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VISION

Vision on technology for a better world

VITO ON BARRICADES FOR FLEMISH ECONOMY AND HEALTH

TOWARDS A LOW-CARBON AND SAFE ENERGY SYSTEM

CCU AS A WEAPON AGAINST GLOBAL WARMING

A SUSTAINABLE ALTERNATIVE FOR COD TEST

VITO ZOOMS IN ON GLOBAL LAND COVER

COVERSTORY

Dear readers,

We are living in extraordinary times. Since the start of the coronavirus crisis, we have entered a new reality that is still changing all the time. As a society, we have primarily been trying to overcome the health crisis in the best way possible. At VITO, our thoughts first and foremost went out to healthcare staff in hospitals and care centres, medical and nursing staff, and the health of our own staff, our customers, suppliers and stakeholders and their families.

At the same time, the country needed to keep going, and that is why we would like to thank everyone with an essential job during these historic times: from retail staff to postal workers and waste collectors.

During the crisis, it has been exceptionally quiet at the various VITO sites – from Mol to China via Genk and Berchem. But despite this, VITO has continued to operate. Thanks to their flexibility and commitment, most of our staff have been able to work from home. We would like to spare an additional word of appreciation for those who continued to work in our labs and our internal services that supported all of this.

We would also like to thank Minister Crevits for her confidence in and support for VITO in allowing us to obtain the necessary accreditation for rapid certification of face masks (including the specialised FFP2 and FFP3 masks), to ensure the start-up of mask production in Flanders, which will be necessary in the coming years. VITO will set up this activity in full synergy with Centexbel, allowing us to maximise the accreditation capacity we can market as quickly as possible.

"Never let a good crisis go to waste" is a quotation attributed to Sir Winston Churchill. He allegedly said this in the run-up to the foundation of the United Nations, shortly after World War II. After all, Churchill believed that this war contributed to the foundation of the UN. Or the adage "Every disadvantage has its advantage", attributed to the late Johan Cruijff, but devised by Willem van Hanegem. Both quotations should inspire policymakers and businesses to consider the coronavirus crisis and the necessary restart as an opportunity, like the reconstruction of the European and Japanese economies following World War II. An opportunity that should be aimed at setting up a more future-oriented economy with more focus on sustainability, from renewable energy to a circular economy, while not forgetting about difficult target groups.

In this edition you will read how we at VITO can offer new technologies for this. This time we will focus on CCU, a technology that converts CO_2 into high-performance products, allowing the chemical industry and the building sector to become more sustainable.

VITO will continue to play its role in full with regard to both the government and the business community. You will discover how we familiarise Flemish businesses with the circular economy and how we help the Flemish government to make its environmental analyses more sustainable.

Together, we will evolve into a sustainable society. And hopefully at an even faster rate following the coronavirus. Enjoy reading this issue of VITO VISION.

Dirk Fransaer
Managing Director of VITO

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COVERSTORY

VITO ON BARRICADES FOR **FLEMISH ECONOMY** AND **HEALTH**

EXPANSION OF TEST INFRASTRUCTURE FOR QUALITY TESTING OF MOUTH MASKS

When national mass production of face masks was started up during the peak of the coronavirus crisis, this suddenly led to a great demand for adequate and accredited quality control. VITO provided this by quickly expanding its existing test infrastructure for the testing of FFP face masks.

Today there is no more doubt: adequate and reliable quality control for protective equipment like face masks is absolutely essential during the coronavirus crisis. The past months and weeks have also made it clear that these tests are best organised nationally as a strategic service for businesses and authorities.

European standard

Until mid-April 2020, our country did not have an accredited lab for quality testing of FFP1, FFP2, and FFP3 half-face masks. "Until recently, this was always done in labs abroad, e.g. in Germany," says Gert Otten of VITO. "The tests determined whether a face mask complied with the current European standard." This is essential during the corona crisis, as face masks can be used by healthcare workers, for example, to protect themselves against the virus. "Once a manufacturer of face masks is given the green light from such a lab, it will receive a certificate of conformity that it can present to its customers."

When several companies in Flanders decided to focus on the mass production of face masks, this suddenly created a demand for quality control and certification. That is why the Flemish Minister of Economy, Hilde Crevits, contacted VITO and asked if they could take on that role. Otten: "As a reference lab, we have a lot of experience in measuring aerosols and gases. So the question from the cabinet was not unexpected. Furthermore, we already have the relevant infrastructure and expertise available, which we use to carry out all kinds of tests regarding air purification techniques for companies. You could view face mask testing as an expansion of this." For this, VITO is also collaborating with Centexbel, the test institute of the Belgian textile industry.

Extensive series of tests

In order to comply with the European standard (NBN EN 149+A1 : 2009), these face masks have to pass an extensive series of tests. "Initially we test whether they stop the virus particles," explains Otten. "We do this using particles of a similar size in the form of an aerosol at high concentrations. The aerosol is drawn in by ventilation equipment and released towards a dummy head that is wearing a mask." Other tests are used to check the strength of the material, the ease with which the mask can be put on and taken off correctly and the practical usability of the mask (they should not be too obstructive, for example).

Due to the high level of urgency, the European Commission simplified its standard a few weeks ago, so the focus now is on the critical safety tests. VITO has successfully managed to expand its test infrastructure for face masks to comply with this "COVID-19 standard" within a few weeks. "Face masks will also be crucial during the exit strategy," explains Otten.

That is why, in a second phase, VITO's aim is to start using its expertise to assist users of face masks as well, e.g. with guidelines for correct usage and for sterilisation and reuse.

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TOWARDS A **LOW-CARBON** AND **SAFE ENERGY SYSTEM**

An energy supply that largely runs on renewable energy sources would be difficult to achieve without Power-to-X. In this system, solar and wind power are used to produce energy carriers like hydrogen or synthetic feedstocks and fuels. But where and how should the technology be rolled out exactly; do we want to make the Belgian energy system both low-carbon and safe by 2050? An interdisciplinary consortium will be looking into this over the next five years.

Within the context of the energy transition, the focus has recently shifted back to hydrogen. Many countries are currently investing heavily in hydrogen technology, including Belgium – one example is the planned plant in Ostend, where hydrogen will be produced using wind power from the North Sea. Various energy-related applications of hydrogen are also being studied and developed – from heating systems for buildings to transport and industrial processes. Hydrogen is often viewed as the final energy carrier in this regard. "And that is not always justified," says Pieter Lodewijks of VITO/EnergyVille. "It is almost always more efficient to use electricity directly – if that is possible, at least."

Taxonomy of hydrogen

So the efficiency of the use of hydrogen depends strongly on the application and the sector. The structure of this within the context of the Belgian energy system is one of the key questions that will be investigated over the next five years as part of the PROCURA project (in full: Power to X and Carbon Capture & Utilisation Roadmap for Belgium). "Synthetic fuels will probably be more suitable for end applications in the transport sector," says Pieter Vingerhoets of VITO/EnergyVille. "Through PROCURA, we want to establish a clear and comprehensive taxonomy of hydrogen. What are the best applications to use it directly, and when is it better to convert it into other synthetic chemicals first? "Within the project, various possible solutions, which could result in a low-emission and safe energy system by 2050, are being tested to determine their potential. We are looking into the scalability of the technology, affordability and the possibility to maintain a balanced energy system with supply security.

Obviously, hydrogen is only one of these solutions. The energy carrier is also part of the wider Power-to-X (P2X) concept, in which cheap electricity is used to produce certain synthetic chemicals and fuels (so-called 'e-fuels'). P2X is a welcome solution, both for Belgium and for Europe, where the energy transition depends on the further expansion of renewable electricity. Lodewijks: "On the one hand, P2X is important for balancing our power system, on the other hand, the energy transition needs molecules in a number of sectors." By the end of the PROCURA project (around 2025), a detailed and clearly calculated scenario should be available, which demonstrates how P2X can contribute to the future Belgian energy system – including concrete policy actions that will have to be taken before 2030. "We are also considering how the use of P2X in Belgium – where the potential for renewable energy is relatively limited – relates to the situation in neighbouring countries, as well as investigating options for importing molecules from regions where this potential is much higher."

Interdisciplinary partnership

PROCURA was launched on 1 March 2020 and is being sponsored by the federal Energy Transition Fund – the budget is 4.5 million euros. It is an interdisciplinary partnership between Belgian knowledge organisations, all providing their own contribution: imec, WaterstofNet, KU Leuven, VUB, the University of Liege and finally VITO/EnergyVille. The interdisciplinary nature of the project is not only found in the partnership, but also within VITO/EnergyVille. "PROCURA combines no less than three of VITO's research domains," says Metin Bulut of VITO. "That is our strength."

The consortium is being led by imec, which provides its expertise in the field of nanomaterials. "In the field of energy, we were already working with technologies like solid state batteries, but we now also want to apply our knowledge to electrolysis systems," says Joachim John, Programme Manager at imec. "The surface properties of materials on a nano scale, for example, play a key role in the efficiency of electrochemical reactions that convert light directly into hydrogen (which can then be converted into so-called solar fuels after adding other chemicals)."

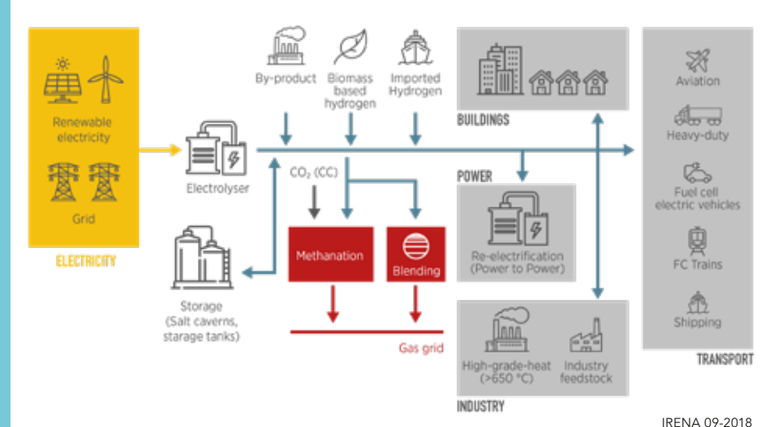
The potential of these solar fuels is a separate work package within PROCURA. Within these packages (there are seven of them), the focus is on the development of technology starting from the basis. But at a higher level, the results of the work packages are combined and incorporated into models and possible roadmaps – each targeting the year 2050. "That makes this project truly unique," says Lodewijks. "It makes it both a high-level study and a fundamental study into new P2X technology. The insights gained from the work packages are incorporated into system models, which we then scale up to a Belgian level at VITO/EnergyVille. This modelling at system level is exactly what we specialise in."

Electrolysis of CO_2

Within PROCURA, the potential of promising CCU technology is also being studied: the direct conversion of CO_2 into "green" molecules using water and electricity (which in turn should ideally come from renewable sources). This "CO_2 electrolysis" could operate flexibly based on the electricity supply, without requiring electrolysis of water as an intermediate step. This may allow the technology to act as an alternative to hydrogen-based strategies. "Chemicals such as methanol, for example, could be more suitable for synthetic fuels," says Bulut. "Its energy density is much higher, so methanol is easier to transport."

The disadvantage is that the technology is still in its infancy. "But it has great potential for producing other molecules as well," says Jan Vaes, Sustainable Chemistry Programme Manager at VITO. "For example, we are also investigating the production of 'green' formic acid from captured CO_2 in this manner, and its use as a high-performance chemical."

Even though PROCURA was set up using the Belgian energy system as a basis, the methodology used is generic, so it can also be applied to other countries. "This is another aspect that makes this project unique; it is unrivalled anywhere in Europe or the world," says Lodewijks. However, the condition is that the energy system should mostly operate on renewable energy (by 2050). Whatever the results of the project, the share of this in the energy mix will have to increase dramatically in any case. Vingerhoets: "We currently need a lot more solar and wind energy to create a balanced system in which, for example, locally produced, green chemical energy storage plays a key role. So we still have a long way to go."



Integration of VRE (variable renewable energy) into end uses by means of hydrogen

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FROM GREENHOUSE GAS TO RAW MATERIAL: CCU AS A WEAPON AGAINST GLOBAL WARMING

CO_2 contains carbon, so it can be used as a basic raw material for chemicals, synthetic fuels, building materials and many other applications. Carbon capture & utilisation is still mostly only available on a lab scale, so it is currently too early for upscaling and a broad rollout. With its rich expertise, VITO is contributing to CCU research through all of its research domains: from scientific and technical considerations to the economic aspects.

Five years ago, the historic Paris Agreement was signed. It was agreed that global warming should be limited to a maximum of 2 degrees – and ideally 1.5 degrees – by 2100. That is easier said than done, as it means that global greenhouse gas emissions will have to be drastically reduced over the coming decades. This decade, a reduction of 900 million tonnes of CO_2 emissions (the most significant greenhouse gas) would already need to be achieved every year (current annual CO_2 emissions are 35 billion tonnes). By 2050, these emissions should not exceed 13 billion tonnes, and by 2070 they should be zero. The latter might seem completely unrealistic, if not for the fact that these are net emission figures. So-called negative emissions, with CO_2 being removed from the atmosphere, are included in the calculation.

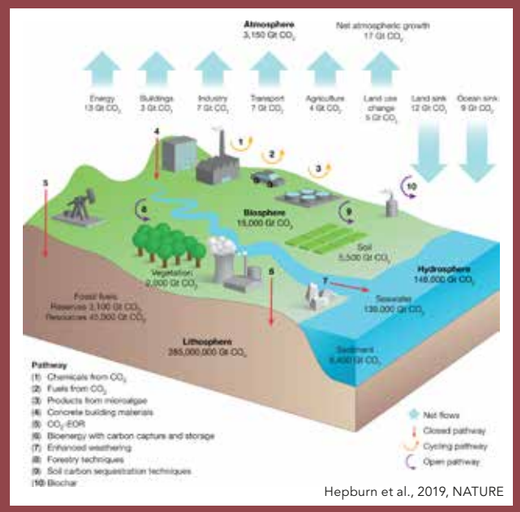
Economic and ecological added value

Until recently, technologies for negative emissions were mainly assigned to the category carbon capture & storage, or CCS. But in recent years, an expansion to this with greater potential has emerged: carbon capture & utilisation, or CCU. Here the captured carbon is processed and recycled as much as possible, preferably in applications with both economic and ecological added value. In a certain sense, this goes back to the natural process of photosynthesis, as planting trees or certain crops can be viewed as a natural version of CCU.

CCU thus differs from CCS, where carbon is stored on a massive scale, e.g. underground – this still is a highly sensitive matter and would not appear to be economically feasible either. When using CCU, CO_2 is (and often remains) stored in products and applications. Another difference with CCS is the complementary nature of CCU with (other) emission-reducing strategies, like advanced decarbonisation of electricity production, increased carbon efficiency in the process industry and maximum carbon recycling during the manufacture of plastics.

CCU within VITO

Roughly speaking, there are ten 'pathways' along which CCU may contribute to the reduction of CO_2 emissions. They are all presented in this figure.



Hepburn et al., 2019, NATURE

VITO mainly focuses on the technology-related CCU solutions, with CO_2 being captured and collected from flue gases or from ambient air (see 'Direct air capture' box). The greenhouse gas can then be used as a raw material for the industrial manufacture of carbon-based products. Three of VITO's research domains are involved in the CCU research: Sustainable Chemistry, Sustainable Energy and Sustainable Materials. The link to the industry is never far away here: VITO is therefore highly interested in CCU solutions that can make the relevant sectors more sustainable.

It will only be possible for CCU to experience a break-through and be implemented on a large scale if the whole picture is correct. It speaks for itself that any possible application should have some potential for value creation from the start of the research process. And the overall CO_2 emissions in every value chain should also be lower than the climate impact of alternative processes to avoid ending up in a situation of greenwashing. The focus on the whole picture does make this a highly complex matter. However, its many areas of expertise make VITO perfectly equipped to tackle this.

Three VITO domains

CCU is highly interesting in terms of making the chemical industry more sustainable and greener. After all, this industry not only emits vast quantities of CO_2 – both through energy generation and production processes – but it also relies heavily on carbon as a raw material. Although greenhouse gas emissions from the chemical industry are relatively limited on a global scale (in Europe it produces 4 percent of greenhouse gases), this share is much higher in the highly industrialised region of Flanders. The chemical industry in our region is responsible for no less than 11.7 percent of Flemish emissions. Apart from increasing the efficiency of processes and advanced electrification, our chemical industry could also benefit from CCU.

By allowing CO_2 to react with hydrogen in a controlled manner using a catalyst, various chemical building blocks can be created, like syngas and methanol. These can then be further converted into renewable fuels or chemical products like plastics – this is the thermocatalytic route. By using electrolysis, CO_2 and water can also be converted into building blocks for bulk chemistry, like formic acid – this is the so-called electrocatalytic route. Catalysts play a leading role within both routes, so the link to materials research is never far away. VITO's Sustainable Chemistry and Sustainable Materials units are therefore working very hard on a new generation of heterogenous catalysts that may substantially increase the efficiency of these processes. Among other things, this is being done by 3D printing catalysts, CO_2 capture equipment and gas diffusion electrodes.

There is no doubt that the chemical sector – which is energy-intensive and has high CO_2 emissions – is a key stakeholder in the CCU development process. Furthermore, it can use its traditional role of innovator to kick-start the rollout and development of CCU technologies and projects in other sectors. This will also allow the chemical industry to strengthen its position of enabler in the renewable energy transition – for example, by providing simplified storage and transport of energy in the shape of 'green' molecules produced with intermittent power sources like solar and wind. Methods to connect CCU with the future supply of renewable energy are being studied within VITO's Sustainable Energy unit. Note that the CO_2 streams required for this may also come from other sectors, like the steel industry.

The building and construction sector may also benefit from CCU to become more sustainable. After all, the production of building materials contributes highly to global warming. The share of concrete in human CO_2 emissions is between 5 and 8 percent worldwide – which is mainly the result of cement production. Here CCU can also help to reduce the emissions. Accelerating a reaction called carbonation – which causes the formation of new rock in the earth's

crust – in optimum conditions and at high CO_2 concentrations allows alternative building materials to be created without having to use cement.

Within its domain of Sustainable Materials, VITO is actively working on the development of these "CO_2-neutral building and raw materials". They typically use mineral raw materials that contain calcium or magnesium and come from various industrial sectors (energy, steel, construction, etc.). An additional advantage of this technology is that it also offers an important contribution to the sustainable use of raw materials. This connects CCU to the transition towards a circular economy and a more sustainable materials policy, which are two key spearheads of the Flemish and European economy.

Smart upscaling

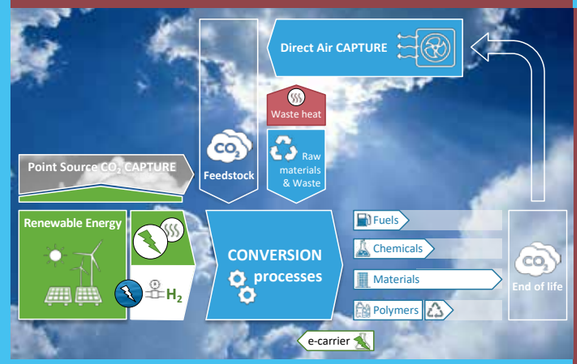
Improving the process efficiency of the catalytic reactions is the greatest challenge right now. In this field, VITO can use the expertise gained during a long-term collaboration with the Applied Electrochemistry and Catalysis (ELCAT) research group of the University of Antwerp. Both at VITO and the University of Antwerp, efforts are taken to scale up electrochemical reactions that work well in a lab (see "CO_2 in the pipeline" box). This is done both in terms of conversion (more active reactions, allowing more end product to be made with less energy) and time (faster and more stable reactions). At the same time, VITO is unleashing its expertise in techno-economic analyses on this upscaling process, allowing the various parameters to be optimised to ensure the economic feasibility of the final application. In this way, VITO is gradually moving the technology from a lab scale to a pilot scale.

Turning the Flemish economy and industry more sustainable and stronger is part of VITO's core mission. The research into CCU should also be viewed in that light. That is why this is being done from various units and research domains to cover all the aspects of CCU: the fundamental chemical aspect, the engineering aspect, the techno-economic aspect, etc. The focus here is not only on Flanders, but on Europe as well. The research focuses on the entire value chain, from CO_2 capture at chimneys or from the air all the way to the marketing of the end product. This makes CCU the subject of a very broad field of research. But at its core the challenge remains the same: reducing greenhouse gas emissions and converting CO_2 into products with economic value.

Direct air capture (DAC)

For the time being, most of the CO_2 required for potential CCU applications is still being captured above chimneys of plants (so-called industrial point sources). But the greenhouse gas can also be collected directly from the air, although its concentration is obviously several orders of magnitude lower there. This approach is called direct air capture, or DAC.

By providing negative emissions, DAC may help to achieve the prescribed emission targets for CO_2. Seeing that this technology is still expensive at the moment, VITO is looking for strategies and developments to reduce the costs of CO_2 capture and accelerate its preliminary implementation in the field.



CO_2 in the pipeline

In 2019, a multidisciplinary partnership was established between the University of Antwerp, Ghent University and VITO to accelerate radical technological innovations within Flanders. Within this Capture initiative, various research programmes involving the capture, separation and conversion of CO_2 can be set up within the various stages of technological development.

The strategic partnership between the University of Antwerp and VITO, which dates back further, is also embedded within this initiative. It mainly focuses on catalysis (by the University of Antwerp) and supporting competencies like upscaling and techno-economic analyses (by VITO). "It is a combination of things," explains Tom Breugelmans of the University of Antwerp. "There are many available technologies and possible CCU solutions. Joining forces allows us to go looking for the ideal combination. The whole life cycle analysis must be right."

The ultimate goal is to valorise the knowledge gained and in this way serve industry in Flanders. This will be done by granting both SMEs and major corporations primary access to the research results and by including them in a vibrant and diverse business community.

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NATURE VALUE EXPLORER SHOWS HOW ECOLOGICAL INFRASTRUCTURE PAYS OFF

The construction of urban green spaces that provide a cooling effect on hot days, removal of paving in rural areas, allowing more rainwater to seep into the soil, forestation to promote carbon storage, etc. These are just a few examples of ecological measures that could protect an urbanised Flanders against the challenges of the 21st century. An online tool developed by VITO – which is freely available – allows both governments and businesses to tangibly and rapidly calculate the social benefits of this. "All it takes is half a day's work."

What impact do changes in land use have on an urbanised Flanders? How can this impact be calculated? And what benefits does green space provide to people and society? Ten years ago, VITO and the universities of Antwerp and Amsterdam started developing an instrument that would answer these questions at the request of the Flemish government. Since then, this Nature Value Explorer has evolved into an online tool and has been modified and expanded several times. Users – from local and regional governments to urban planners, conservationists and educational institutions – can use the tool to discover and calculate the socioeconomic significance of green space.

Pragmatic methods

The tool, which is freely available, offers an insight into the benefits that vegetation and water can offer – examples are cooling, infiltration, air and water purification, recreation and benefits to human health. "It calculates these benefits both in the city and in rural areas," says Inge Liekens of VITO. "The results show the impact of changes in land use, the added value of nature-based solutions, the benefits of control measures or the advantages of green development projects for people." The calculation is performed using pragmatic methods developed in various scientific projects, and based on existing spatial data – for example, geographic data for Flanders. The tool is also compatible with various existing planning methods.

The Nature Value Explorer has been revamped over the past ten years. The latest version is from April 2018: that is when the tool became "spatially explicit". Liekens: "Users wanted a fast tool that involved little extra work. Since then, it has become possible to add ecological measures to drawings. Grassland here, heathland there, water here, a park there, etc. This makes changes in land use the core of the tool." It was quite a big step forwards, but it still wasn't enough for some users. "Urban planners and landscape architects often develop their plans in sophisticated drawing programs. Until recently they had to retrace everything in the Nature Value Explorer. That has also changed: their plans can now be uploaded very easily using shapefiles. This makes the tool even more user-friendly, and using the tool only takes half a day's work." New updates are already being planned for the tool. VITO is currently testing a module that can be used to visualise biological value. "We will also provide a separate results page with the effects nature has on our health."

Interest outside Flanders

In the meantime, there is also an interest in the Nature Value Explorer on the other side of the linguistic border. In collaboration with the University of Liège, the Walloon government wants to check whether the methods and calculations of the tool can also be applied in Wallonia. "But Wallonia will have to provide the spatial input charts for this, as our tool is based on Flemish data," says Liekens. And people have also started using the tool abroad. "We have a few users in the Netherlands, and other countries have also expressed an interest in using the tool as part of climate adaptation."

Climate adaptation

As indeed, the tool also has potential with regard to the climate. "Many local governments have committed themselves to supporting the fight against global warming, often in the shape of concrete objectives. We can use the Nature Value Explorer to calculate the effects of local measures, especially in the field of climate adaptation: for example, how ecological infrastructure can help to limit the urban heat island effect in built environments. To also help municipalities to select these measures, VITO wants to link the information on the climate portal of the Flanders Environment Agency (VMM) on the impact of global warming with possible measures and their effect on this impact. "At the moment we have developed an initial prototype. We are now looking into how to continue its development with various partners. But it could also become a new, separate tool – separate from the Nature Value Explorer," says Liekens.

"Visualising nature in a positive manner"

Guy Heutz, the manager of the Hesselteer ecological consultancy firm from Antwerp, has been using the Nature Value Explorer since 2017. "We want to make our clients more aware of the added value of nature. That green spaces not only require work and maintenance, but have social benefits as well. This tool is highly suitable for that."

Heutz also praises the update to the Nature Value Explorer from April 2018. "This made the tool much more user-friendly. Using the tool now takes much less time, partly thanks to the convenient dashboard used to control the tool."

The Nature Value Explorer allows users like Heutz to visualise nature clearly and in a positive manner. "And no longer from a defensive reflex, which would mainly focus on limiting damage to nature. This turnaround is highly valuable."

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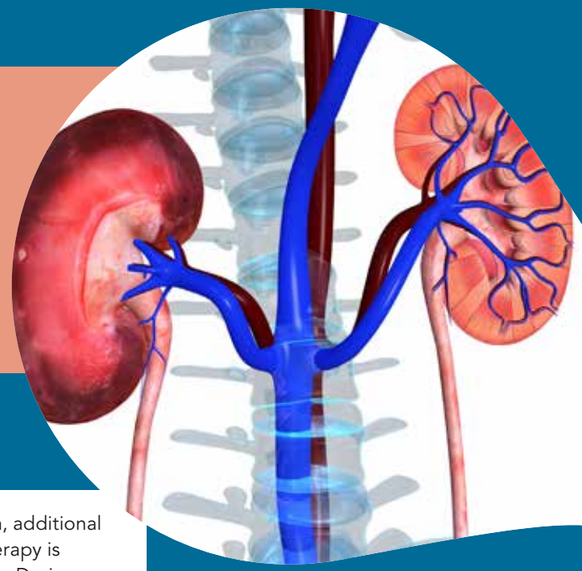
URINE TEST DETECTS KIDNEY REJECTION EARLY



After receiving a new kidney, transplant patients need to undergo painful biopsies for years to monitor their condition. Together with European partners, VITO searched for and found a set of biomarkers that are easily measurable in urine and that provide an accurate and rapid indication of rejection. It's now a matter of putting the test into clinical practice as quickly as possible, including at Leuven University Hospital.

After performing an organ transplant, there is always a risk of the donor organ being rejected by the receiver's immune system. That is why doctors always look for the best possible match with an organ donor for transplant patients who are waiting for a new organ. Despite this, rejection still occurs quite frequently. In the case of kidney transplants, it happens in more than 30 percent of patients over a period of 10 years following the transplant. If the kidney is rejected, the patient needs to go back on dialysis, which has a huge impact on their quality of life – not to mention being very expensive for the healthcare services.

Therapy against rejection

That is why transplant patients are carefully monitored after receiving a new organ. This is done by means of biopsies, where a long needle is used to remove part of the organ tissue, which is then tested in the medical lab. If the tissue shows signs of rejection, additional immunosuppressive therapy is started up straight away. During the first year after their transplant, patients with a new kidney undergo two to three biopsies.

These biopsies are extremely unpleasant. Furthermore, the rejection symptoms are often already at an advanced stage when they are discovered, so therapy will make little difference and it will no longer be possible to save the kidney. For years, medical researchers have therefore been looking for an alternative method that is not only more comfortable for the patient, but can also detect so-called subclinical ('early') symptoms of rejection.

Panel of proteins

For the kidneys – which play a key role in the removal of waste products from our body – it would seem obvious for such a non-invasive test to use a patient's urine. That is why a group of European health and knowledge organisations set up a project in 2013 to develop a diagnostic test for this. VITO and Leuven University Hospital were also involved in this project, together with three transplant centres abroad. In the course of this Biomargin project (which was carried out under the European FP7 funding programme, the predecessor to Horizon 2020), the urine of transplant patients was analysed to search for proteins that could indicate kidney rejection. "In recent years, thousands of proteins were screened in this way," says Inge Mertens of VITO. "We did this both for transplant patients without complaints and for patients with complaints, distinguishing three types of rejection." The efforts paid off, as the researchers were able to identify no fewer than ten proteins that together provide a good indication of whether a kidney is being rejected – including in the subclinical phase. "This set of proteins gives us clear biomarkers for rejection, allowing to detect this subclinically by means of a simple urine test."

The Biomargin project ended in 2018. The test method has now been patented. VITO and its partners are currently working on the development of an initial prototype of a urine test that is just as quick and user-friendly as a pregnancy test. But is that not the task of the pharmaceutical industry? "We have noticed that the full development of the test is still too expensive for companies," says Mertens. "The annual number of kidney transplants is just too low for this (in Belgium, about 450 people receive a new kidney every year). It's now a matter of continuing the development of this new urine test in the initial phase, after which we can try and get businesses more interested."

Fast implementation in practice

But in the meantime, transplant surgeons are the ones asking for the test method to be introduced as soon as possible. This is also required to judge the value of the test better and to determine the extent to which it can replace invasive procedures like biopsies. As part of a follow-up process, the test will therefore (probably) be introduced soon by Gasthuisberg University Hospital in Leuven. "We are currently trying to find funding for this," says Maarten Naesens, a nephrologist and transplant surgeon at Leuven University Hospital. "The test may have been developed on a platform that is available in hospital labs, but it still needs to be translated into a routine protocol that we can use here."

According to Naesens, who participated in the Biomargin project, the best benefit of the test is the highly accurate determination of rejection – or more precisely: the lack of this. "If the results are negative, the risk of actual rejection is very low," says Naesens. "So we're hopeful that this will allow us to strongly reduce the number of biopsies." And the test works in two directions. "If subclinical indications for rejection are found, it will be possible to perform a biopsy at the right time."

"It's now a matter of making this urine test clinically available as soon as possible," says Inge Mertens. "We want to be able to quickly convert the scientific results (which will soon also be published in a professional journal) into a usable test. After that, we can get to the market introduction."

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A SUSTAINABLE ALTERNATIVE FOR COD TEST

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Together with two major manufacturers of test kits, VITO has introduced a greener analysis method for measuring chemical oxygen demand in wastewater. Flemish businesses can now contact VITO with questions, offering its role of independent facilitator between governments and industry.

The chemical oxygen demand (COD) is one of the oldest parameters used to determine water quality. Since the 1940s, this has been measured to see how much organic material is present in water. A significant part of organic pollutants (leaves, food residue, dead organisms, wastewater discharges, etc.) are broken down by microorganisms using oxygen. This causes the oxygen concentration to drop, putting fish and other aquatic life at risk. The COD indicates how much oxygen will be consumed if the wastewater is oxidised by this chemical process.

Prompted by REACH

The commonly used method to measure the COD has also been the same for decades and is based on an extensive test in which significant amounts of reagents are used. However, many of these reagents – like potassium dichromate, a chromium (VI) compound – are toxic and can even be carcinogenic. Furthermore, the reagents are only used once and are then disposed of. So the current method is everything but sustainable. Partly as a result of the stringent European REACH legislation, which strictly regulates the use of substances like potassium dichromate, both users and the industry have been searching for sustainable alternatives for quite some time. One of these users is the Flanders Environmental Agency (VMM). “We focus strongly on green chemistry, so we try and limit the use of hazardous substances as much as possible,” says Johan Annys of the VMM. “We do the same when analysing waste and surface water.”

Three years ago, VITO therefore joined forces with the German companies Merck and Hach (two major manufacturers of test kits). The aim: developing, testing and validating a sustainable alternative to the existing COD test, in particular for water with a chlorine concentration above 1,000 mg/l. “In the partnership with Merck and Hach, we played the role of reference laboratory,” says Christine Vanhoof of VITO. “We divided the assignment into two parts: one test for what is called the low COD measuring range and one for the high COD measuring range, which respectively have low and high chloride concentrations. This mainly involved reducing the amounts of reagents and eliminating the interference with substances such as chloride. This interference was a problem especially for water samples with high chloride levels.”

Small and practical test kit

For the low COD measuring range, the Merck and Hach labs managed to develop a sustainable test kit that required up to ten times less of the reagents than before. The kit is also much smaller, and therefore much more practical. “The traditional method – which we call the macro-method – is based on large equipment in labs,” says Vanhoof. “The new kit consists of tubes of only 20 millilitres.” The disruptive chloride interference could also be eliminated by adding very small amounts of mercury.

Both Merck and Hach developed a test kit for measuring low COD levels (less than 70 mg O_2/l) in waters with high chloride concentrations, but in the end the accredited laboratories only considered the Hach kit due to its user friendliness. Vanhoof: “This test kit also yielded the best time savings and was therefore the most efficient one.” The new test kit was then extensively tested by VITO and the VMM, during which a crystal-clear method and manual were also prepared.

The partners then started on the development of the alternative test for measuring high COD levels (above 70 mg O_2/l) in waters with high chloride concentrations. The newly developed kit also appeared to serve as a good basis here, so this test kit was also fully ready and validated a year later. “At that point the bulk of the work was done. The only thing we are still doing within this project is finalising the methodology.”

Another key advantage of the new COD test is that the reagents used are collected, so they no longer need to be processed as waste, creating an (almost) closed cycle. “We collect the used reagents at our lab in Düsseldorf,” says Carsten Schulz, Product Manager at Hach. “We are currently able to recycle and reuse 75 percent of the substances.”

Another advantage compared to the existing macro-method is that the new test method is largely automated. “Companies like Merck and Hach have developed robots to perform analyses,” says Kristof Tirez of VITO. “This was highly labour-intensive when using the existing macro-method.”

Proactively saving costs

The new COD test method for samples with high chloride levels has been introduced this year. The VMM will use it to check the quality of wastewater and surface water. “We’re actually already doing that,” says Johan Annys. “The test kits for samples with low chloride levels have already been available much longer.”

Tirez: “This parameter determines the Flemish discharge charges, which often run to thousands of euros for companies. So it is important that clear and reliable analysis methods are agreed with the accredited laboratories.”

To help the Flemish government as much as possible, but also Flemish companies, VITO has recorded the method for new test kits (in both the low and the high COD measuring ranges) in a compendium. And it doesn’t stop there: VITO also acts a point of contact, which is a role it performs as an independent expert on environmental testing. “Both governments and companies are welcome here if they have any questions or comments about the new tests,” says Vanhoof. “We want to keep supporting them, also now that the development of the tests is finished.”

At Hach they can look back with satisfaction on the partnership with VITO and the VMM, which was carried out based on the design thinking approach. “We collaborated on the basis of an iterative process: we created a prototype, after which

VITO and the VMM tested it and provided us with feedback, after which we improved our prototype. This allowed us to create a workflow in which all the problems were resolved by us and the tests were validated by VITO,” says Schulz.

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VITO ZOOMS IN ON **GLOBAL LAND COVER**

In just over a year it should be finished: the new land cover map that VITO is developing as part of ESA's WorldCover project. By improving the resolution from 100 to 10 metres, many more details will become visible, ensuring that the map will meet the requirements of its many users even better.

Every year, VITO creates a new land cover map with global coverage. It does this on behalf of the EU's Copernicus Earth Observation Programme, with the data being supplied by the European Space Agency, ESA. The resolution of these maps is 100 metres. As a result of this, large fields, forests and urban districts can be distinguished, but smaller agricultural parcels and individual trees, roads and buildings cannot.

However, in 2021 the resolution of the map will be increased tenfold, with pixels that match squares of 10 by 10 metres on the ground. VITO was tasked with developing this map by ESA within the scope of the WorldCover project, which runs for two years and finishes in September 2021. "This will allow us to see individual trees rather than forests, plus we will be able to distinguish the roofs of houses and buildings – all of this on a global scale," says Ruben Van De Kerchove of VITO. "The amount of detail will therefore increase massively, and processing all of this is a very big challenge."

Checking through human eyes

Even though the methodology of the data processing will largely remain the same, quite a few modifications are still required. The legend will have to be modified and the algorithms in complex environments (like cities) will have to recognise many more objects. "One example is a green roof: that should be marked on the map as a building, not as vegetation," says Van De Kerchove. "So the algorithms need to be properly trained." In collaboration with partners, VITO has marked out a total of 150,000 labelled points across the whole world for this. "Each point matches an area of 100 by 100 metres and is further subdivided into a hundred points of 10 by 10 metres. Each of these points is checked visually through human eyes."

The increased resolution also leads to a massive increase in the amount of data that needs to be processed. Until recently, VITO did this mainly using its own computer clusters, but the new map involves one hundred times as much data. "We're working with big data here; the amount of input data is around 2 to 3 petabytes. We process this in the cloud." This does come with a price tag, so VITO is trying to minimise the processing time. "This is a technical exercise in which we want to have our algorithms run as quickly as possible without loss of quality. Every second in the cloud costs money."

Update in real time

The data for the 10-metre map is supplied by the European Sentinel satellites. Sentinel-2 (which is actually a combination of two satellites) passes the same location above the earth's surface every five days. This will allow the land cover map to be updated almost in real time. The satellites also have a large range: they can photograph a strip 290 kilometres wide in a single image. Van De Kerchove: "So a country like Belgium can be almost fully covered by a single image, and this can be done every five days."

The Sentinel-1 satellites (which are also two) can help if areas are cloudy for prolonged periods of time. In contrast to Sentinel-2, which only takes pictures in the visible and infrared spectra, Sentinel-1 has an active sensor that essentially probes the earth's surface with radar waves. "This allows us, for example, to distinguish water from vegetation, and urban areas from rural areas – we do this based on the extent to which the waves are scattered and reflected. However, these radar images have quite a lot of noise, so we always combine them with the optical images from Sentinel-2."

In close consultation with users

Although the results of WorldCover will be publicly available, the map will be mainly used by international organisations. One example of these is UNCCD, the United Nations Convention to Combat Desertification. "Countries and organisations can use the WorldCover map to monitor themselves and others with regard to land cover – and they can check, for example, that soil degradation is not increasing."

The map is also a welcome tool for climate research, as well as for monitoring biodiversity and food security. As every user has its own wishes and priorities, VITO is developing the 10-metre map in close consultation with the users. "A climate modeller, for example, will benefit more from stable maps on which the details remain the same as much as possible, while a biodiversity researcher would want to zoom in on those details. We want to satisfy all of these requirements," explains Van De Kerchove.

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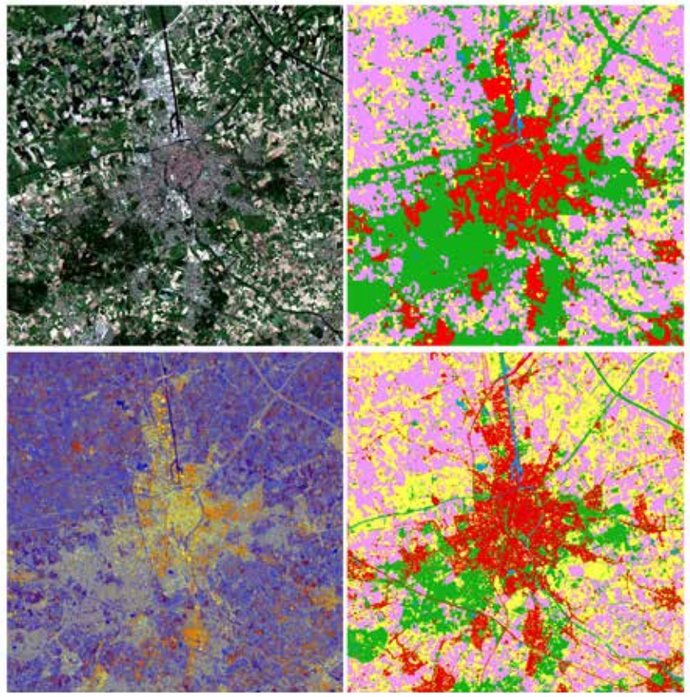
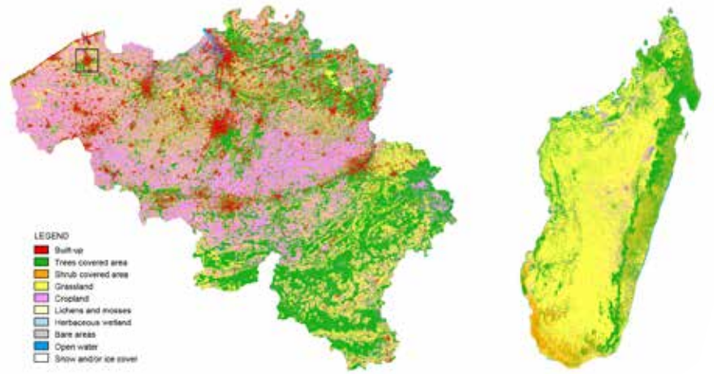


Sentinel 2 colour image (upper left), Sentinel-1 composite (bottom left), Copernicus 100m land cover map (upper right) and prototype Woldcover map at 10m (bottom right) of Bruges and surroundings



Prototype WorldCover land cover maps over Belgium and Madagascar

DISPLAY AS A SERVICE

VITO SHOWS THE WAY TOWARDS A **CIRCULAR BUSINESS MODELL**

More and more companies want to make their business processes – or at least part of them – more sustainable through a circular strategy. But that is easier said than done. VITO is offering a helping hand: by calculating concrete figures for the switchover to a circular business model, as well as the potential impact on the environment and climate. This allowed Q-lite to switch to a circular business model by renting out displays in the form of a comprehensive "service".

Increasing the sustainability of business processes is possible via various routes: companies can reduce the environmental and climate impact of their raw materials, they can make sure that their products last longer and that defects are easier to repair, or that they can be reused or can be easily disassembled and recycled at the end of their lifespan. Closing the cycles of (raw) materials as much as possible is what it's all about in the circular economy.

From products to services

But how does a company know if it has chosen the right circular strategy to suit its own specific business processes with the lowest environmental impact? Only the management itself can make that choice, as every business is different and this choice also impacts the business processes – from production processes to logistics and possibly even the very nature of the company. After all, running a circular business often means that companies start selling services instead of products, and that is a fundamental change for many companies.

Q-lite is such a company. The Belgian manufacturer of smart and sustainable display solutions (including LED displays) has largely reinvented itself as a service provider. In its circular "Display as a service" business model, Q-lite no longer sells displays, but rents them out for a period of 7 to 15 years. The customer pays an annual fee for this, but that includes installation, maintenance and even electricity. Furthermore, the customer is given the guarantee that the display can be upgraded during the period of use. After the end of the contract, the display is collected by Q-lite for reselling or recycling.

Analysed by VITO

Q-lite developed its circular business model with help from VITO, which has a lot of expertise regarding the link between sustainable innovation and economic added value. "We provide an insight into how a strategic choice towards a circular business model can be made," says Jeroen Gillabel of VITO. "For this we basically analyse the company first: which steps has it already taken itself, which products or services are eligible, what are the relevant circular strategies, etc."

In Q-lite's case, it was obvious from an environmental point of view that a longer lifespan could be an interesting option – which is often the case for electronics – with a possible focus on repair and remanufacturing. This came as no surprise to the company from Baarle-Hertog. "The circular model is nothing new to us," says Jeroen Raeijmaekers of Q-lite. "We already started using it a few years ago, mainly in the design phase of our displays. But we were wondering how we could extend the lifespan of our displays even more, and whether that would be a good strategy. And we wanted to know what we could gain from this in terms of sustainability. VITO was the right partner for this as well."

VITO not only indicated the right direction; they also calculated concrete figures for choosing a longer lifespan and a service instead of a retail model. Gillabel explains: "For this we used a calculation model we developed ourselves in which we can calculate economic and environmental parameters for various circular scenarios. We were able to identify that the service model indeed lowers greenhouse gas emissions and the use of materials when the duration of the contract is long enough. "On top of this, this quantitative approach allowed Q-lite to determine the right annual fee for the "Display as a service". And the company was made aware of the risks associated with this new business model. "After all, customers no longer pay the full amount in advance," says Raeijmaekers. "And what effect do factors such as raw material prices, recycling proceeds and fluctuating electricity prices have? VITO studied these kinds of matters for us, and they were integrated in the calculation tool. This allows us to make corrections later on."

Longer term

Will the new business model be a success? Raeijmaekers admits that his company is taking a risk. "Because of all the extra services, it starts out more expensive for customers, but in the longer term they can profit both financially and in the field of sustainability. We are confident that our customers will choose this option in the future. We're also early adopters: the trend of sustainable displays still needs to start really." It helps that Q-lite has many cities and municipalities among its customers. They often think in the longer term and are often also committed to concrete sustainability and environmental objectives – like the climate-related Covenant of Mayors.

The investment Q-lite made for the change in business processes was paid for by additional funding from the principal shareholder, VP Capital. The investor has a framework contract with VITO, in which projects are outsourced to make its companies more sustainable.

This kind of contract research is very useful for VITO to expand its expertise even more in the field of circular business, in particular to refine it based on concrete business processes. "In this way we will gradually evolve towards a more generic method and calculation tool, which in turn will allow us to further streamline this kind of work. But we still have a long way to go before we have a comprehensive tool that allows us to show any type of company the path towards a circular future," says Gillabel.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VITO EMPLOYEE **IN THE SPOTLIGHT**

Luca Scapino (30) has been working as a researcher for the Thermal Energy and Energy Markets group of VITO/ EnergyVille in Genk since October 2019. Before, he had already finished his PhD research there. "Energy has always been the main theme throughout my education and career." Fundamental research has always interested me, but I also want to stay close to economic and industrial reality. To me, VITO/EnergyVille is the perfect combination of academic work and business."

During your PhD research, you studied energy storage through 'thermal sorption' for four years. Can you explain what this means?

"There are various ways to store energy thermally (i.e. by means of heat). You can heat a medium like water and then remove the heat from it at a later stage. That is called sensible heat storage. Or you can use your energy to change the state of a substance (solid to liquid, for example); this process is reversible and is called latent heat storage.

A third form of thermal energy storage is sorption; that was the subject of my PhD. For this we use a reversible thermochemical reaction: we use heat to break a substance down into various components. By putting these components back together, the energy we put in earlier is returned to us. So as long as they remain separate, the energy remains stored. The advantage of the process is that thermal losses are small. The energy density is also high, which makes it suitable for practical and, for example, mobile solutions."

Are there any commercial applications yet?

"It is still too early for that, as the technology is now only available on a lab scale. But because of the minimal thermal losses, you could already start thinking of interesting applications like long-term heat storage. You could, for example, take the heat harvested by solar collectors during the summer and store it in your attic. That will allow you to heat your house during the winter.

It's exactly this potential that makes it worth the effort to evaluate the technology from the very start. At VITO/EnergyVille, we are used to assessing technologies – even at their earliest stages of development – on a system level within the evolving energy landscape." I performed a techno-economic assessment for a specific energy system. It showed that the integration of thermochemical storage could yield potential benefits of up to 40 percent. It should, however, be noted that many aspects are currently still unknown, like the actual costs of sorption agents."

You studied at Eindhoven University of Technology (TU/e), a relatively new partner within the PhD programme of VITO/ EnergyVille. What was the collaboration like?

"We matched straight away in terms of subject matter. Energy has always been the main theme throughout my education and career. For my Master's degree I studied Sustainable Energy Technology, and if you want to continue in that field you will come across VITO/ EnergyVille sooner or later. I didn't really view myself as an academic either. Fundamental research has always interested me, but I also want to stay close to economic and industrial reality. To me, VITO/EnergyVille is the perfect combination of academic work and business.

As usual I had promotors both at TU/e and at VITO/EnergyVille – two at each organisation, in fact. Initially things were a bit confusing with four supervisors, as it was not always clear who was responsible for which part of the PhD supervision. Fortunately, this problem resolved itself automatically. That division of roles may need some further clarification, as I'm already hearing that more students at TU/e want to do their PhDs at VITO/EnergyVille."

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