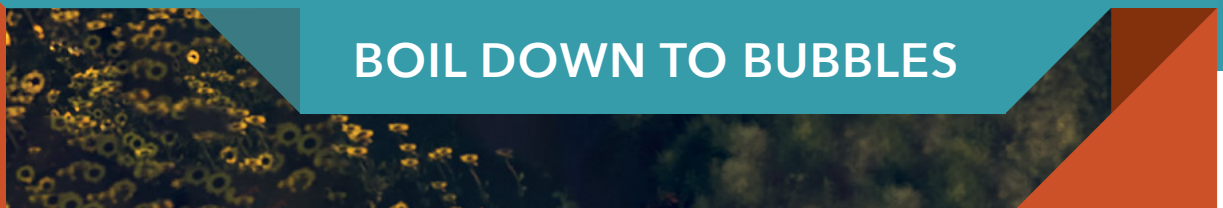
VOLUME 2 - JUNE 2023

TIME TO ENERGIZE

THE ROAD AHEAD

WHAT TO DO WITH CO_2

BOIL DOWN TO BUBBLES



EIRES
EINDHOVEN INSTITUTE FOR RENEWABLE ENERGY SYSTEMS

TU/e

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CREDITS *Time to Energize* is a publication of TU/e's research institute EIRES. The Eindhoven Institute for Renewable Energy Systems (EIRES) is TU/e's answer to the broad, multidisciplinary question that is the energy transition. EIRES enables a CO_2-neutral energy system by developing solutions that deliver the energy transition to people's homes in a manufacturable, scalable, and affordable way.
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WORD OF WELCOME

This new edition of the EIRES Magazine highlights many of the activities, achievements and developments of the past year that involved the EIRES community.

EIRES has just passed the 'midterm' of its first five year term. The EIRES management took this opportunity to evaluate the implementation of the original EIRES strategy. Overall the findings were positive: EIRES has gained a clear visibility within the energy community and managed to build a strong research portfolio, with many grants obtained by EIRES principal investigators.
Another important outcome was that we need to build stronger research communities within the larger EIRES community. As a result, we will relabel our focus areas, connecting them to larger-scale EIRES initiated research programs, such as BEHeaT. In addition to that, new faces will join the management team according to a newly established succession scheme.
I am convinced that the EIRES Strategy 2.0 will strengthen both our efforts of bringing together the excellent research on renewable energy systems across the departments, and of establishing tight relations with our external partners. I hope you enjoy reading this magazine, which contains many timely items to give you an impression of what we've been working on so far.

Richard van de Sanden
SCIENTIFIC DIRECTOR

ROOM FOR DEBATE ON THE ROAD AHEAD

EIRES acts as a unifying umbrella with over 150 researchers working on energy technology at TU/e. Although the common goal is clear, namely, to accelerate the energy transition, there is ample room for debate when it comes to exactly how to achieve that. Guided by Mark Boneschanscher, Managing Director of EIRES, Floor Alkemade, Professor of Economics and Governance of Technological Innovation, and David Smeulders, Professor of Energy Technology, discuss their personal views on what has to be done and by whom.

‘BEHAVIORAL CHANGE HOLDS GREAT POTENTIAL, WE SHOULD TAP INTO THAT’

FLOOR ALKEMADE

IS THE ENERGY TRANSITION A TECHNOLOGICAL OR A SOCIOECONOMIC CHALLENGE?

David Smeulders (DS): ‘Technology certainly is important, but you can’t have one without the other.’

Floor Alkemade (FA): ‘During the final months of 2022, we saw a huge reduction in the use of natural gas. Partly due to the rise in costs, but also as a result of conscious behavior. I am convinced that behavioral change holds great potential, and that we should tap into that. We are facing a tight deadline when it comes to climate change. So we cannot afford to wait for the best or most elegant technological solutions, but we simply have to go for what is available and possible now.’

DS: ‘Do not forget that a large share of the reduction in gas usage arose from partly shutting down industry. My biggest fear is that greening the economy comes down to impoverishment.’

FA: ‘I do understand that fear of causing an economic downturn. However, it is time to start reevaluating what types of industry we actually want and need to house as a country. Should we try to keep energy-intensive industry here or will these industries move to countries where renewable energy is available in abundance?’

DAVID SMEULDERS (L) AND FLOOR ALKEMADE (R)

DS: 'The last thing we should do is to scare away companies. We desperately need investment capacity to realize our climate ambitions. It is not up to politics to decide whether or not companies like Tata Steel, zinc factories or aluminum production facilities have a future in our country. It is up to the companies themselves. They should be welcome as long as they see opportunities to make a profit here. However, this should not prevent us from looking at things like carbon emission rights in a European context. Emission does not stop at the national borders.'
FA: 'To me, the discussion should focus on whether or not we should actively support companies to do things that are not profitable here with the current energy prices. I do not plea for an active policy of chasing them away, but in my opinion, energy costs should reflect the environmental costs, and subsidies and support should only go to activities that accelerate the energy transition.'

DS: 'I am against taxing the use of energy. It is the emissions we should make more expensive. The world as a whole needs to increase its energy consumption to relieve poverty. But we have to find ways to do so without increasing the amount of CO_2 in the air. That is the challenge.'
FA: 'To me, it is a no-brainer that we should not facilitate polluting activities in our country. The question we should ask ourselves is: What industries do we want here, and how can we attract and retain those?'
DS: 'In such a debate, emotions tend to take over. Take the NAM. We have come to a point where people who work there are held personally accountable for the earthquakes in Groningen. And Shell employees are all considered to be environmental criminals.'

SHOULD UNIVERSITIES COLLABORATE WITH SHELL, AND IF SO, UNDER WHAT CONDITIONS?

FA: 'Recently, I took part in a PhD committee in Norway. The PhD researcher concluded that there is a large overlap in the knowledge base when it comes to fossil fuels and offshore wind. We can already see that finding appropriately qualified personnel will be the bottleneck for the energy transition. It doesn't help to frame the people who are currently working on fossils as the bad guys. We simply need their knowledge to be able to make the transition.'
DS: 'For once, I fully agree. To me, the transition should be an inclusive one. That means we also need to invite the fossil fuel companies. Think about it this way: if they only invest a small percentage of their budgets in the transition, that still is a huge amount of money.'

WHAT IS YOUR ADVICE FOR EIRES?

DS: 'Listen to the region. Brainport is known for its short lines of communication between academia and industry. Ask industry how they see our role. And negotiate for them to fund a number of PhD researchers dedicated to fundamental energy research.'

'I AM AGAINST TAXING THE USE OF ENERGY. IT IS THE EMISSIONS WE SHOULD MAKE MORE EXPENSIVE.'

DAVID SMEULDERS

FA: 'We should help our stakeholders unlock academic knowledge on the subject. In my group, we collaborate a lot with public parties, such as local governments and network operators. They have trouble translating the available scientific knowledge to their daily practice.'
DS: 'A worrying development is that domain-specific expertise is becoming rare among civil servants. Most officials are generalists, not specialists. We need a National Planning Agency for Energy that can act as a natural point of contact for universities. We already see this collaborative planning when it comes to the hydrogen agenda, for example with GroenvermogenNL.'

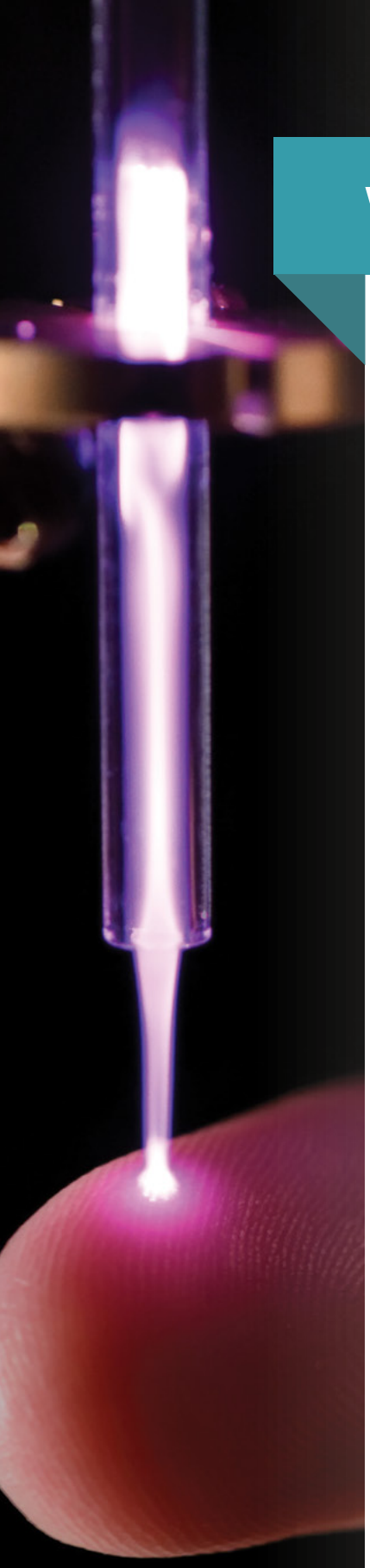
WHAT IS YOUR HOPE FOR THE FUTURE?

DS: 'We should focus on socio-techno-economic solutions. And despite all of the challenges I see, I am positive we will make the energy transition happen.'
FA: 'I am also optimistic this can be solved. However, I am worried about the pace: will we be fast enough? There is urgency, there are agreements, there is technology. And still, we do not act.'
DS: 'In this country we are way too hooked up on procedures.'
FA: 'And we do not look ahead. What we need are adaptive policies. Make a plan: when we reach this amount of electric cars, we will scale up the infrastructure this way.'

DS: 'In 2008, the Netherlands Scientific Council for Government Policy warned that we needed to invest in our electricity grids in order to guarantee grid stability with an increasing supply of renewables. And in 2013, Minister of Economic Affairs Henk Kamp repeated this message when he urged the Authority for Consumers & Markets not to steer on costs, but to invest in the grid. The greatest threat for the energy transition is the fear of not doing the right thing, and as a result of that fear, deciding to do nothing at all.'
FA: 'Whatever we can do now, we should do. Even if it is not the best or the cheapest solution. Every step in the right way is a step we should take. And not tomorrow, but today.'

EIRES IN A NUTSHELL

The Eindhoven Institute for Renewable Energy Systems (in short: EIRES) stimulates and develops interdisciplinary research in the field of energy conversion and storage in close connection with industry. EIRES acts as a platform and a one-stop-shop for energy related research at TU/e, and takes up a steering role in developing and expressing thought leadership in the (inter)national debate on the energy transition.



WHAT TO DO WITH CO_2

In an attempt to reduce the amount of CO_2 in the air, scientists all over the world are looking for possibilities to turn the waste molecule into feedstock. EIRES researchers Ana Sobota and Fernanda Neira D'Angelo talk about their projects to break down the molecule, and use it to build useful chemical compounds.

'Converting carbon dioxide is far from easy. It is a fully oxidized molecule, which has no heat value or functionality whatsoever. It is what we call a low value molecule, meaning that you need to introduce a lot of energy to be able to do anything useful with it. One of the biggest challenges in CO_2 conversion therefore is to develop environmentally advantageous and economically competitive technologies,' says chemical engineer Fernanda Neira D'Angelo, who coordinates the TU/e's reactor design efforts in the four-year European project C2FUEL.

POKING WITH PLASMAS

One of the options under consideration, is to use so-called non-thermal plasmas to break down the CO_2 molecule, explains physicist Ana Sobota. The term non-thermal plasma refers to an electrically charged state of matter where the heavy ions are about room temperature, and the electrons contain a lot of energy. Through collisions with these 'hot' electrons, the CO_2 molecules start to vibrate. When the vibration is strong enough, the bonds between the individual atoms making up the molecule will break. 'To split CO_2 in a single step requires a lot of energy. With a plasma, instead of hitting it with a hammer, you poke it a little bit, but over and over again. The molecule accumulates the energy from all of the pokes, until eventually it breaks.'

Sobota is involved in the PIONEER project, which studies three topics: the fundamentals and mechanisms of CO_2 plasmas, advanced catalysis for CO_2 activation, and innovative routes for plasma catalyst interaction. Sobota's PhD student Harry Philpott focuses on the interaction between the plasma and the catalyst. 'One of the challenges is that conventional chemistry does not use electric fields, while in plasmas, electric fields are exceptionally high. So the first thing we need to know is how high these fields are exactly as the plasma comes into contact with the surface of the catalyst.'

ANA SOBOTA (L) AND FERNANDA NEIRA D'ANGELO (R)

EXPLORING EDGES

Plasma catalysis is a rather new field, Sobota explains. 'That means that everyone is working at the edge of their discipline, trying to answer fundamental questions like What happens when a plasma meets a catalyst? What reaction rates can we expect under plasma conditions? What is the optimal combination between plasma, catalyst and reactor type?' Over the past decade Sobota has been working on methods to measure the interaction between plasmas and a variety of materials. 'What once started with rather simple perfect dielectrics, now culminated in this project in studying catalysts, which are very complex molecules. I am very happy that we were able to develop a method to actually measure these electric fields at the relevant interfaces.'

'TO SPLIT CO_2 IN A SINGLE STEP REQUIRES A LOT OF ENERGY'

ANA SOBOTA

Where the PIONEER project focuses on the fundamentals, the C2FUEL project Neira D'Angelo is engaged in, has a slightly different focus. 'C2FUEL is led by ENGIE, a French energy company dedicated to the energy transition,' she tells. The aim is to develop energy-efficient, economically and environmentally viable CO_2 conversion technologies which are to be demonstrated at Dunkirk between a DK6 combined cycle power plant, the Arcelor Mittal steel factory and one of the major European harbors. The idea is to selectively remove the carbon dioxide present in the blast furnace flue gas and combine it with green hydrogen generated by electrolysis fed with renewable electricity to produce two promising energy carriers.

'The aim of the C2FUEL project is to produce both formic acid and dimethyl ether,' Neira D'Angelo explains. Dimethyl ether is already known as an alternative diesel-like fuel for trucks and ships. Formic acid is a promising substance to carry hydrogen, which can be used as a fuel as well. Now, the focus is on scaling up the production of dimethyl ether.

▸▸ CONTINUED ON NEXT PAGE

REMOVE WATER

In terms of reactor design, which is the part of the project TU/e is responsible for, one of the biggest challenges is that the chemical reaction is thermodynamically limited. 'During the reaction a lot of water is produced, which deactivates the catalyst and limits the conversion. Therefore we had to come up with solutions to remove the water from the reaction,' Neira D'Angelo says. That is easier said than done, the chemical engineer explains. 'For this specific application, a membrane reactor is the most suitable candidate. However, if you use an ordinary membrane, chances are that hydrogen will also go through.'

'TECHNOLOGY IS NOT THE MAJOR BOTTLENECK WHEN IT COMES TO USING CO_2 AS A FEEDSTOCK FOR FUELS'

FERNANDA NEIRA D'ANGELO

Eventually, together with project partner Tecnalia, TU/e researchers developed a stable membrane that is selective for water only. 'We have tested our membranes first at lab scale to see what would be the optimal composition, how to produce them at larger scale, and how their performance is affected by different reaction cycles. Project partner Tecnalia has then produced the membranes at the required scales.' Though the true proof of the pudding will be in the eating, Neira D'Angelo is confident that the final reactor will do what it is supposed to do. 'Currently we are building a scaled up version of our lab-scale reactor in a container, which will be shipped to Dunkirk later this year.'

SOLVING BOTTLENECKS

When looking at the energy transition in a broader sense, one of the most uplifting characteristics of the C2FUEL-project is that the technology that has been developed is not process specific, and thus can also be of use for other applications. 'All in all, I think technology is not the major bottleneck when it comes to using CO_2 as a feedstock for fuels. Of course, there are still some technical issues to solve, but we have shown already that this is feasible. The biggest problem is the economic side of things. One of the main tasks I see for us as researchers is to develop solutions with increased performance to drastically reduce costs.'

Sharing knowledge and expertise is key to accelerate the developments, both scientists think. Sobota: 'To me, perhaps the nicest thing coming from the PIONEER project is a database that will be online soon, which provides a comprehensive overview of where we have looked and what we have found. These data are open for scrutiny by other researchers, potential partners and the scientific and regulatory communities. The aim is to not only help them get an idea of where to look and what to expect with certain set ups, but also what doesn't work. Since the latter seldomly ends up in publications, I think that is an extremely useful addition to advance the field.'

More information:
c2fuel-project.eu
co2pioneer.eu

CREATING VALUE FROM CARBON DIOXIDE

EIRES researchers are working on a variety of subjects in order to convert CO_2 into valuable chemical compounds or fuels. TU/e is widely known for its strong expertise in the development of efficient catalytic processes and membrane gas separation concepts, and for its exploratory research to enhance chemical conversion processes by electricity.

SHAPING THE ELECTRICITY GRID

With the increasing amount of renewable energy being generated and the concurrent transition to electrified transport, research into energy conversion is vital to ensure the reliable, robust, and stable performance of our electricity grid. TU/e's cross-departmental Eindhoven Grid Laboratory strengthens this research.

'Our initial mission is to cover electrical grid-connected power converters. In addition to that, we have a branch focusing on green hydrogen, where we will study electricity-to gas-to-electricity systems, in which hydrogen is used for temporary energy storage. Later on, we also plan to include other topics, like High Precision High Voltage,' lab manager Paulo Torri from the Department of Electrical Engineering explains.

A multitude of research questions can be addressed in the lab, ranging from when, where and how to convert high voltage to medium voltage, to how to introduce hydrogen electrolyzers to the grid for balancing peak loads and demands.
The Eindhoven Grid Laboratory enables a systems approach, where academics and industry can jointly develop and test power systems, highly efficient energy conversion solutions, and grid concepts.

MEDIUM VOLTAGE GRID

The primary focus is the medium voltage level of the power grid. High voltage power lines are used to transport energy over large distances with minimal losses. The medium voltage level, ranging from about 10 to 35 kilovolts, is used to deliver electricity inside the city and from city to city. For this power range, the energy conversion and control are mainly based on conventional equipment. But with the introduction of intermittent solar and wind energy and the increasing amount of electric vehicles that need to be charged, there is an urgent need to rethink the design of this medium voltage power grid.

Simulations alone are not sufficient for this, Torri says. 'To ensure novel concepts and systems will be embraced and eventually implemented by utility companies, we must be able to do actual experiments in a lab.'

More information: tinyurl.com/TUeEGL

NEWS OVERVIEW
GOING PUBLIC

'THE NETHERLANDS HAS SET AMBITIOUS GOALS FOR THE CLIMATE. BUT AT THE SAME TIME, WE KEEP INVESTING IN FOSSILS ON A LARGE SCALE. THAT IS NOT EFFICIENT, EXPENSIVE, AND IT SLOWS DOWN THE TRANSITION.'

Pieter Pauw on Dutch climate policy, EenVandaag, October 28, 2022

'IN THE NETHERLANDS, WE ARE PUTTING TOO MANY EGGS IN THE SAME BASKET. WE REALLY CAN'T WAIT UNTIL EVERYTHING IS ELECTRIFIED.'

Bart Somers on why the combustion engine does have a sustainable future, podcast Science is here, August 4, 2022

'WE SHOULDN'T DREAM ABOUT GAME CHANGERS THAT WILL MAKE US CO_2-NEUTRAL TOWARD 2050. INSTEAD, WE SHOULD BRING INNOVATIONS THAT ARE CURRENTLY UNDER DEVELOPMENT TO THE MARKET AS FAST AS POSSIBLE.'

Mark Boneschanscher, Storage Magazine, December 2022

'WE SHOULDN'T OVER-INSULATE AND THEN HAVE TO BUY AN AIR CONDITIONER IN THE SUMMER, OR DON'T INSULATE ENOUGH AND END UP FEELING COLD IN THE WINTER.'

Lisanne Havinga on smart sustainable renovation, Brainport Eindhoven Home Of Pioneers, May 18, 2022

DOING BETTER WITH BATTERIES

Erik Nijkamp and Paul Volčokas from TU/e's Team Better/e aim to pave the way for ecofriendly, cost-effective batteries able to power entire cities in times of insufficient supply of renewable energy.

The fact that the current generation of TU/e students, more than ever, is driven by societal challenges, is well-illustrated by the dozens of student teams the university harbors. Erik Nijkamp and Paul Volčokas from Team Better/e, a student team that started in the midst of the pandemic, share their plans and ambitions.

UPSCALING REDOX FLOW BATTERIES

The students work on redox flow batteries. Due to problems with the required membranes, redox flow batteries have only been considered a realistic probability for small-scale applications. But in recent years, membrane technology has significantly improved. Nijkamp: 'We are convinced that redox flow battery technology can also be made ready for large-scale applications. We want to accelerate this development by advancing this technology to such a level that others are interested in stepping in and taking over.'

Nijkamp: 'One of the chemical challenges we will have to tackle is how to fight the hydrogen evolution reaction that occurs when hydrogen gas is formed. Another problem we must solve is that sometimes solid iron is formed, leading to slurry in our tanks.' 'What's worse, that solid iron can form dendrites, which puncture our membrane and cause safety issues,' Volčokas adds.

'WE ARE CONVINCED THAT REDOX FLOW BATTERY TECHNOLOGY CAN BE MADE READY FOR LARGE-SCALE APPLICATIONS'

ERIK NIJKAMP

POWERING A BUILDING

The team's first aim is to demonstrate that their idea works on a single-cell level. Volčokas: 'When we've achieved that, we will build a small-scale demonstrator for Eindhoven Airport to show the public what we are working on. And then the next step is to develop our single cell into a stack of cells.' Nijkamp: 'I like to dream big. It would be great if Team Better/e could build a battery that can power an entire building on campus.'

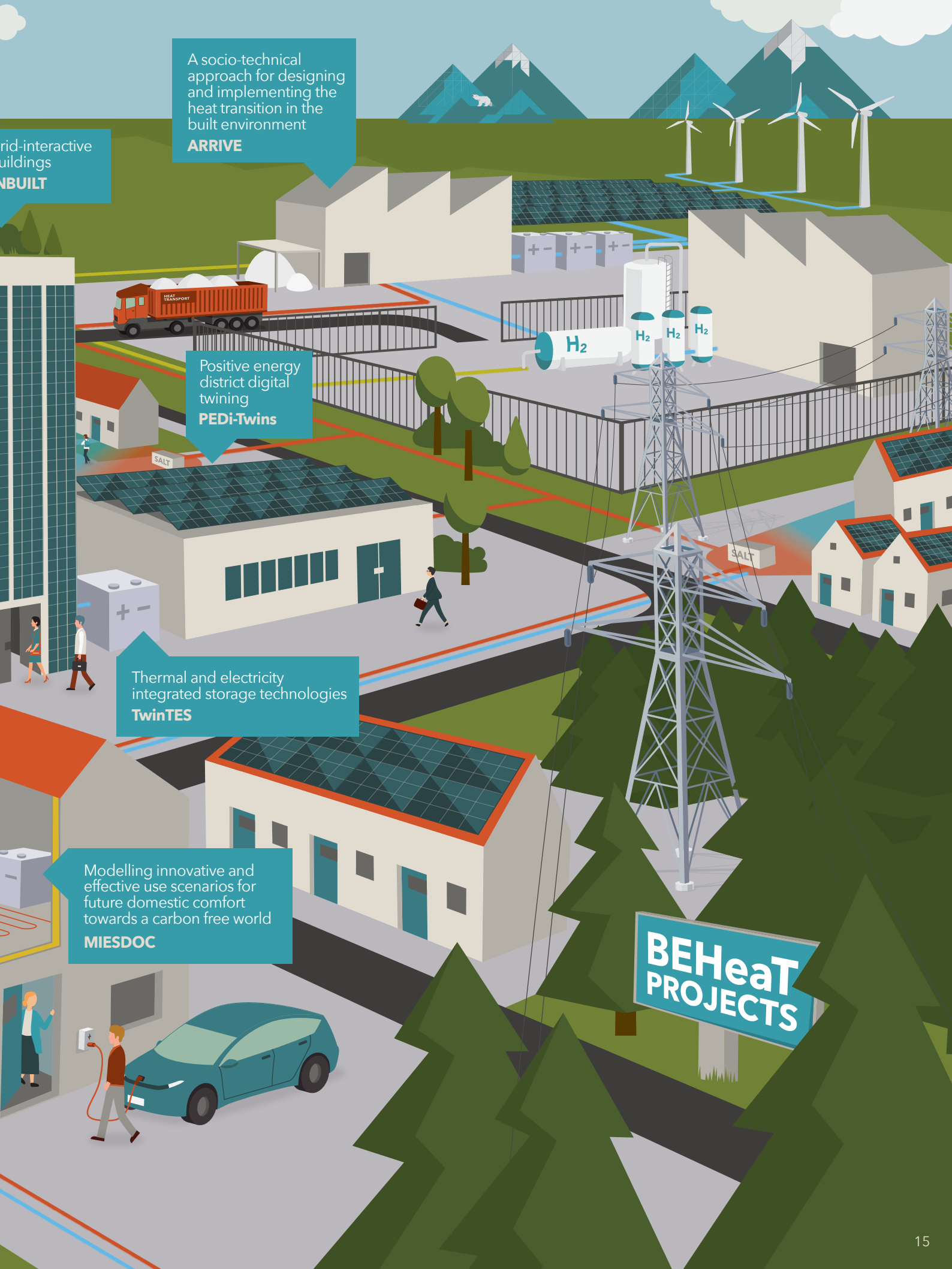
More information: www.teambettere.com

PAUL VOLČOKAS (TOP) AND ERIK NIJKAMP (BOTTOM)

BEHeaT PROGRAM

EIRES launched its first, dedicated, large-scale, long-term research program called BEHeaT (Built Environment Heat Transition) and granted the first nine projects on the heat transition in the built environment.

www.tue.nl/eires/beheat


A socio-technical approach for designing and implementing the heat transition in the built environment
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Positive energy district digital twining
PEDi-Twins
Thermal and electricity integrated storage technologies
TwinTES
Modelling innovative and effective use scenarios for future domestic comfort towards a carbon free world
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THE DUTCH ELECTROLYZER:

BOILING DOWN TO BUBBLES

With its 'Dutch Electrolyzer,' EIRES wants to demonstrate what is needed to accelerate the energy transition. Bert Vreman, research professional at Nobian and part-time professor at the Power & Flow group of TU/e's Department of Mechanical Engineering, explains the mechanical engineering challenges associated with realizing cost-effective, industrial-scale electrolysis for green hydrogen production.

Bert Vreman starts by debunking a common misconception: 'Industrial-scale electrolyzers producing hydrogen already exist; that is not what's new here.' Large-scale electrolyzers are commonly used to produce caustic soda, chlorine, and hydrogen from sodium chloride solutions. Still, implementing electrolyzers that are able to produce green hydrogen from water at a large scale is far from simple. The keywords here are efficiency and cost-effectiveness since, at the moment, producing hydrogen from natural gas is still cheaper than through water electrolysis.

SIMPLE IN THEORY, HARD IN PRACTICE

The idea of producing hydrogen via water electrolysis is simple: Dip two conductive metal strips in an electrolyte solution and apply a voltage to them. One of the electrodes attracts positive ions; there gaseous hydrogen is formed. The other does the same with the negative ions, leading to oxygen formation. Collect the hydrogen-containing gas bubbles and you're done. But at the moment, this process cannot compete with natural gas-based hydrogen production.
One of the problems is that the materials currently used for the electrodes and catalysts are too expensive, and too rare. Research within the EIRES focus area Chemistry for Sustainable Energy Systems therefore focuses on designing and engineering cost-effective materials to replace expensive metals and compounds such as platinum and iridium oxide.

Another problem is that the electrolysis process is not as effective as it could be in theory. That is where the EIRES focus area Engineering for Sustainable Energy Systems comes in. 'We are concentrating on improving the efficiency of the process,' Vreman states. The gaseous bubbles formed play an important role here, since if the liquid electrolyte contains bubbles, the electric current cannot pass through it as easily. But these bubbles are largely terra incognita; many fundamental questions are still open, Vreman explains. 'How are they formed? How do they move along the electrode? What determines how long they will stick to the electrode, blocking its surface and effectively decreasing its activity? How large do they get, and how do they influence the liquid flow behavior?'

'THESE BUBBLES ARE LARGELY TERRA INCOGNITA; MANY FUNDAMENTAL QUESTIONS ARE STILL OPEN'

BERT VREMAN

IMPOSSIBLE TO SEE

What complicates the research tremendously, is that it is impossible to put a camera on the electrolyzer and observe what happens, Vreman says. 'The bubbles are too small, and there are too many of them. With optical methods, you don't see a thing in electrolyzers with macro electrodes at high current density.' That is why the scientists use experiments with small-scale simplified systems and simulations based on physical and chemical models to get an idea of what happens.
'One of the properties we need to study is the coalescence behavior of the bubbles,' Vreman says, 'so how, when and where several individual bubbles melt together to form a bigger bubble. To be able to model this behavior, we need to know the chemical properties of the electrolyte in the vicinity of the bubbles and the electrical charges on the bubble surface. But these also cannot be measured directly.' Besides the problem of the lack of experimental data, building realistic bubble models is also complicated because of the interconnectedness of the multitude of parameters that influence the formation and behavior of the bubble. 'Think of the contact angle between the bubble and the electrode, the material and geometric properties of the electrode, the chemical composition of the electrolyte and the bubbles, the coalescence, the gas fraction, the effect of temperature, the effect of high pressure …'

So where to start when you want to untangle such a tight and complex knot? 'We took an experiment from literature where the gas fraction could be measured and tried to reproduce that with our simulations. And to gain some experimental data, we experiment with small-scale, single bubble set-ups. In addition, together with TU Dresden, we are currently looking into the possibility of micro-CT imaging technology to get a visual on the bubbles after all.'

'UNDERSTANDING BUBBLE BEHAVIOR IS A MULTIDISCIPLINARY ENDEAVOR PAR EXCELLENCE'

BERT VREEMAN

MULTIDISCIPLINARY COLLABORATIONS

Understanding bubble behavior is a multidisciplinary endeavor par excellence, says Vreman. 'Within TU/e, there is a close collaboration between the Mechanical Engineering and Chemical Engineering and Chemistry departments. Take the Alkaliboost project, which is a collaboration between TU/e Mechanical Engineering, Chemical Engineering and HyCC (Hydrogen Chemistry Company). Another collaboration is the Bubblelectric project, which is carried out by a consortium consisting of TU/e, TU Delft, University of Twente, Shell, Nouryon and Nobian.'

Studying bubbles is a particularly tough area of research, Vreman says. 'We only take little steps at a time. And to be frank: After the efficiency gain due to the application of zero gap technology (in which the electrodes are pressed onto the membrane in between), we are not sure how much there is still to gain in terms of efficiency by understanding and controlling the bubble dynamics. And suppose we were able to significantly improve the efficiency by removing bubbles faster by increasing the liquid circulation through the electrolyzer, but we would need a large and expensive separator to extract the hydrogen, then we might not gain anything.'

Still, Vreman thinks there are good reasons to keep investing in this type of research. 'Bubble dynamics is a very interesting phenomenon for many more applications than water electrolysis alone. It also plays a role in brine electrolysis, lithium chloride electrolysis, boiling and evaporation processes, or bubble column reactors. By the way, what many people do not realize is that green hydrogen production via electrolysis is not just the future, it is also today: in the industrial process to produce caustic soda and chlorine, we also make hydrogen. So when we use electricity from renewable sources to power that process, we are producing green hydrogen already.'

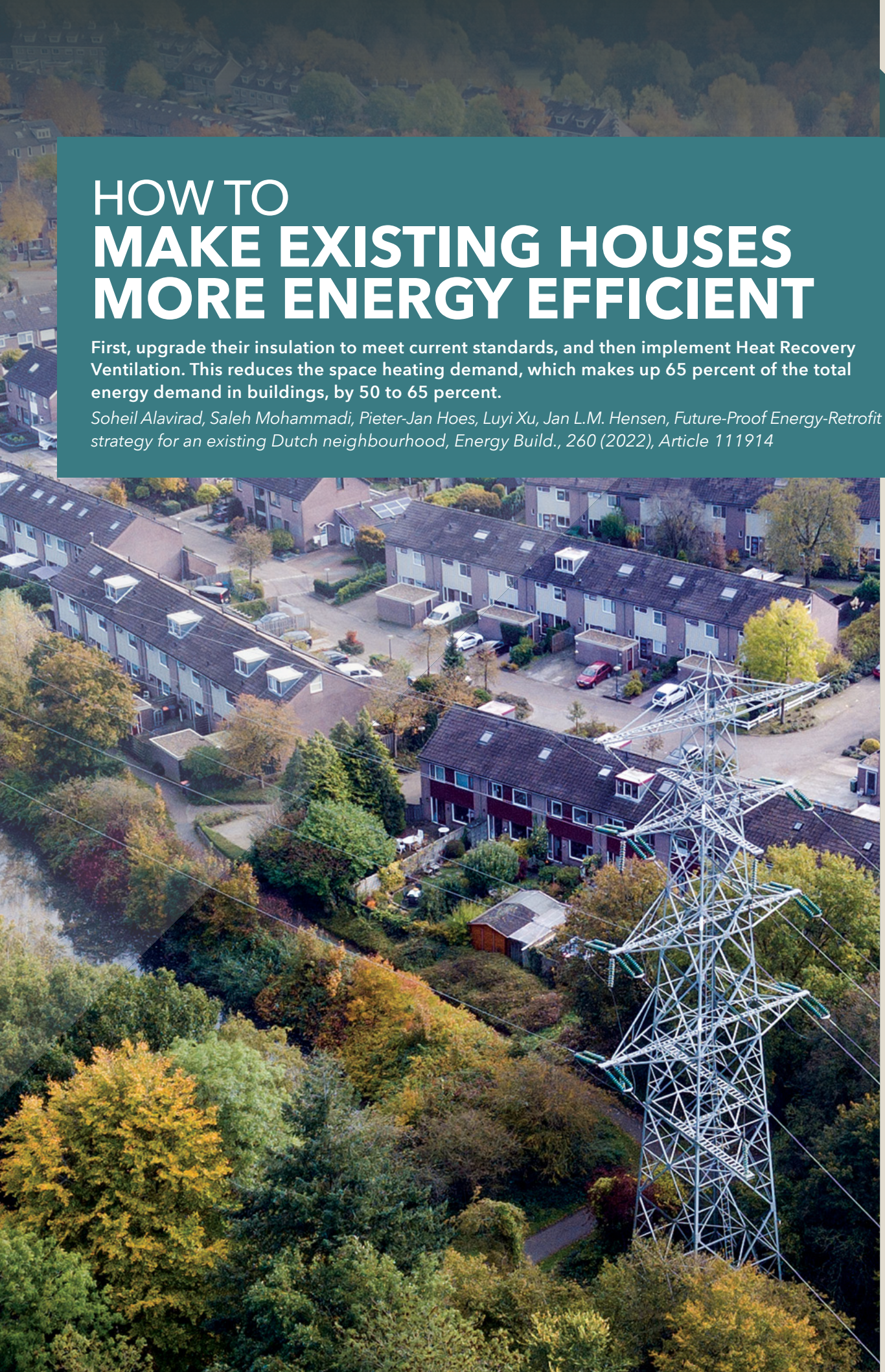
DUTCH ELECTROLYZER

With the Dutch Electrolyzer as an iconic project, EIRES wants to connect basic research in the fields of electrochemical reactor engineering, electrocatalysis, electricity conversion, and process systems engineering at TU/e to the Brainport high-tech industry. The aim is to learn step-by-step how to upscale a commercially viable, renewable electricity-fed, hydrogen-producing electrolyzer to a megawatt scale. Hydrogen is not only important as a basic fuel to re-generate electricity through fuel cells, but it also is a major building block for the chemical industry.

HOW TO
MAKE EXISTING HOUSES MORE ENERGY EFFICIENT

First, upgrade their insulation to meet current standards, and then implement Heat Recovery Ventilation. This reduces the space heating demand, which makes up 65 percent of the total energy demand in buildings, by 50 to 65 percent.

Soheil Alavirad, Saleh Mohammadi, Pieter-Jan Hoes, Luyi Xu, Jan L.M. Hensen, Future-Proof Energy-Retrofit strategy for an existing Dutch neighbourhood, Energy Build., 260 (2022), Article 111914



HOOKED ON THE GREATNESS OF SMALL THINGS

As a kid she wanted to be an astronaut, exploring the greatest of objects and the largest of distances. But during her studies, she got hooked on the smallest of things instead. At TU/e's Energy Technology group, Azahara Luna Triguero puts her personal motto 'Small things matter' into practice.

Originally, Azahara Luna Triguero decided to study physics, since 'that could lead me to the stars.' Instead, she became fascinated by the physics of atoms and molecules and obtained her PhD on the topic of nanoscale materials for energy applications. 'In the field of energy technology, I can really make a difference.'

In September 2020, she joined TU/e, where she wants to help industry find new materials crucial to making the energy transition happen. To this end, she studies physical and chemical properties of porous crystalline materials with the aid of classical molecular simulation techniques. Her main research interests are the adsorption-based capture and purification of valuable chemicals and adsorption-based thermochemical energy storage.

FINDING NEW MATERIALS

'In my first line of research, I look at fluids that can be used as new refrigerants and are more energy efficient and less toxic than the current refrigerants, which are mostly based on hydrofluorocarbons,' she explains. 'I want to predict the thermophysical and thermodynamical properties of fluid mixtures under specific application conditions to develop guidelines for finding new refrigerants.'

Her second line of research is aimed at materials for hydrogen storage and purification. The idea is to chemically modify material structures to store more hydrogen in less volume, at lower pressures, and without cryogenic cooling. 'We want the solutions we come up with to be plausible, so we start from existing crystalline materials and modify them to achieve the desired behavior.'

'WE MODIFY EXISTING CRYSTALLINE MATERIALS TO ACHIEVE THE DESIRED BEHAVIOR'

AZAHARA LUNA TRIGUERO

Through her educational activities, the ambitious scientist broadens her impact.
'I am coordinating a course aimed at lifelong learning. Researchers and lecturers engage with municipalities and industries to exchange the latest insights and viewpoints concerning energy technology in a broad sense. So we not only have engineers and natural scientists, but we also have people from law, social sciences, and communications involved.'

GERARD DE LEEDE (SECOND FROM THE RIGHT)

SUNNY FUTURE FOR SOLARGE

Start-up company Solarge has a fresh take on solar energy: 'With our lightweight, sustainable panels, we open up entirely new markets,' states CTO Gerard de Leede with conviction.

Solarge arose from a collaboration between Heijmans, SABIC and Solliance. The idea was to develop solar panels based on plastic composites instead of on glass. The company recently opened its first full-fledged production facility.

The innovative aspect of Solarge's solar panels is the packaging of the PV cells, De Leede explains. 'The PV cells we are using are just off-the-shelf cells, which are also used for conventional panels. But by replacing the glass with glass fibers and a layer of polymer composites, we have reduced the panels' weight by some fifty percent.' And that has major advantages, he explains. 'In the Netherlands, some sixty percent of the roofs are not suited for current solar technology, since the panels are too heavy. With our lightweight alternatives, we open up new markets, such as applications on barn roofs, or on the sides of trailers or buses.'

MORE ENVIRONMENTALLY FRIENDLY

And the weight reduction is not all. 'A second major added value of our technology is that it drastically reduces the carbon footprint of solar energy.' Current conventional panels take up to three to four years to compensate for the carbon emitted during production. With Solarge's panels, this is reduced to three to four months. 'Another problem we tackle is that of the waste associated with solar panels. Our panels are produced in a circular way; all of the components can be reused. And finally, our panels are entirely PFAS-free.'

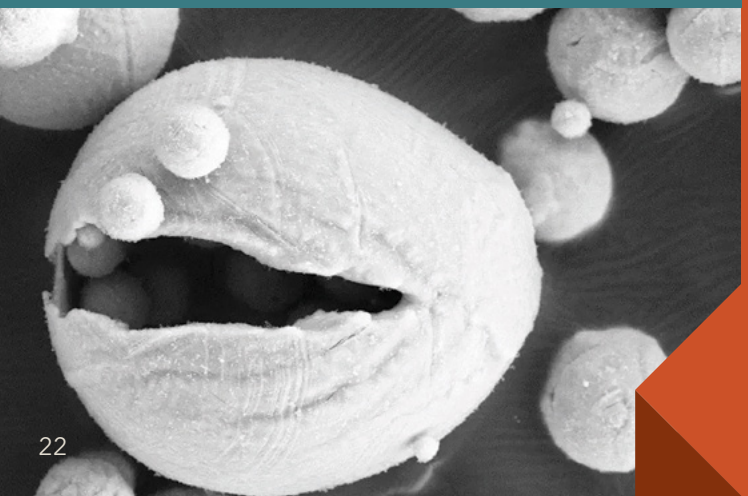
Overall, De Leede is convinced that with their unique product, Solarge has a good chance of success. 'Besides all of the merits of our product, the current geopolitical developments encourage us to think that now is the time to bring back solar manufacturing to the Netherlands. When it comes to energy, we are way too dependent on a handful of countries. Europe should regain power, and keep sustainable energy production in its own hands.'

More information: solarge.com/en

NEWS & EVENTS

FRUITFUL EIRES ENERGIZING DAY

On Friday, July 1, 2022, EIRES welcomed some 175 participants to its first Energizing Day. The program opened with an extensive overview of the EIRES strategy, research landscape, and progress made over the past two years. Next, four internationally renowned speakers informed the audience on the latest developments in energy-related research. After the closing interactive panel discussion that touched upon what should be done next, the energized participants had enough to talk about over closing drinks.



OPENING ZERO EMISSION LABORATORY

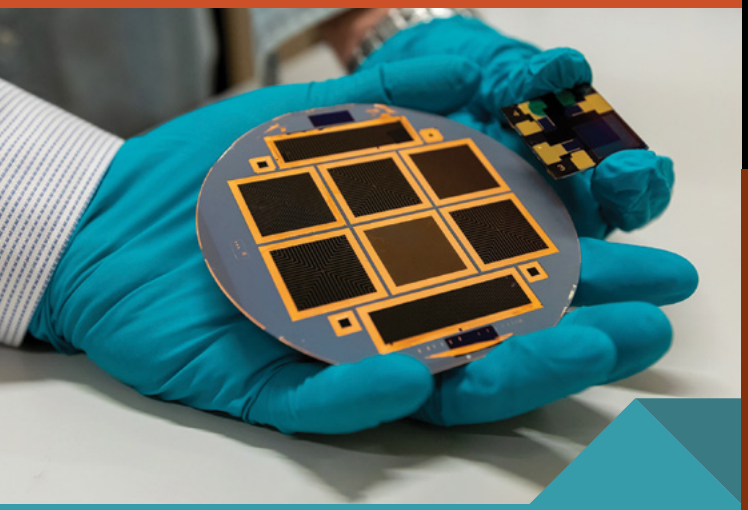
In September 2022, the recently renovated Zero Emission Lab (ZELab) was opened. The ZELab is an internationally leading lab that aims to investigate zero-impact internal combustion engines (ICEs), and contains eight engine test cells and state-of-the-art experimental set-ups. In the foreseeable future, internal combustion engines will remain the dominant option for heavy-duty transport, given that electrification is simply not yet an option for long-haul vehicles such as ships or trucks. Therefore, the combination of ultra-efficient ICEs and renewable fuels is critical to accelerating the reduction of greenhouse gas emissions, which is the main focus of the ZELab.

IRON AS ENERGY CARRIER

Scientists from the Max-Planck-Institut für Eisenforschung (MPIE) and TU/e proved that iron can be used for energy storage and described which parameters determine the efficiency of the storage and reuse. The researchers focused on the characterization of the iron powders after reduction and combustion using advanced microscopy and simulation methods to analyze the powder purity, morphology, porosity, and the thermodynamics of the combustion process. Future studies will now analyze how to increase the circularity of the process, as the size of some combusted particles is decreased compared to their original size due to partial iron evaporation, micro-explosions, and/or fracture of some iron oxide particles.

ENERGYDAYS ON DECISIONMAKING

On October 6, 2022, EIRES organized EnergyDays, a quarterly event at which speakers from a range of perspectives discuss energy. Under the theme 'Decision-making in times of climate change,' two academics, a rising talent, a politician and a representative from the service sector debated what should be done in the short and long term.



SOLAR CELL DEVICES HIT 30% EFFICIENCY

TNO, TU/e Eindhoven, imec and TU Delft, partners in Solliance, presented four-terminal perovskite/silicon tandem devices, which passed the barrier of 30 percent efficiency. Such high efficiency enables more power per square meter and less cost per kWh. Achieving high-power density will create more opportunities to integrate these solar cells into construction and building elements so that more existing surface area can be covered with PV modules.

EIRES LUNCH LECTURES

In 2022, EIRES organized 15 well-attended lunch lectures. The online format that started as an emergency measure during COVID-lockdowns turned out to be an easily accessible way for people to get up to speed with the latest in energy research. Next to TU/e researchers, international renowned scientists like Andreas Hauer from Bavarian Center for Applied Energy Research, and Emilia Motoasca from VITO NV Belgium shared their insights on energy technology.

EIRES Lunch

DRIVING THE ENERGY REVOLUTION

EINDHOVEN INSTITUTE FOR RENEWABLE ENERGY SYSTEMS

TU/e

FIRST FULLY COMMERCIAL PLANT ON IRON POWER

IRON+, a joint venture between the three companies EMGroup, Pometon and Metalot, and Swinkels Family Brewers signed a letter of intent to build the first fully operational commercial megawatt size plant ever operating on iron power. The plant will supply sustainable process heat for the brewing process of Swinkels Family Brewers in the coming 20 years. Two years ago, the Metal Power Consortium already performed a successful first demonstration at the Bavaria brewery in Lieshout to produce CO_2-free beer for the first time.

What roles do regional and local governments play in realizing the energy transition, and how can EIRES help? Rik Thijs, alderman for Climate & Energy, Public Space and Sustainability at the Municipality of Eindhoven, and Anne-Marie Spierings, Regional Minister for Energy, Circular Economy and the Environment at the Province of North Brabant, provide their views from the outside.

INTERVIEW WITH RIK THIJS: **'FROM THINKING TO ACTING'**

WHAT AMBITIONS DOES EINDHOVEN HAVE WITH REGARD TO THE CLIMATE AGREEMENT?

'In 2016, the municipality of Eindhoven issued a climate decree stating that with respect to 1990, we want to reduce CO_2 emissions by 55 percent in 2030, and by 95 percent in 2050. And together with the municipality of Helmond, we even went one step further and expressed the ambition to be climate neutral by 2030.'

HOW DO YOU PLAN TO ACHIEVE THAT?

'We get rid of fossil fuels, compensate for climate adaptation, and promote circularity to also reduce indirect emissions via consumption. One of the key elements in our approach is our tight collaboration with four housing corporations. Together we are taking big steps in making entire districts more sustainable and gas-free. In addition to renovating existing and building new houses, we help individual households take energy saving measures by providing them with free help through our energy coaches and the so-called Klusbus.'

WHAT ARE THE BIGGEST CHALLENGES THE CITY IS FACING?

'One of the most burning questions is how to design a future proof energy grid. In the coming years, Eindhoven will build 21.000 new houses within the ring road alone. How should we design our heat networks and our electricity grid to cope with this expansion? Besides technological innovations, that also requires social innovations, and legislative changes. The underlying challenge is to make the energy transition a fair one, where nobody is left out.'

HOW DOES EINDHOVEN SPEED UP INNOVATIONS?

'First, we act as launching customers for new technology, showing the market what is possible. Second, where possible we remove barriers for implementation. For example by granting authorizations for innovative projects, like installing a PowerNest for local energy generation on top of a building.'

HOW CAN EIRES BE OF HELP?

'There should be tighter connections between the university and other types of education in the Brainport region. We need to educate professionals who have the skills and knowhow to actually implement all of the available new technologies. In this region we tend to focus on the "golden brains", but if we really want to transform our energy system, we need the "golden hands" just as bad. If anything, the latest IPCC report made painfully clear that we need to transition from thinking to acting, and that we need to do that now.'

INTERVIEW WITH ANNE-MARIE SPIERINGS: **'FOCUS ON IMMINENT SOCIETAL CHALLENGES'**

WHAT PART DOES THE PROVINCE OF NORTH BRABANT PLAY IN THE ENERGY TRANSITION?
'Though our statutory duties on this topic are rather limited, North Brabant has been ahead of the troops for over a decade. For example, we have been actively stimulating electric driving since 2009. We are also investing in smart grids and solar energy innovations, and we have developed an energy fund to realize significant reductions in CO_2 emissions.'

WHAT INNOVATIONS ARE MOST URGENTLY NEEDED?
'We need solutions to store large amounts of energy for long periods of time, that do not take up too much space and aren't too expensive. And we need alternatives for high temperature processes that emit less nitrogen.'

HOW CAN WE ACHIEVE THE REQUIRED ACCELERATION?
'We need to fill the gap between the development and the large scale implementation of technological innovations. A change in approach can be of help. EIRES builds its storytelling mainly on climate change. But we are facing other problems with a more imminent urgency, like the nitrogen crisis. These current challenges offer promising possibilities for energy transition innovations that also emit less or no nitrogen.'

HOW CAN EIRES MAKE USE OF THOSE?
'Instead of focusing on the economics side of potential business cases, put more emphasis on the societal advantages of your innovations. Industries are obliged to take their responsibility in reducing greenhouse gas emissions. Jump in. Take heat networks as an example. Our current heat networks are fed by either coal plants or bioreactors. Both of these heat sources have to be phased out. That means there is a big opportunity for new heat sources that are sustainable. A second advice would be to take a step back and objectively judge your technology on its merits. Take the student team STORM: though their aim was to develop an electric motorbike, what they turned out to be really good at, is developing batteries in all shapes and sizes.'

WHAT IS YOUR GENERAL MESSAGE ABOUT THE ENERGY TRANSITION?
'We need to emphasize what can be done today, not only focus on technologies for tomorrow. Sure, future solar panels will be even better, but current-day technology is fine. And there is one simple thing anyone of us can start doing this very minute: buy less stuff. Everything we buy has to be produced and recycled afterwards, requiring a lot of energy and resources. And buying less immediately saves you money too.'

AWARDS & GRANTS

1.4 MILLION EUROS FOR RESEARCH ON CIRCULAR RENOVATION

A consortium led by Lisanne Havinga and Torsten Schröder, both from the Department of Built Environment, will research how to renovate buildings in a circular and emission-free way. The building program of the Dutch Research Agenda (NWA) allocated 1.4 million euros to this project for a period of five years. The team will look at the entire chain, from the design phase of a building to its demolition, and back again to the design phase. Havinga: 'By including the entire chain, you might find different solutions in terms of worker capacity.'

OFFSHORE WIND AND GREEN HYDROGEN PRODUCTION

The Netherlands Enterprise Agency awarded a 4 million euro grant to the GROW consortium FlexH2 project. The project intends to develop and demonstrate technology that will accelerate the scale up of offshore wind, green hydrogen production and its integration into the energy system. The proposed wind-to-hydrogen solution, which will be tested in laboratories at a medium voltage kW scale, enables direct sourcing of renewable electricity to green hydrogen production.

EIRES-POSTDOC WINS POSTDOC PAPER PITCH COMPETITION

Stein Stoter from the Department of Mechanical Engineering took first prize in the second edition of the TU/e Postdoc Association paper pitching competition. Nine postdocs pitched their research papers during the competition, which is co-organized with the four campus institutes – EIRES, EAISI, EHCI, and ICMS.
Stein Stoter presented a pitch in relation to a paper published in Computer Methods in Applied Mechanics and Engineering. For his research, Stoter creates computer models to study the motion of fluids like water or air.
The paper he pitched about considered turbulence, the complex swirling motion of water or air near objects. This is important for societal applications in engineering, such as designing wind turbines.

BILL GATES' CLIMATE FUND INVESTS IN TWO TU/E SPIN-OFFS

Breakthrough Energy, a private investment coalition founded by Bill Gates, made funding and resources available to the TU/e spin-offs RIFT and Cellcius. Mark Verhagen (CEO), Lex Scheepers (CTO) and Vincent Seijger (CTO) have been selected as Fellows in the so-called Fellows program via RIFT (Renewable Iron Fuel Technology). The Fellows program is a two-year mentoring program that helps develop and commercialize promising technologies.
Olaf Adan has been selected for an Explorer Grant with the spin-off Cellcius, which was spawned by TU/e and TNO. Explorer Grants support the ideas of young companies that have not yet evolved to the point of becoming eligible for the Fellows program.

CLEANER SHIPPING WITH AMMONIA

A consortium of industrial partners and academics, including TU/e researchers, received funding from the NWO Perspectief program to develop an ammonia-based alternative for fossil fuels for heavy transport. Ammonia, known for its characteristic smell, has a relatively high energy density. That means that you can store a lot of energy in a far smaller volume than in the case of green hydrogen.
The AmmoniaDrive program therefore focuses on how to use ammonia in an energy-efficient, clean, affordable and, above all, safe way to make today's heavy transport more sustainable.

ERC CONSOLIDATOR GRANT FOR SOCIAL TIPPING DYNAMICS

Floor Alkemade was awarded a Consolidator Grant of 2 million euros by the European Research Council for her research to investigate how social tipping dynamics can realize the much-needed acceleration of the energy transition. Alkemade: 'If we better understand the role of social processes and how the interactions between different processes lead to an acceleration of the energy transition as a whole, then we can build better models. And with that, we will support policymakers and investors in their choices about, for example, subsidy schemes, investments, and infrastructure.'

IN THE LIMELIGHT

HITTING THE JACKPOT TWICE

Last summer, TU/e chemist Hans Kuipers was awarded his second ERC Advanced Grant, this time to work on reactors with three phases in so-called Slurry Bubble Columns Reactors (SBCRs).

Slurry Bubble Columns Reactors are the workhorses of the chemical process industry. Kuipers' research aims to develop advanced models of so-called three-phase catalytic reactors, where gases, liquids and solids interact with each other while catalytic reactions take place at the same time. Naturally, this releases a lot of heat.

Multiphase reactors already exist and are actively used in industry. However, developing three-phase catalytic reactors can be cumbersome and time-consuming, and some reactors are huge, with heights reaching up to 60 meters. 'The enormous scale means that it is crucial to have reliable design and optimization procedures,' Kuipers explains. 'The unique aspect of our project is that it will predict the interactions between the different phases as catalytic reactions take place. We want to improve the state-of-the-art by developing computer models validated with experiments, which can result in huge savings on development time and costs while avoiding the construction of oversized reactors that do not use feedstocks in an optimal way.'

CLEAN SYNTHETIC FUELS

Potential savings are not only interesting for the chemical process industry, but also for other industries utilizing these reactors. In particular, this applies to the large-scale production of clean synthetic fuels from raw materials such as hydrogen and carbon monoxide.

Kuipers: 'I am hopeful that this project will make a difference when it comes to developing ways to produce our future clean fuels. Contributing to positive change for the world is more than ever an important motivator for PhD researchers and supervisors alike.'