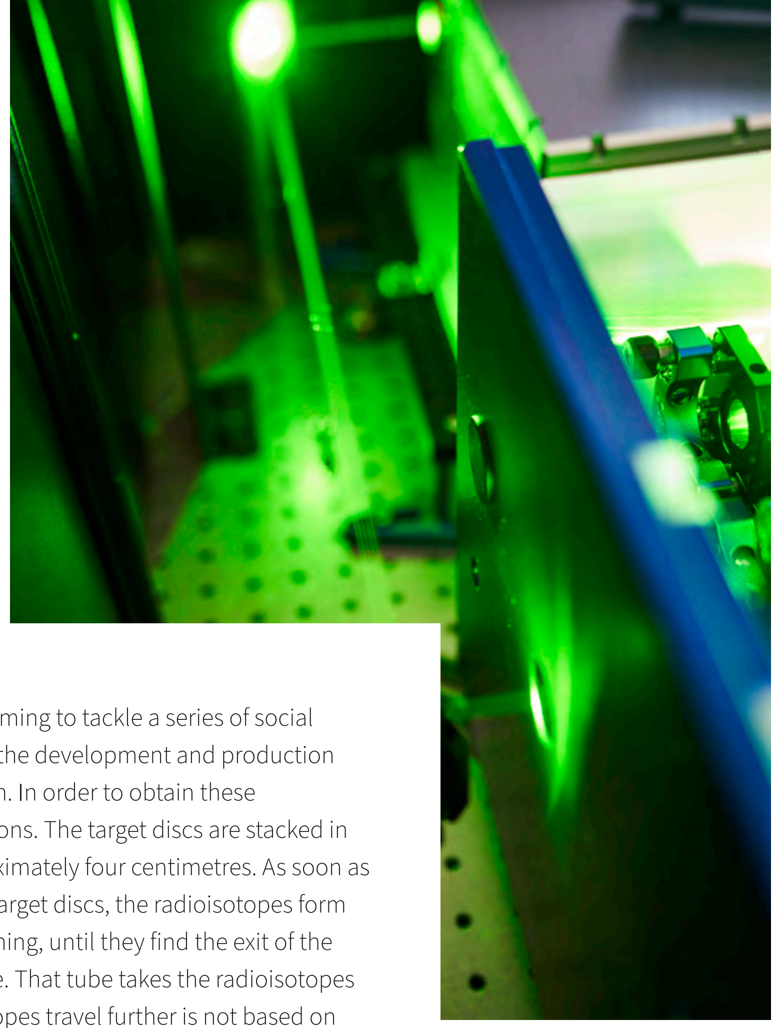
Adrian Fabich
MINERVA Design and Build

At 100% power and without any interruption for several hours, we firmly established the nominal proton beam.

Dirk Vandeplassche

SCK CEN decomposes atoms

Laser light rips electrons off the nucleus of an atom in order to isolate specific radioisotopes



In just one year, SCK CEN completed the construction of an impressive laser installation. It brings the nuclear research centre another step closer to its goal: **the development and production of a new generation of medical radioisotopes.** "These lasers will allow us to isolate specific, life-sustaining radioisotopes," says Lucia Popescu, one of the driving forces behind the project.

With the MYRRHA project, the nuclear research centre SCK CEN is aiming to tackle a series of social challenges. One of the ambitions that SCK CEN wants to achieve is the development and production of radioisotopes for medical applications and fundamental research. In order to obtain these radioisotopes, SCK CEN bombards so-called 'target discs' with protons. The target discs are stacked in ISOL@MYRRHA's *target container* – a tube with a diameter of approximately four centimetres. As soon as a proton beam with an energy level of 100MeV shoots through the target discs, the radioisotopes form and evaporate. They begin to wander around, bumping into everything, until they find the exit of the target container. That exit is also the entrance to a thin transfer tube. That tube takes the radioisotopes to the next part of the ISOL installation. "Of course, which radioisotopes travel further is not based on chance. We select them carefully. Only the radioisotopes that we have in mind are guided through the installation," says Lucia Popescu, an engineer at SCK CEN.

The selection is provided by laser light, which shines through a set of mirrors in the transfer tube. The researchers use two laser types. "Dye lasers and pump lasers," clarifies fellow engineer Kim Rijpstra. The lasers initiate an incremental ionisation. "Electrons rotate on energy shells around an atomic nucleus. The dye lasers allow an electron to jump from one shell to another, which is further from the nucleus. Once far enough, a final laser beam catapults the staggered electron out of the atom. By stripping the atom of its electrons, it gains a positive charge. The atom becomes ionised and can then be accelerated and precisely controlled."

Fingerprint of an atom

Just as each person has a unique fingerprint, each chemical element in the periodic table has its own electron configuration. The shells of each chemical element are different and the electrons are distributed differently among different shells. "The deeper inside the atom, the more energy it takes for an electron to jump away completely. By adjusting the colour of the dye lasers, we can identify which jumps will occur. This way, we aim our arrows at specific electrons and choose which specific atoms we encourage to travel further," explains Kim Rijpstra. Then, the ionised atoms are accelerated in an electric field and separated by a magnetic field based on mass. At the end of the journey, the selected isotopes are collected.

Laser installation

Since the end of 2020, the laser installation that will sort the radioisotopes in the future has been in pride of place in the technical area at SCK CEN. For its design, SCK CEN worked closely with KU Leuven, one of the Belgian universities. Once the design was finalised, the parts were ordered. "When they were delivered in early 2020, we immediately rolled up our sleeves and got to work. After one year of hard work, the installation was ready. This achievement brings us another step closer to our target," is the proud message. That target is 2027. From then on, the research centre wants to begin the development and production of a new generation of radioisotopes. There are still a few other milestones to tick off before that, though, the first of which is linking the laser installation to the ISOL@MYRRHA installation.

> Those lasers will allow us to isolate specific, life-sustaining radioisotopes.
>
> **Lucia Popescu**

ISOL@MYRRHA: the beating heart for isotope production

The ISOL installation *(Isotope Separation On-Line)* is the beating heart of the *Proton Target Facility* (PTF), where the radioisotopes are created. These radioisotopes are used for medical purposes or for fundamental and applied research in physics and materials research. The unique feature of this installation is the intensity of the proton beam. This proton beam is 100 times more intense than in other European installations. This means that the nuclear research centre SCK CEN can produce more isotopes within its spectrum.

Making a real difference with elementary particles

For centuries, humans have been trying to unravel the complexity of the world, and science is the tool that helps to provide understanding and create order in the apparent chaos. Fundamental science is the engine for amassing knowledge and developing new solutions for applications with societal relevance. The enthusiasm and sense of constant wonder among our employees provide the necessary impetus to continue making progress.

Marc Schyns
Advanced Nuclear Systems

MYRRHA reactor vessel slims down

Renewed design combines safety and economic feasibility

Four metres shorter and two metres narrower. **The renewed design of the MYRRHA research reactor** is not only smaller, but also more economical and significantly safer. The message: "This revision brings us another step closer to the realisation of MYRRHA."

Good science takes time: time to make considerations, to let ideas take root and to conduct thorough tests. Sometimes, scientists and engineers must adapt a concept and then repeat the qualification testing. This is all the more true when they are moving into unexplored territory. Rafaël Fernandez knows this too. This engineer at SCK CEN and his team are drawing up the design of MYRRHA, the world's first research reactor driven by a particle accelerator. The core will not be cooled with water, but with a liquid metal. "Lead-bismuth," Fernandez clarifies. "An innovative installation requires innovative materials. We have to be sure that every material used or component chosen in our reactor design can handle the conditions of the research reactor without problems. We have an extensive R&D program to test every design aspect in practice: from safety to economic feasibility and even logistics. We use that knowledge to systematically adjust our design."

Last year, the engineers completed revision 1.8. This design provides an answer to all the safety requirements and points for improvement, as identified by the research programme in revision 1.6. "The coming year should conclusively answer the question of whether the final design is now on the table. We will subject the new components to extensive testing," says fellow engineer Graham Kennedy. A final design is therefore in sight.

Far-reaching improvements

What changes did the researchers actually make? "First and foremost, we made the reactor vessel slimmer. In height it shrank by about four metres, in diameter by almost two metres. This modification was necessary in order to be able to transport the reactor vessel in its entirety from the manufacturer to SCK CEN," says engineer Graham Kennedy. "It takes 200 cubic metres less of lead-bismuth to fill the reactor vessel, a substantial saving."

The challenge was to reconcile that downsizing with the safety requirements. The engineers had to fit larger heat exchangers into a smaller reactor vessel to compensate for a less efficient heat transfer process. Rafaël Fernanadez explains: "The lead-bismuth transfers its heat to the water that flows through the heat exchanger tubes. In this design, the tubes are double walled. That double wall is an additional safety mechanism that we've built in. It should prevent the water and lead-bismuth from mixing in the event of a rupture and causing certain radioactive products to evaporate through that reaction. A double wall reduces heat transfer. This is precisely the reason why we install double-glazed windows in houses, but in the MYRRHA research reactor, we want to cool things down instead of retain heat."

Safety

The engineers managed to put together the complicated puzzle. "The input from colleagues who each have a different background and who looked at the issue through different lenses is what helped us succeed. More than that, we were able to combine the best of both worlds. By modifying the design, we significantly improved safety and were able to reduce costs. And sometimes we had to drop old concepts. For example, we went from two fuel handling machines to one, and were able to reduce thermal stresses by modifying the diaphragm design. The diaphragm is a partition that separates the relatively cold high-pressure lead-bismuth from the hot low-pressure refrigerant." In the next step, the engineers will link the reactor vessel design to the secondary and auxiliary systems.

Scaling the highest heights

The best view comes after the toughest climb – a statement that is familiar to any mountaineer and is also true for ambitious projects such as MYRRHA. Such innovative installations require a more extensive R&D programme in the development phase, but they offer a genuinely positive outlook. More than that, they are the key to tackling societal challenges. I offer my congratulations to the team that is designing this unique 'key' and is realising the construction of MYRRHA.

Hamid Aït Abderrahim

Deputy Director General and Director of MYRRHA

Online learning takes off

Half of SCK CEN Academy's training courses have been delivered online

Across the world, the coronavirus has glued airplanes to the tarmac, kept office workers chained to a home office, and sent event and training calendars into disarray. It was no longer possible to continue with conventional training. What the virus failed to do, however, was quell the hunger for learning. In 2020, online learning took off like never before. Distance learning initiatives shot up like mushrooms in no time at all. The SCK CEN Academy also shifted up a gear (online) to keep participants' nuclear knowledge up-to-date or to expand on it. "We were in the process of rolling out an online learning service, but the coronavirus crisis has accelerated the process," notes Michèle Coeck, director of the SCK CEN Academy. In a short space of time, the SCK CEN Academy has delivered twenty training sessions in an online format that were previously scheduled as face-to-face, which were immediately met with great approval. There was much to consider. "Teaching online not only requires the use of different tools, but also different didactics. In online training, participants lose concentration more quickly and creating interaction is a formidable challenge. Presenters need to anticipate all of that. **What this means in practice is abandoning usual routines and learning new methods.** The past year was an excellent practical learning experience, but the subject has meanwhile found an important place on the agenda in the education field. We, together with colleagues and stakeholders, are paying extensive attention to it, including during the ETRAP conference (International Conference on Education and Training in Radiation Protection) in March 2021," explains Michèle.

Close online supervision

The SCK CEN Academy moved heaven and earth to enable students to follow the necessary training courses. "Under no circumstances did we want to leave our students out in the cold. The same is true for all Bachelor's, Master's and doctoral students who write their thesis or do an internship here. They were able to count on the same close supervision, but online," concludes Michèle.

65
Completed theses
2 secundary education
16 Bachelor
32 Master (+ BNEN)
15 PhD

84
PhD students
29% from Belgium
71% from abroad

24
PhD students selected in 2020

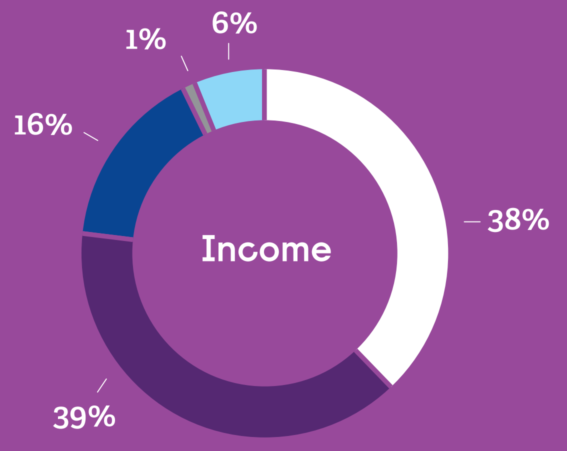
503
Scientific publications & presentations

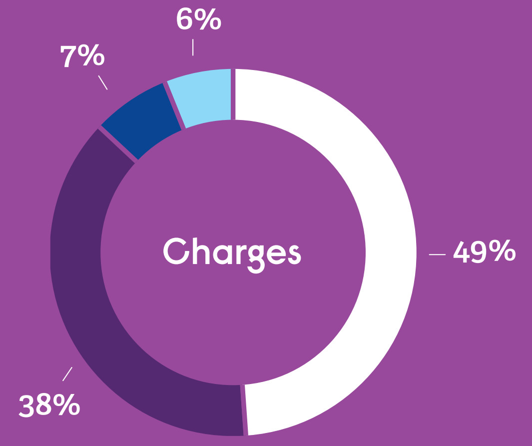
35
Internships
in Belgium and abroad

37
Training courses
with 930 participants
49% online

Key figures

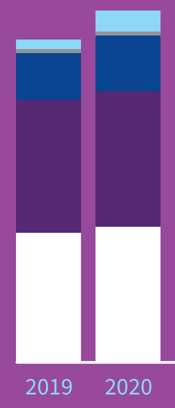
Budget execution





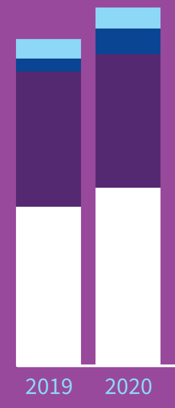
Budget evolution

Income (in kEUR)



	2019	2020
Turnover	73.473	76.652
Subsidies from government, grants	76.723	77.372
Other	26.528	32.446
Financial income	1.093	1.101
Extraordinary income	4.792	12.277
TOTAL	182.609	199.847

Charges (in kEUR)



	2019	2020
Personnel costs	90.221	100.371
Purchases, services	78.253	76.549
Provisions	6.138	15.026
Depreciation	11.201	11.984
TOTAL	185.813	203.930

Active in 65 countries

(indicated in white)

Staff

943 Employees

708 men

235 women

50 nationalities

39% with an academic degree

13 average years of service

Keeping a grip on the finances to ensure the future

The first step to keeping your finances in balance is to analyse all your income and expenses. Last year, we repeated this first step several times: we literally and figuratively went through our budgets with a fine-tooth comb. They do not include any luxuries, but they do allow the core tasks to be performed to a high standard. If we continue to follow our self-imposed financial goals and constraints, we can swing the pendulum in the positive direction. In this way, we can ensure our future.

Peter Baeten

Deputy Director General

Belgian Nuclear Research Center
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

65 years of experience in nuclear science and technology

SCK CEN is one of Belgium's largest research centres. It has more than 850 employees who devote themselves every day to developing peaceful applications of nuclear energy. The research activities of SCK CEN relate to **three main themes.**

The safety of nuclear facilities

The development of nuclear medicine

The protection of the population and the environment against ionising radiation

SCK CEN is recognised worldwide and shares its knowledge through numerous publications and training courses in order to keep up this exceptional pool of talent.

More info: www.sckcen.be