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TIME TO ENERGIZE

WHAT ABOUT MATERIALS?

FUSION: BEYOND THE FUNDAMENTALS

HISTORY OF METAL FUELS

EIRES
EINDHOVEN INSTITUTE FOR RENEWABLE ENERGY SYSTEMS

TU/e

CONTENTS

ROOM FOR DEBATE 04
Jos Brouwers and Auke Hoekstra

A MULTISCALE VIEW ON MATERIALS 07
Introduction to the Center for Multiscale Electron Microscopy

NEWS & EVENTS 08
Research results and meetings

BEYOND THE FUNDAMENTALS 10
About the transition of fusion research

FIGHTER FOR A FAIR TRANSITION 13
Portrait of EIRES researcher Christina Papadimitriou

EIRES COMMUNITIES 14
The latest additions to the EIRES landscape

ENERGY DAYS 16
Quotes about the energy transition

MAKING CRUCIAL CONNECTIONS 17
Energy Learning Community

TURNING THE POWER OF IRON INTO PROFIT 18
On the development of metal fuels research

COLD CATALYTIC CONVERTER 21
Purifying exhaust gases at room temperature

AWARDS & GRANTS 22
New research projects and prizes

TOWARD A JUST ENERGY TRANSITION 24
Recommendations for policymaking

PAINTED PANELS TO HARVEST SOLAR HEAT 25
How start-up Calosol took a different turn

OUTSIDE IN 26
Silvia Lenaerts and Marco de Baar

SPOT ON SOLAR CELLS 28
Second ERC Advanced Grant for René Janssen

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WORD OF WELCOME

Welcome to the third edition of our annual magazine Time to Energize. This magazine provides some insights in the developments that mark the second strategic period of our institute.

Over the past year we have broadened the scope of EIRES. Our four existing, yet somewhat redefined, focus areas have been extended with a fifth: the incorporation of the Center for Computational Energy Research, a joint initiative between DIFFER and TU/e, into our institute complements our existing expertise with the much needed computational competence. In addition, we have also stimulated the establishment of dedicated communities. These are centered around specific topics that are of interest to the energy transition, ranging from hydrogen to batteries, and from fusion to future chemistry. It is in these communities where people working on similar societal challenges, albeit from different backgrounds, meet and jointly explore new approaches, directions and solutions.

All in all, energy research in Eindhoven is blooming, and industry and society are reaping the benefits from it. It is therefore with pride that I present to you this anthology of this year's inspiring stories, leaving you with an impression of Eindhoven's buzzing energy community.

Richard van de Sanden
SCIENTIFIC DIRECTOR

JOS BROUWERS (LEFT) AND AUKE HOEKSTRA (RIGHT)

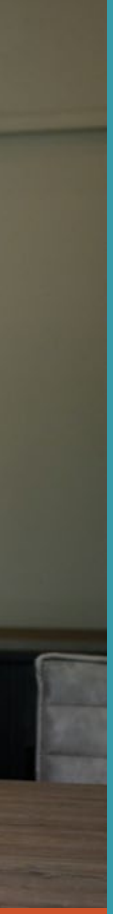
MAKING MORE OF MATERIALS

The materials aspect of the energy transition is gaining in importance. Guided by EIRES managing director Mark Boneschanscher, Jos Brouwers, Professor of Building Materials and Auke Hoekstra, director of the NEON research program, discuss their personal views on carbon footprints, scarcity issues and political aspects associated with resources.

THE ENERGY TRANSITION IS EVOLVING TOWARD A MATERIALS TRANSITION. WHERE IS THAT TRANSITION HEADED?

Auke Hoekstra (AH): 'We have reached a point where generating enough renewable energy is not the problem anymore. And when it comes to storage, batteries are developing at an extremely fast pace, and multiple types of solar fuels are under development for seasonal solutions. Materials and resources will be the real issue. How much land are we going to dedicate to supplying in our need for energy, and how does that affect food production?'

Jos Brouwers (JB): 'Whenever people talk about a materials transition in the context of sustainability, there is a tendency to focus on rare earth materials for PV, and materials like lithium and cobalt for batteries.



But most people do not realize that the most produced material in the world is concrete. Even if the production of one kilo of concrete might not have such a large environmental impact, the sheer production volumes give rise to large effects on land and energy use.

'MOST PEOPLE DO NOT REALIZE THAT THE MOST PRODUCED MATERIAL IN THE WORLD IS CONCRETE'

JOS BROUWERS

In our research we aim to lower the environmental impact of building materials like concrete, steel and cement. We have launched a recycling lab and we are improving production methods in terms of energy use. Also, we are transitioning towards more biobased materials such as wood and flax.'

AH: 'I built my entire house of compressed wood! I honestly do not understand why anyone would want to burn something as valuable as wood as a fuel.'

JB: 'Did you know that, depending on what you take into account, the CO_2 footprint of concrete is equal to that of wood? Only if you consider the embodied CO_2, wood scores better.'

AH: 'Can we correspond about that? I find that hard to believe …'

SHOULD WE MOVE THE PRODUCTION OF ENERGY-INTENSIVE MATERIALS LIKE STEEL TO COUNTRIES WHERE THERE IS ENOUGH SOLAR POWER?

AH: 'For bulk production that sounds like a smart idea. When it comes to high quality products, the Netherlands has a strong added value in innovating production. Besides, it is also in these more high end products where the most profit is to be made.'

JB: 'What about the strategic consequences? Think about the corona crisis, when we depended on China and India to provide us with face masks and ingredients for medicines. As a world citizen, you would think it would be better to move energy-intensive industry to where there is enough of sunlight. Alas, in real life politics tend to get in the way.'

AH: 'Indeed, you would need to have a diverse portfolio of suppliers, and perhaps spread production over different continents to make sure you do not depend on the whims of one region.'

JB: 'Besides, whether or not we should produce things like steel in the Netherlands also depends on the cost of transporting hydrogen or other future energy carriers.'

AH: 'When you look at the current developments in energy storage, there are indeed a lot of promising pathways.'

WHAT ROLE CAN OR SHOULD TU/E PLAY?

AH: 'We house a unique combination of expertise, ranging from chemical engineering to knowhow about constructions and systems engineering. We should be the partner government actors like the Municipality of Eindhoven come to for advice. Take the Dutch Mountains project that is to be realized in the railway zone here in Eindhoven. That is a massive urban development project, which includes aspects of energy technology and smart mobility – topics we are experts on. Why is our university not involved in the development of these plans?'

JB: 'Individually, people are indeed working on all of the involved aspects, but the question is how TU/e could bring all of this expertise together. Every department, every group and even every staff member has their own way of working. We need to connect people, tell stories about who is working on what, share best practices.'

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5

AH: 'That brings me to a heartfelt advice, based on a story I once heard from a consultancy agency. If they stumble upon some organizational parts that need to be better connected, they go looking for an external job for which those departments simply need to collaborate.'
JB: 'That has been on my mind as well. Take my own department of the Built Environment. Why don't we actually build something? We could equip such a building with new construction materials, smart windows, solar panels, charging stations, you name it. And subsequently study such an object and its interactions with the environment in real life.'
AH: 'That also connects to an idea I have had for a long time: I would like to include the campus as a whole in a large scale modelling experiment, where we describe the current energy supply and demand situation and start playing out different scenario's.'

WHAT IS NEEDED FOR THE UNIVERSITY TO GET INVOLVED IN SUCH LARGE SCALE PROJECTS?

AH: 'A dedicated budget and an overview of everything that is going on at the campus. The closer to home, the easier it is to motivate people to get involved.'
JB: 'Indeed, we should be doing projects for TU/e itself in the same way as we do projects for other parties outside of university. Valorization is an important aspect of our work. Why not valorize internally as well?'

'I WOULD LIKE TO INCLUDE THE CAMPUS AS A WHOLE IN A MODELLING EXPERIMENT'

AUKE HOEKSTRA

AH: 'Yes! TU/e as a launching customer for its own ideas and innovations! And let's not stop there: TU/e should act as an advisory body for society as a whole when it comes to the grand challenges.'
JB: 'That requires a mental shift.'
AH: 'Achieving such mental shifts is what I live for. Perhaps this interview can be a start to pave the way.'

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.

A MULTISCALE VIEW ON MATERIALS

The Center for Multiscale Electron Microscopy (CMEM) houses a series of state-of-the-art electron microscopes to study materials. Lead scientist Heiner Friedrich: 'Modifying a material's structure at the microlevel is key to achieve a wide range of functionalities at a macrolevel. Our microscopes are instrumental in that.'

After a major technical upgrade, in May 2023 the Center for Multiscale Electron Microscopy was reopened with a celebratory ceremony. 'We had been running before under different names for about twenty years', says Heiner Friedrich, 'facilitating materials research, both from a fundamental and an applied perspective.' The lab welcomes TU/e researchers from all departments, and occasionally also accommodates industrial research.

THREE AREAS

The Center is primarily known for three areas of expertise, Friedrich explains: 'We operate a cryo-electron microscope for soft matter and polymer research, electron microscopes capable of in situ studies where materials can be placed in more realistic liquid or gaseous environments, and 3D electron microscopy to gain quantitative insights into the 3D organization of materials.'

STORING HEAT IN GRAPHENE

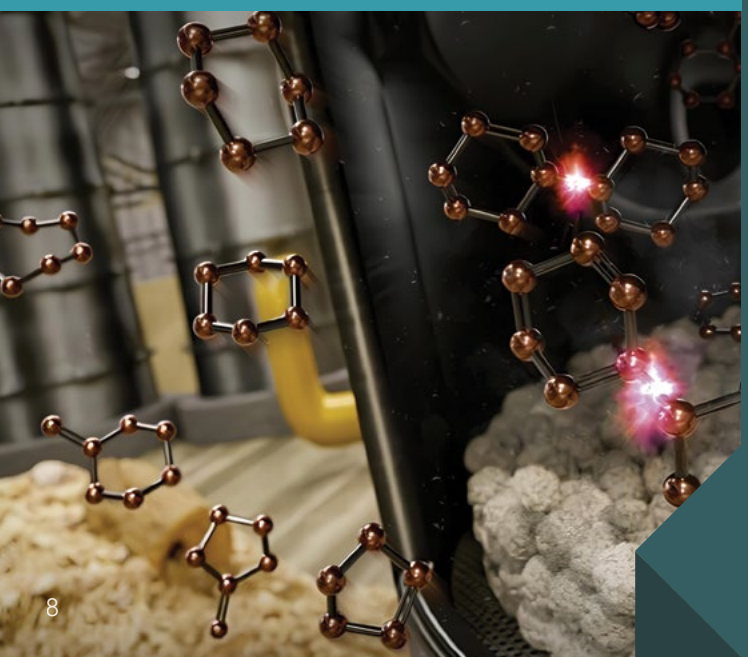
Besides leading CMEM, Friedrich is also deeply involved in materials research himself. 'For example, in the WAX+ project we are looking at the possibilities of using graphene to improve the thermal conductivity of cheap, non-toxic, and stable technical grade paraffins for heat storage applications.'

With the facilities at CMEM, researchers can study materials from the nanometer scale to tens of micrometers and with (sub) nanometer resolution. 'To find a meaningful way to adjust a material's multiscale morphology, you need to understand what is in between the atomic level and the scale of application,' Friedrich states. The Center's facilities are the eyes of the scientists who for example want to follow how catalysts age, what membranes or electrolyzers look like at the smallest scales, or how salt(hydrates) used for heat batteries might change after several charging and discharging cycles.

NEWS & EVENTS

ELEO BATTERY PRODUCTION PLANT

On 26 January 2023, King Willem-Alexander opened ELEO's new battery production plant on the Automotive Campus in Helmond. With the opening of the plant, the TU/e start-up is increasing its battery production capacity tenfold. The company, which makes high-performance battery systems for a variety of industrial applications, expects to grow from 60 to 200 employees over the coming two years.



GREATNESS OF A GAP

Green hydrogen is a serious contender to become a renewable energy carrier. For example, we could use it to store solar and wind energy during peaks in order to use the energy when the sun is no longer shining and the wind is calm. This would require more electrolyzers that can efficiently and flexibly handle fluctuations in power supply. However, the electrolyzers that can already do so use rare and expensive raw materials for their electrodes, such as platinum and iridium, while more affordable alkaline electrolyzers struggle to operate flexibly. This is where a team of TU/e researchers, led by Thijs de Groot, may have now found a solution. In an article in the *International Journal of Hydrogen Energy* they elaborated on the usefulness of a small cathode gap in alkaline electrolyzers.

PLANT-BASED AVIATION FUELS

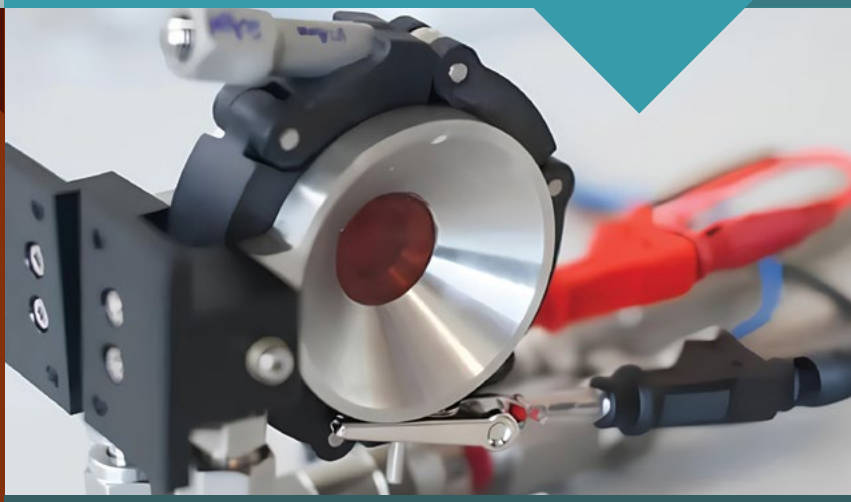
While smaller vehicles turn to e-mobility, heavy-duty transport systems such as trucks, ships, and airplanes will rely on traditional liquid hydrocarbon fuels for the foreseeable future. As an alternative to fossil oils, these renewable fuels can be produced from plant-based lignin. Unfortunately, yields are limited by the current processing approaches, hampering the adoption of these alternative plant-based fuels. In a new study led by Emiel Hensen's research group, a novel catalytic approach has been developed that can significantly improve yields from lignin by cracking hard-to-break carbon-carbon bonds. The study was featured on the cover of the first-ever issue of *Nature Chemical Engineering*.

KICK-OFF BATTERYNL CONSORTIUM

On 12 January 2023, companies, multinationals and knowledge institutes attended the kick off of the BatteryNL consortium. The consortium aims to develop the next generation of batteries that are safer, have higher energy densities and have a longer life-cycle – all of which are crucial for a society based on sustainable energy sources.

SIR ONE TO STORE HYDROGEN ENERGY

TU/e student team SOLID has developed an alternative technique that enables the safe storage and transport of hydrogen energy. In this process, small iron balls are used as energy carriers. The students have built a test setup, the so-called Steam Iron Reactor One (SIR One). The team's ambition is to scale up the system in the coming years and realize a demo in the port of Rotterdam in 2027.

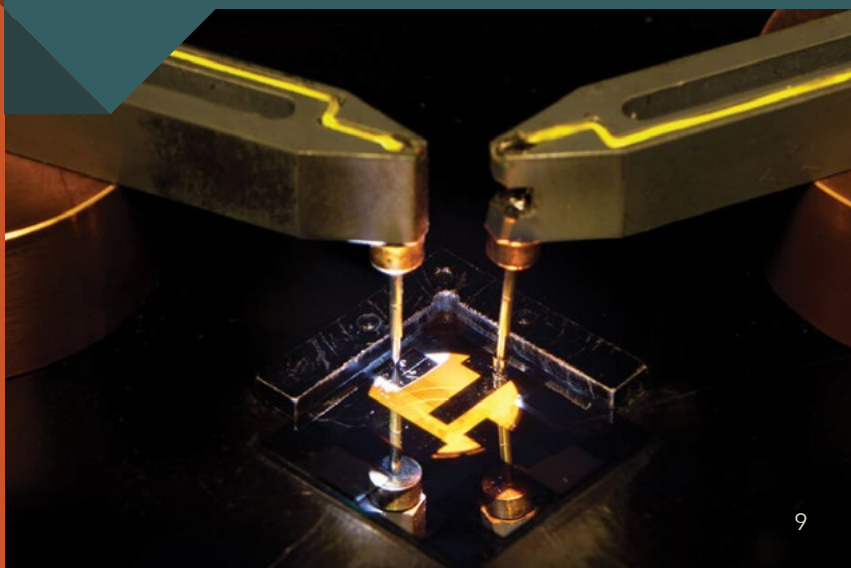


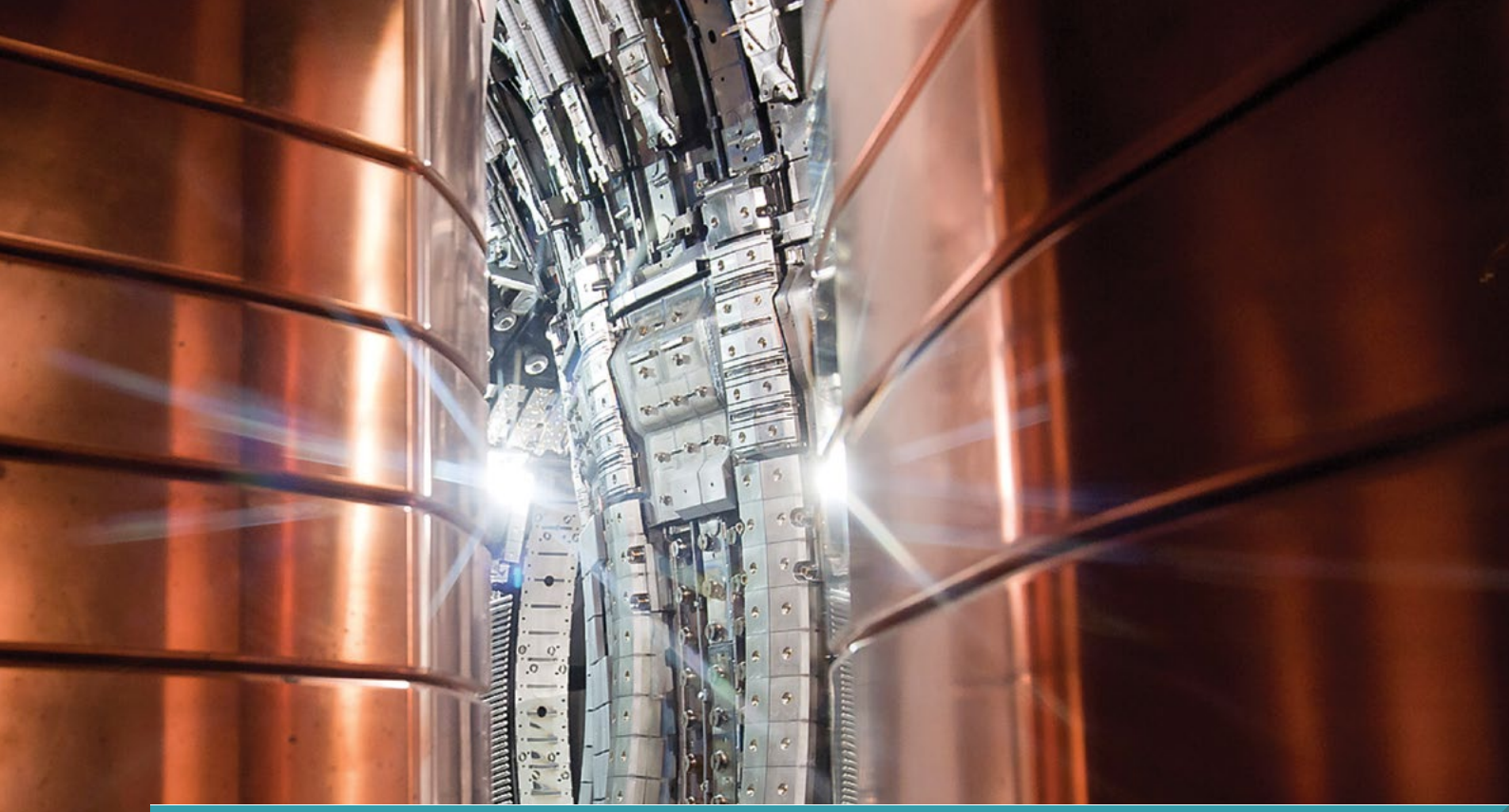
IMPROVING PEROVSKITE SOLAR CELLS

The Netherlands is among the European leaders when it comes to generating solar energy. The need for efficient solar cells is therefore great. René Janssen and his colleagues published a paper on how to improve perovskite solar cells by playing with their composition. The paper was published in the renowned journal *Nature Energy*.

HEATING HOUSES WITH IRON

RIFT, the spin-off that emerged from student team SOLID, successfully completed its first major test. RIFT heated five hundred homes in Helmond through the so-called Iron Fuel Technology, in which a heat boiler generates heat through the combustion of iron powder. This way, no CO_2 was released when households turned on the heating or stepped into the shower.





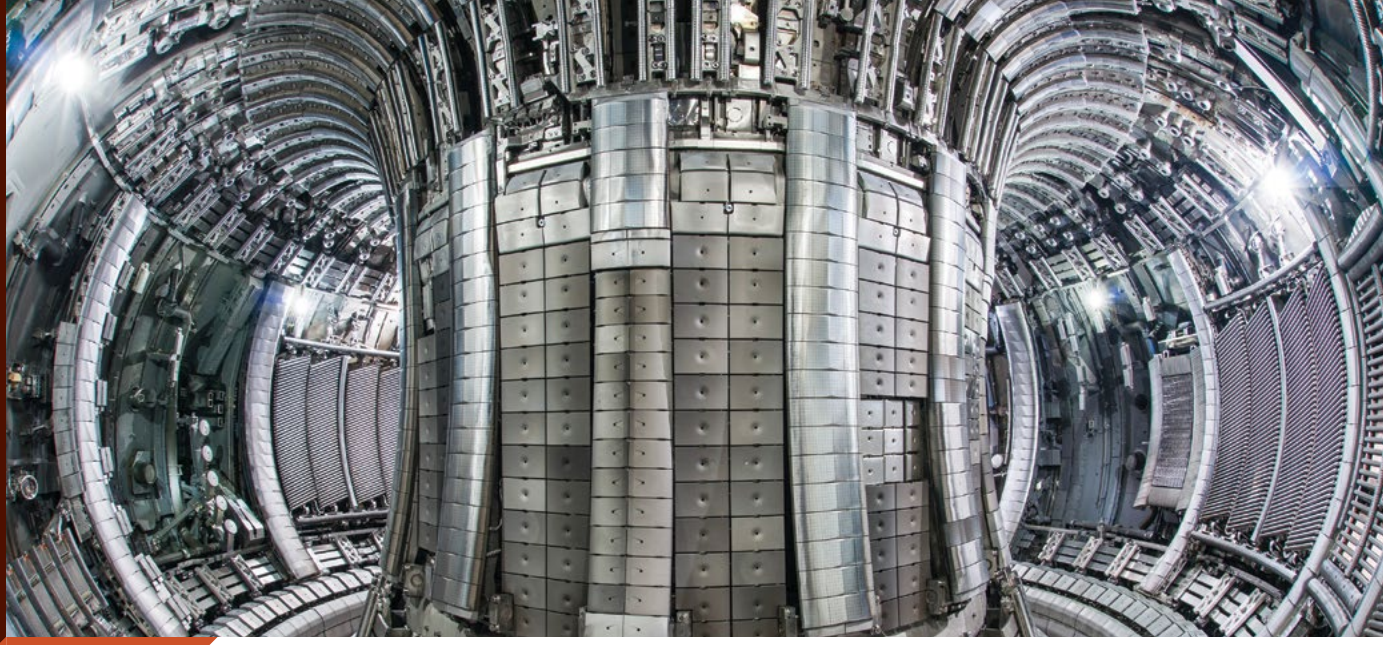
BEYOND THE FUNDAMENTALS OF FUSION

Nuclear fusion is slowly but surely turning from a dream that used to sound rather far-fetched into a feasible technology. That development requires a transition in the academic and commercial approach to the subject, explain Professor of Science and Technology of Nuclear Fusion Niek Lopes Cardozo and EIRES program manager for fusion energy Guido Lange. With its new fusion program, EIRES aims to build a fusion supply community at TU/e.

Guido Lange studied applied physics at TU/e with a major in fusion. After a short detour into the world of software engineering and data analytics, he returned to his earlier love for fusion energy in different roles at TU/e, FuseNet and EUROfusion. 'Eindhoven is internationally recognized for its expertise in fusion research,' Lange observed in these roles. 'Combining DIFFER and one of the world's only universities to offer a dedicated fusion master, the Eindhoven campus houses unique, world-class research and education in this field.'

Where scientific endeavors into fusion energy in the past used to be focused largely on fundamental plasma physics, this is rapidly changing, the Eindhoven alumnus states. 'Especially since the construction of ITER – the world's largest fusion experiment – started, not only the more engineering-oriented questions are becoming more succinct, but also topics in the fields of legislation, socio-economics and organizational challenges are gaining in importance.'

This development is also recognized by 'Mr Fusion', Niek Lopes Cardozo, who recently delivered his valedictory lecture at TU/e. 'The closer we get to realization of nuclear fusion, the more the research moves away from the plasma physics it started with. Engineering challenges are gaining in importance, for example when it comes to control and systems



engineering. In our dedicated master program here at TU/e, we teach about every part of the reactor, and explicitly include societal aspects as well.'

BIGGER PICTURE

Over the past 43 years, Lopes Cardozo himself has worked on a myriad of topics related to fusion, ranging from X rays, transport phenomena, magnetic topology, and plasma wand interactions to the prospects of fusion energy in view of the outstanding technical challenges on the one hand and the progress in other energy technologies on the other.

'In recent years I got more interested in the bigger picture. Take the materials we need to build a fusion reactor. Are they available in the quantities we need? To be able to make a real difference in the global energy system, we would need some 10.000 of these nuclear fusion power plants. What does that mean for the supply chains and the amount of people who should be working on this?'

SUSTAINABILITY AND SCALABILITY

At the moment almost everyone in the field is focused on building a prototype of a functional fusion power plant. Not that many people are working on upscaling yet, the Eindhoven professor observes. 'For the first generation these questions might not seem that relevant. But if you are smart, you start thinking about things like carbon footprints and scarcity of resources right away, so you can adjust your designs in such a way that the reactors will be both sustainable and scalable.'

The researcher names some examples of issues at hand. 'In the current designs, lithium-6 is used as fuel. For a single plant, some 100 tons of it are required. But while there is plenty of lithium, the process to separate lithium-6 from the much more prevalent isotope lithium-7 could be a bottleneck.

'IF YOU ARE SMART, YOU START THINKING ABOUT THINGS LIKE SCARCITY OF RESOURCES RIGHT AWAY'

NIEK LOPES CARDOZO

The only method available on industrial scale uses thousands of tons of mercury. That is a very toxic component which is extracted under poor working conditions and has some geopolitical issues associated with it. This separation technology does not scale at all, and alternatives haven't been developed at scale yet.'

Another issue with upscaling fusion power is the sheer size of the endeavor, he emphasizes. 'At the moment, worldwide, we are able to build five to ten nuclear fission plants a year, involving some 2,5 million people worldwide. For fusion to have an impact in, say 2050, we would need to build 500 of these each year, for 20 years on end. That would translate into more than 100 million people working on nuclear fusion alone…'

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TOWARD BUSINESS DEVELOPMENT

Across the world, fusion is getting more and more in the picture. That notion is reflected in the fact that for example in the UK, the US and Germany, an increasing amount of private-funded initiatives are arising, states Lange. 'During the last five years the number of private fusion companies worldwide has quadrupled to almost 50, ranging from Eindhoven-based companies that provide 3D metal heat pipes or model the plasma to an MIT spin-out that has already raised close to two billion dollars to build their own prototype fusion reactor.' 'Indeed, private parties are stepping in fast now,' Lopes Cardozo confirms. 'That is a promising development, since as soon as commercial parties start to work on something, typically the lead times and cost of goods tend to go down.' Though the question if fusion will ever be an economically viable alternative for other types of energy is not yet fully answered, the lead times are simply too long to sit around and wait, Lange thinks. 'We need to assess at an early stage if novel technological solutions are scalable and manufacturable and to facilitate research and industry to build and test those solutions. And we need to develop new business models for these types of extremely long term innovations, since the timelines to realize reliable reactors can easily take up to 25 years. That is way too long for any commercial venture to be interested, and in current times, also exceeds the horizon of many governments.'

'WE NEED TO DEVELOP NEW BUSINESS MODELS FOR EXTREMELY LONG TERM INNOVATIONS'

GUIDO LANGE

INCLUSIVE COMMUNITY

By setting up a new multidisciplinary program for fusion, TU/e and DIFFER aim to leverage on the expertise and know-how that the Eindhoven region has accumulated so far. In addition, TU/e sees possibilities to extend the scope of fusion research to also include the social sciences, Lange explains. 'The current fusion master is a collaboration between the Departments of Applied Physics & Science Education, Electrical Engineering, and Mechanical Engineering. But looking at how the field develops, and keeping in mind that one day, we really want to have fusion power plants that provide part of our energy, now is the time to also include departments like Industrial Design and Industrial Engineering and Innovation Sciences to help build a viable fusion development roadmap. The ultimate aim of the new Eindhoven fusion program is to build a network around fusion energy, develop an extensive knowledge base, and establish new connections to the manufacturing industry.'

FIRST DUTCH FUSION DAY

We are getting ever closer to achieving nuclear fusion energy. Both the Netherlands and TU/e can play an important role on the global nuclear fusion stage. But this requires close cooperation between academia and industry. A step toward this goal was taken during the very first Dutch Fusion Day organized by TU/e, DIFFER and ILO-net on 3 May 2024.

FIGHTER FOR A FAIR TRANSITION

Promote science to give back to society. That is the ambition of Christina Papadimitriou. 'We tend to develop high tech solutions that are accessible for privileged people in western countries, but energy should be for all.'

As an assistant professor in the Electrical Engineering department, Christina Papadimitriou is working on intelligent electrical energy systems. 'During my studies I got intrigued by the question how to integrate renewable resources into the grid,' the Greek scientist recollects how she entered the energy research field.

BOTTOM-UP APPROACH

At the moment, Papadimitriou is working on several different projects. 'For example, I am the technical coordinator of an Horizon2020 project called eNeuron. That project takes a user point of view to local energy systems.' The goal is to develop a practical framework for optimizing the design and operation of local energy communities that act as energy hubs. 'We aim for a modular plug and play approach where you can add or remove a range of energy technologies, and electric vehicles, and see how that influences the optimal operation of the community, the grid and the energy balance in individual buildings or households. We use sophisticated algorithms to manage trade-offs and conflicting requirements of different stakeholders.' The approach is a bottom-up one, she stresses. 'We start from small entities and build up towards quite complex systems. Our workflow management architecture is modular and flexible and agnostic towards the energy carrier that is used.'

She is convinced that the final solution for our future energy system will start from the smallest blocks. 'Each home or building will become self-sufficient in terms of energy. But it will be a challenge to also include non-privileged people in that transition. Energy should be for all, not only for the privileged. Or, in the words of the European Green Deal: we have to make sure that the transition leaves no one behind.'

AI
DATA&ENERGY
IRON FUELED BREWERY
HEAT BATTERY
SALT
IRON POWER
FUSION
HEAT
HYDROGEN FACTORY
H_2
H_2
H_2
H_2
POWER TO MOLECULES
HYDROGEN
SOLAR PV
BATTERIES
FUTURE CHEMISTRY
EIRES COMMUNITIES

ENERGY DAYS QUOTED

‘THE ELECTRICITY GRID IS NOT FULL, IT IS MERELY JAMMED. IF WE WOULD EVEN OUT THE ENERGY DEMAND OVER THE NET, WE WOULD ONLY BE CONSUMING 30 PERCENT OF THE TOTAL AMOUNT OF ENERGY THAT IS AVAILABLE. SO THERE IS PLENTY OF SPACE, WE SIMPLY NEED TO USE IT WISELY.’

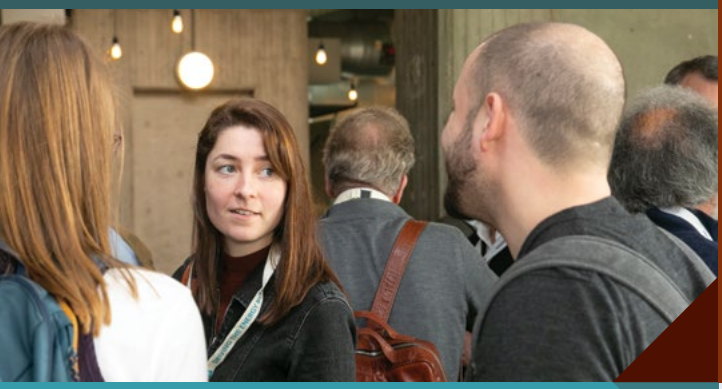
Bram Cappers, co-founder of Tibo Energy, 21 March 2024

‘FOR THE TECHNOLOGY OF THE FUTURE WE WILL HAVE TO CONSTANTLY CONVERT DIFFERENT FORMS OF ENERGY INTO EACH OTHER. SINCE WE NEED DIVERSIFIED SOLUTIONS, WE ALSO NEED DIVERSIFIED ENERGY RESEARCH.’

Karsten Reuter, Director of the Fritz-Haber-Institut der Max-Planck-Gesellschaft, 16 November 2023

‘AT THE MOMENT, NEARLY 4000 PARTIES ARE WAITING TO GET CONNECTED TO THE GRID OR TO GET AN UPGRADE OF THEIR EXISTING CONNECTION. EVEN THOUGH BOTH THE NATIONAL GRID PROVIDER TENNET AND WE AS REGIONAL GRID OPERATORS ARE INVESTING HEAVILY, WE SIMPLY CANNOT KEEP UP WITH THE REQUIRED PACE.’

Han Slootweg, director of asset management at grid operator Enexis, 21 March 2024



‘DO NOT USE YESTERDAY’S TECHNOLOGY FOR TOMORROW’S ENERGY SYSTEM, BUT MAKE A MASTERPLAN THAT INCLUDES NEW SOLUTIONS.’

Wiebrand Kout, founder and CTO of Elestor BV, 16 November 2023

MAKING CRUCIAL CONNECTIONS

To make the energy transition happen, what we need above all are well-educated, skilled people on all levels. With that motto in mind, over the past years a consortium established the regional Energy Learning Community.

Perhaps the most scarce resource when it comes to the energy transition is a skilled workforce: people who can invent new energy technologies, people who can connect innovative technology to daily practice, and people who can build and install the resulting technologies.

CONNECTING STUDENTS

To increase the supply of these well-trained people, TU/e, Avans University of Applied Sciences, Summa College, eXentr, LEDDriven, Omines and Team RED joined forces. In a three-year project funded by OPZuid and managed by Stimulus, the partners brought together students from secondary vocational education, higher vocational education and university, and connected them to SME's from the region to work on the energy challenges from today and tomorrow.

SPIN-OFFS

Project manager and co-initiator of the project Mark Cox sums up some of the spin-offs of the project: 'A new study association for electrical engineering, SV Silicium, was founded at Avans University of Applied Sciences. TU/e witnessed the birth of a new student teams like Shift and Neg-C. And the challenge-based learning approach, were students get hands-on experience with the state-of-the-art in energy technology, is increasingly incorporated in the educational programs at all levels.'

In concrete terms, these educational reforms have resulted in a new lab at Avans, where students can gain experience with advanced electrotechnical systems for electricity grids. And Summa Automotive has established a new teaching facility at the Helmond Automotive campus where the future automotive professionals can learn about the ins and outs of electric vehicles.

Cox: 'We are now exploring possibilities to also open up these types of advanced training facilities to other educational institutes, for example by making them remotely accessible.'

TURNING THE POWER OF IRON INTO PROFIT

Since 2015, Philip de Goey has relentlessly been pushing the development of iron powder as a medium for large-scale, long-term storage of sustainable energy. 'Over the past decade, we have built an international track record in iron power, both on an academic level and in creating business in this field. Now is the time to take the next step as a country and start capitalizing on our unique position.'

His final gig. That is how Professor of Combustion Technology Philip de Goey refers to the field of research he personally initiated at TU/e some ten years before his planned retirement. It was during a meeting in the frame of the ESA project Perwaves that De Goey became intrigued by the concept of storing sustainable energy in metals. During the two hour commute back to his home, he planned an entire trajectory of how to turn this dream into a reality.

'Around 2009, Jeff Bergthorson from the McGill University approached me to collaborate with him on the study of powder combustion in zero gravity. While clean burning of solid fuels is difficult enough as it is, when it comes to metals, we always assumed that it would be impossible to achieve a clean oxidation. But in that meeting early 2015, the idea came to us that if you could prevent the powder

from evaporating during combustion, you could perhaps use the metals to store energy in a clean and cyclic way.'
During his commute from Noordwijk to Budel, De Goey decided that in his final ten years as a scientist he would not only focus on the burning of metals and on reducing the resulting oxides back into fuel, but also in parallel on how to bring this technology to market.

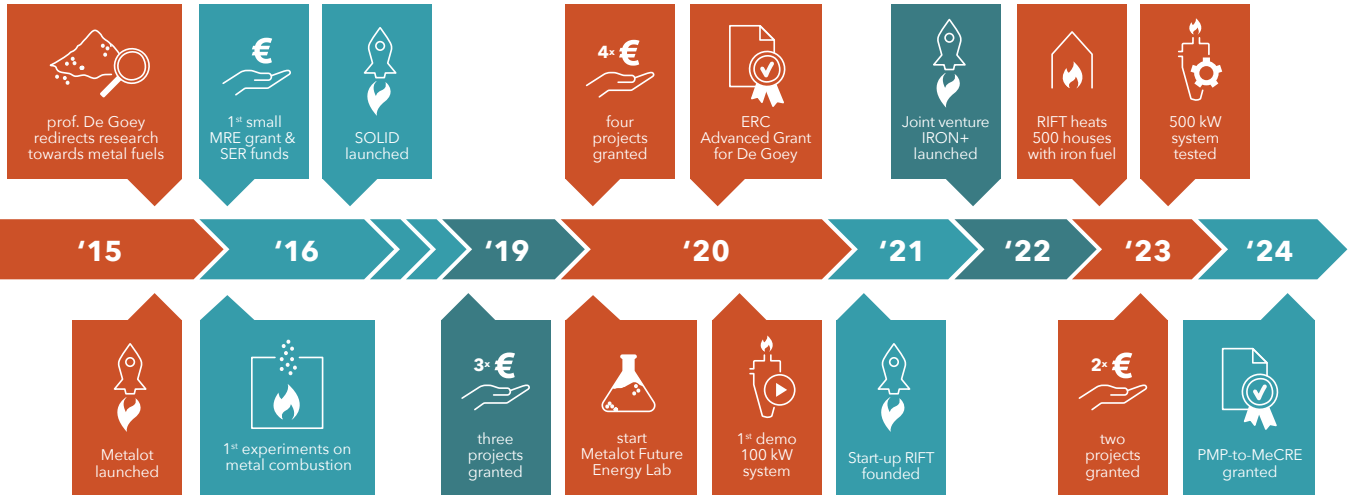
NETWORK AND FUNDING

One of the first things the scientist focused on, was to bring together academia, governments and industry to jointly work on this technology. In 2016 this resulted in Metalot, a network organization where innovation, research, business and education come together to accelerate the pace of sustainable, circular developments in the field of metals and renewable energy. In the meantime, his research group was starting first experiments on metal combustion and applying for research grants to explore both the combustion of iron into iron oxide, and the reduction of the iron oxide back to iron. Gaining funds was far from easy, De Goey recollects. 'Our first four larger scale research proposals were all rejected.' But the pioneer remained confident and together with his partners from Metalot and TU/e he continued to advocate the potential of metal fuels as a sustainable storage solution for the energy transition. From 2019 on his message started to resonate with funding organizations, and the project grants started to pour in.

TECHNOLOGICAL CHALLENGES

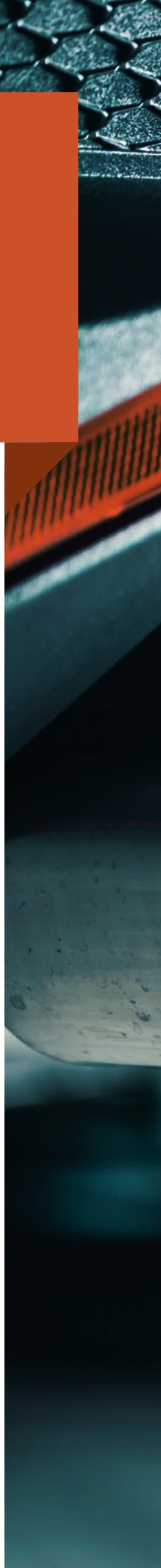
Over the years, the research has tackled multiple technological challenges, starting by selecting the right metal to focus on. 'Rather soon we were convinced that iron would hold the highest promise when compared to for example aluminum or magnesium. This is partly since there already were carbon-free methods to reduce the iron oxide back to iron, but a more important reason is that in iron, the flame temperature is comparable to that of natural gas, enabling the retrofitting of current fossil fuel infrastructure. This of course greatly simplifies the introduction of a new fuel.'
In the various projects, the researchers have looked at aspects like: How to keep an iron flame burning ('as one possible solution, we investigated a tornado-shaped combustion device and developed that into a patent').

'THE FLAME TEMPERATURE IS COMPARABLE TO THAT OF NATURAL GAS, ENABLING THE RETROFITTING OF CURRENT FOSSIL FUEL INFRASTRUCTURE'
PHILIP DE GOEY



HOW METAL FUELS WORK

Iron powder is burned, for example in a refurbished coal-fired power plant or to generate energy for industry. The resulting rust powder is reduced back into iron powder by letting it react with green hydrogen produced with the aid of solar or wind energy. When used this way, iron powder is a cyclic fuel that can be used again and again, emits no CO_2 and very little nitrogen oxide, is safe, very compact and cost competitive.



How to produce the iron powder with the required composition and specifications ('that is what our most recently granted project is about'). How to prevent the iron from evaporating and the iron oxide particles from sticking together. And how to reduce the iron oxide resulting from the combustion in the most efficient and most cost-effective way ('we have built and tested three different reactor demonstrators, but we are also looking at possibilities of using new exciting innovations like direct electrolysis without the presence of hydrogen').

'THE UNBRIDLED OPTIMISM OF YOUNG PEOPLE HAS CERTAINLY GIVEN THE DEVELOPMENTS AN IMPORTANT BOOST'

PHILIP DE GOEY

STIMULUS FROM STUDENTS

'In terms of valorization, it has been extremely helpful that in 2016 an honors student team was formed that is dedicated to metal fuels, team SOLID. The enthusiasm and unbridled optimism of these young people has certainly given the developments an important boost,' acknowledges De Goey. It was team SOLID that, as part of a Metal Power Consortium Lighthouse project, in 2020 made the international headlines with a pilot to demonstrate a 100 kW steam boiler system at the Swinkels/Bavaria brewery.
In 2021, team SOLID in its turn resulted in the launch of a new start-up company, RIFT, which has acquired over ten million euros of funding and in 2023 demonstrated an iron combustion based heat boiler that heated 500 houses in Helmond for a few days.
A second start-up was launched in 2022: IRON+, a joint venture between Pometon, EMGroup and Metalot. They have developed a MegaWatt size iron power plant, which was recently applied to a duration test, again at the Swinkels/Bavaria brewery.
After the establishment of IRON+, Metalot stepped out to maintain its independent position and was replaced by recycling company Nowit. Metalot is currently building the worldwide ecosystem.

IN THE STARTING BLOCKS

All-in all, some 9 years after De Goey's initial idea, everything is now in place to scale up the iron power technology toward commercially viable proportions, he says. 'We have the scientific expertise, the practical knowhow, and the appropriate partners on board. Now it is time for the Netherlands to take advantage of our position as a frontrunner in this field and to start reaping its benefits.'

CLEANER AIR WITH A COLD CATALYTIC CONVERTER

In a paper in the prestigious journal *Science*, EIRES researchers outline a new catalyst that can purify exhaust gases at room temperature.

Valery Muravev, Alexander Parastaev, Yannis van den Bosch, Bianca Ligt, Nathalie Claes, Sara Bals, Nikolay Kosinov, Emiel J.M. Hensen, Size of ceria support nanocrystals dictates reactivity of highly-dispersed palladium catalysts, Science, (2023)

AWARDS & GRANTS

POTENT IRON POWDERS

EIRES researchers Xiaocheng Mi and Giulia Finotello were awarded a new project in NWO's Open Technology Program. The grant of 845,000 euros enables them to appoint one postdoc and two PhD researchers as part of the next steps in the large-scale deployment of metal powders as renewable energy carriers. The research – taking place under the name CIRCL, Closing the Iron Reduction-Combustion Loop – involves Metalot, RIFT, Shell and EIRES, and focuses specifically on the regeneration of burned iron powder.

GROWING WITH GREEN STEEL

By implementing circular chains and reducing emissions, Growing with Green Steel aims to accelerate the transformation to a sustainable steel sector by five years and thereby build a strong international competitive position. The project does this by focusing on innovations through manufacturing companies that help reduce the sector's CO_2 and other harmful emissions, and reuse raw materials. The National Growth Fund is investing € 124 million in the project.
Involvement from TU/e: Mark Geers, Niels Deen, Philip de Goey, Johan Maljaars.

MATERIAL INDEPENDENCE & CIRCULAR BATTERIES

Battery technology plays a crucial role in the energy transition to store green energy. The Material Independence & Circular Batteries program focuses on realizing a strong position for the Dutch manufacturing industry in the global battery chain, with sustainability and circularity at its core. This is essential to achieve climate goals and sustainable economic success in the Netherlands.
The National Growth Fund is investing up to € 296 million in the project. Of this amount, € 118 million has been conditionally allocated and € 178 million is booked as a reservation.
Involvement from TU/e: Antoni Forner Cuenca, Theo Hofman, Pascal Etman, Tijs Donkers, Henk Jan Bergveld, Adriana Creatore, Kitty Nijmeijer, Patrick Anderson.

SOLARNL FOR CIRCULAR SOLAR PANELS

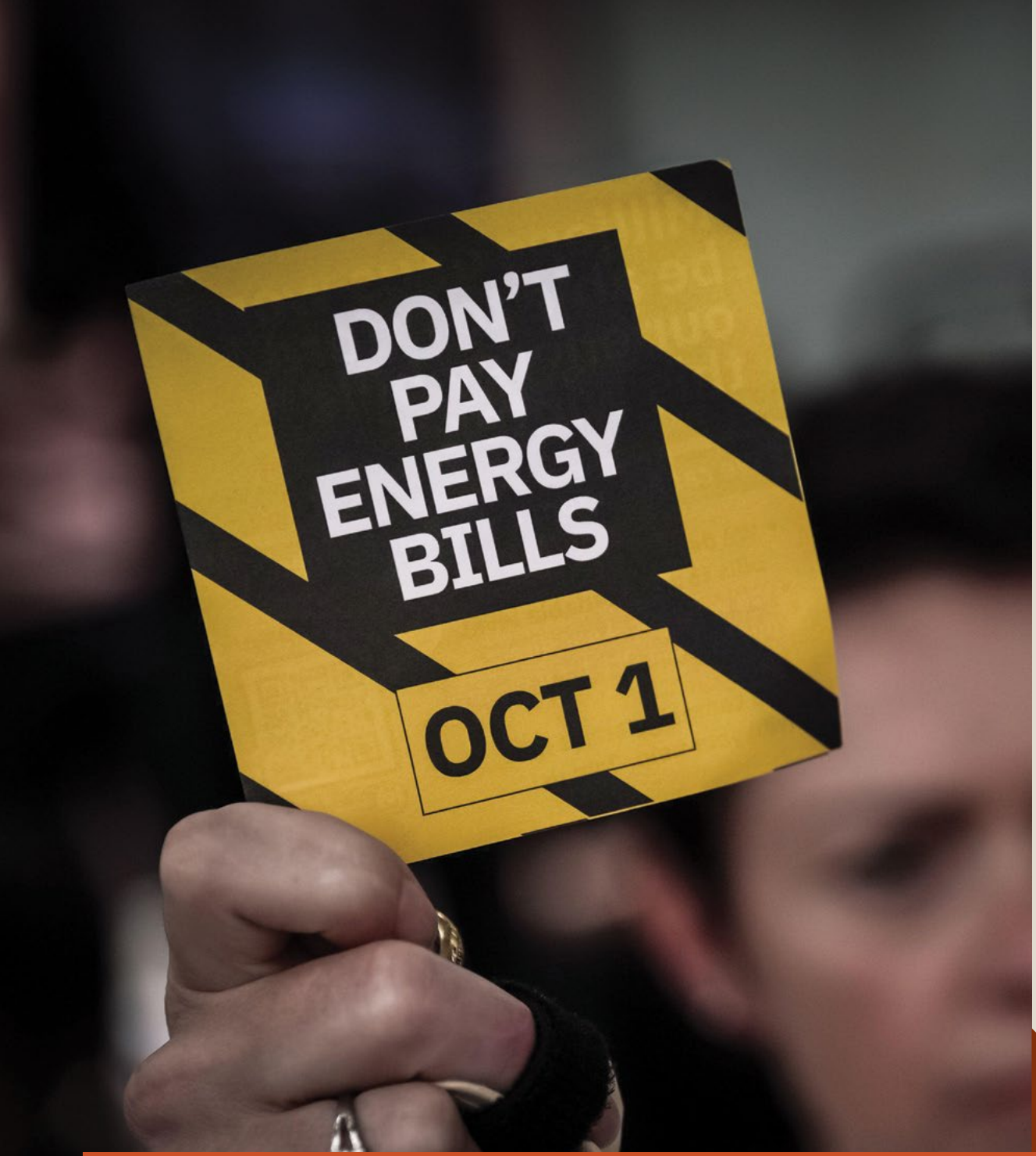
Energy from sunlight plays a key role in the transition to renewable energy. Globally, solar PV is growing rapidly and the capacity in the Netherlands is increasing substantially. The SolarNL program focuses on the development and industrialization of new solar PV technologies. The next generation of solar panels is fully circular, has very low CO_2 emissions, can be integrated into façades or car roofs, for example, and is much more efficient, requiring less space.
The National Growth Fund is investing up to € 412 million in the project. Of this amount, € 135 million has been granted definitively and € 177 million conditionally. In addition, € 100 million has been reserved for a possible loan for one of the consortium participants.
Involvement from TU/e: René Janssen, Erwin Kessels, Adriana Creatore.

CHARGING ENERGY HUBS

The demand for electricity and renewable energy is increasing for vehicles that do not emit CO_2. The current electricity grid and laws and regulations are not yet geared to this increasing demand. The proposal seeks to address this problem by developing so-called Charging Energy Hubs. These will enable the integration of charging infrastructure, battery storage and renewable energy sources within the existing grid.
The National Growth Fund is investing € 44 million in the project.
Involvement from TU/e: Theo Hofman, Mauro Salazar, Guus Pemen, Maurice Roes.

ERC GRANT FOR PHILIP DE GOEY

Philip de Goey, Professor of Combustion Technology in the Power & Flow section within the Department of Mechanical Engineering, was awarded an ERC Proof of Concept Grant by the European Research Council for his research into the combustion of metal fuels.
In 2020, De Goey already received an ERC Advanced Grant (2.5 million euros) for MetalFuel on which 6 researchers are working on new science regarding the combustion of metals.



TOWARD A JUST

ENERGY TRANSITION

Policymakers are confronted with a growing urgency to act upon climate change, while simultaneously, justice considerations are increasingly foregrounded. Based on a thorough analysis, EIRES researchers outlined recommendations for just energy transition policymaking.

Natascha van Bommel, Johanna I. Höffken, The urgency of climate action and the aim for justice in energy transitions – dynamics and complexity, Environmental Innovation and Societal Transitions, 2023

CALOSOL: PAINTED PANELS TO HARVEST SOLAR HEAT

Over sixty percent of all the energy we use comes in the form of heat. Why not use the façades of buildings to harvest that heat directly from the sun? That is the vision Calosol, a spin-off from TNO and building company Emergo, wants to realize.

It was a radical change in thinking that ultimately led to the façade panels Calosol is now commercializing. 'AkzoNobel had developed a coating to cool buildings by reflecting sunlight. At a trade fair where they were presenting their innovation, I asked them "Why not turn this idea around and absorb the energy to heat the building instead?"', recollects co-founder and CTO Bart Erich, who also is a researcher at TNO and TU/e.

CAPTURING THE INVISIBLE

This idea led to the development of a coating that efficiently absorbs an important yet invisible part of the solar spectrum: the near infrared, which makes up about fifty percent of all radiated energy. 'We apply this coating to specifically designed panels to be attached to building façades. The biggest advantage of the coating is that it can be produced in a wide range of colors and still absorbs enough of the energy. This is an important feature if you want to apply it in the built environment,' explains Erich. The heat is transported via fluid in the back of the panels and acts as a heat source for a heat pump allowing it to be used for heating or warm tap water.

'WHY NOT ABSORB THE ENERGY TO HEAT THE BUILDING INSTEAD?'

BART ERICH

The panels have been installed on the façade of a sports hall in Almere, where they provide heat to the showers, the floors and radiators, and in two renovation projects for social housing companies in Eindhoven and in Helmond. 'At the moment we are building a catalogue of the different products that are available now, and continu our research on the fundamental challenges that still exist.'

What role should EIRES play in university, science and society, and how can national and international collaborations in the field of energy research accelerate the pace of the energy transition? TU/e's rector magnificus Silvia Lenaerts and DIFFER director Marco de Baar provide their views.

INTERVIEW WITH SILVIA LENAERTS: 'CHERISH THE OUTSIDE-IN APPROACH'

WHAT IS THE ROLE OF THE RESEARCH INSTITUTES AT TU/e?

'The institutes are very important, since they act as windows on society and catalysts for our collaborations on the great challenges of our time. I view them as strategic instruments to steer research on specific topics and to put that research in the picture.'

HOW DOES EIRES COMPARE TO OTHER ENERGY RESEARCH INSTITUTES?

'A striking characteristic of EIRES is the choice to look at the entire chain from materials to systems of systems. The institute not only studies materials from the microlevel up, but also looks at the integration of new materials and devices in the entire energy system. And social innovations are considered as well. The combination of the technological and the societal innovation aspects of the energy transition in a single institute is rather unique.'

HOW DO YOU VIEW THE RELATIONSHIP BETWEEN EIRES AND DIFFER?

'Though there are a lot of collaborations between the two already, I think we could do more. We could share our infrastructure and jointly apply for big infrastructure investments, and TU/e could follow DIFFER's example in becoming even more open to exchange of researchers between universities. I see ample opportunities for DIFFER and EIRES to strengthen each other. And let's face it, when it comes to the energy transition there is so much to do in so little time, no one can afford to indulgence in navel-gazing.'

WHAT ROLE SHOULD EIRES TAKE UP IN THE ENERGY TRANSITION?

'I view universities in general as neutral drivers that can bring together different parties from government, academia and industry. I strive for a university without walls, which is open to society, industry and start-ups to learn and experiment together. On the topic of energy, we could do more with vocational and professional education institutes here in the region. We could realize joint demonstration set-ups and organize hands-on learning experiences, just as is happening at the automotive campus in Helmond around future mobility.'

WHAT SHOULD EIRES FOCUS ON IN THE COMING YEARS?

'I applaud the fact that the institute focusses on scalable, modular systems and the integration in the energy system of the future. I think in the end we will have an energy system that is more decentralized, modular, and a combination of technologies, and that nowadays, reducing our demand for energy deserves to get more attention.'

INTERVIEW WITH MARCO DE BAAR: **'WE NEED TO COVER ALL SCALES'**

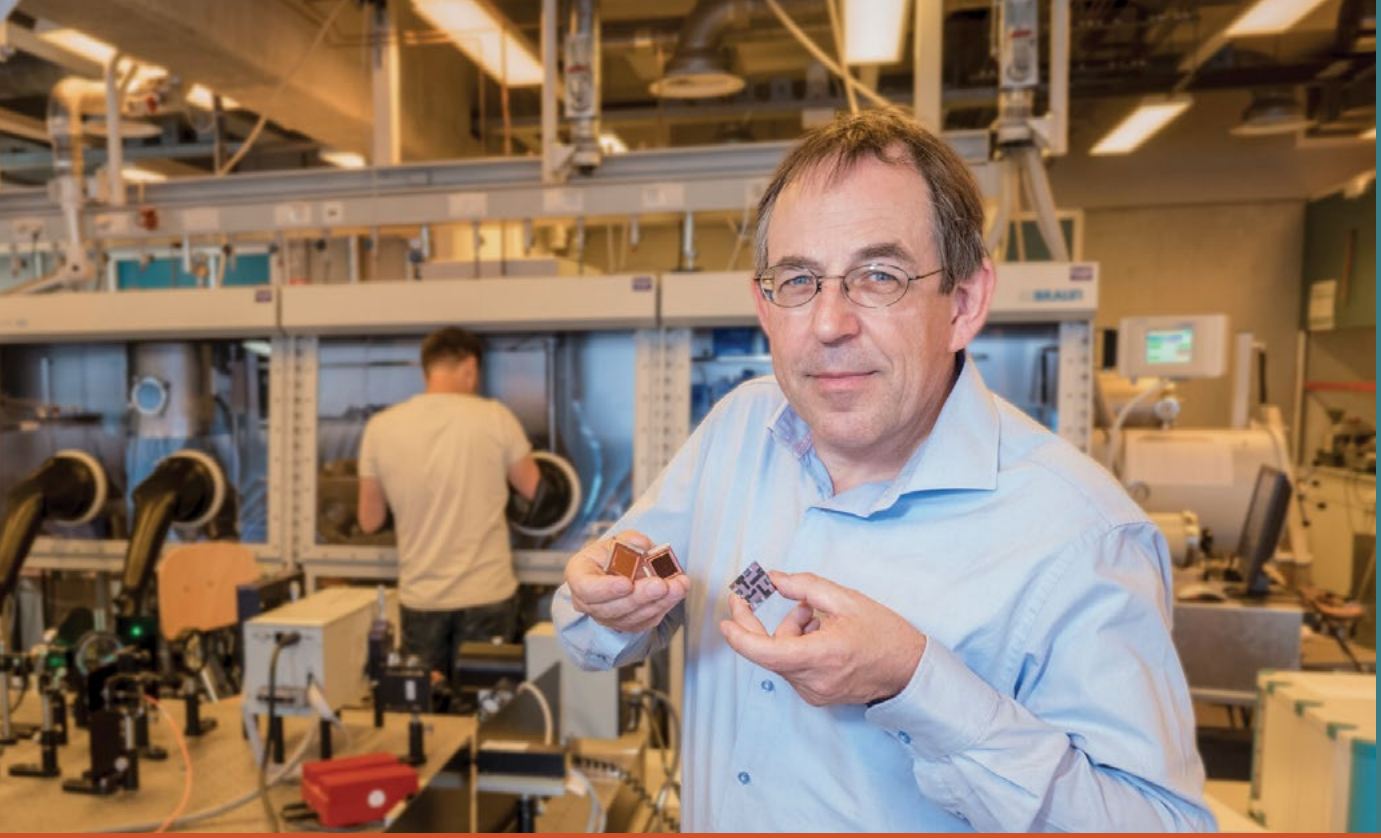
WHAT ROLE DOES DIFFER PLAY IN THE DUTCH ENERGY RESEARCH LANDSCAPE?
'We are a national institute that develops and provides unique scientific infrastructure both for our own research groups and for other national and international scientific actors.'

WHAT WILL DIFFER FOCUS ON IN THE COMING YEARS?
'Our main focus will be on expanding our infrastructure for the solar fuels research. We want to be able to make clusters of nanoparticles that can store renewable energy through chemical conversion. The dream is to end up with a robotized lab where smart autonomous robots understand the electrochemical objectives we are aiming for in new materials and revolutionize the materials research process.'

HOW DO DIFFER AND EIRES WORK TOGETHER?
'DIFFER has a national role to be relevant for knowledge institutes and private partners in the energy sector. That is why we are collaborating wherever and whenever we can, and, in that sense, we do not favor Eindhoven in any way.
Having said that, many of our scientists also have appointments at TU/e and collaboration occurs naturally. A nice example is the Dutch Fusion Day we organized on 3 May 2024. That was a joint initiative to explore which parties would be interested in working on aspects of fusion energy and how to attract new companies and start-ups to the field.'

WHAT IS THE BIGGEST CHALLENGE IN THE ENERGY TRANSITION?
'There is no single challenge. We need to cover all scales, from materials and processes all the way up to the system level. We need to achieve a huge acceleration. This is only possible if we combine low and high Technology Readiness Levels and incorporate high level systems engineering principles right from the start. For example, when we are developing new materials for energy storage, we need to include aspects like scarcity of resources, toxicity and cyclicity at the earliest stages, to prevent us from developing something that might be technically superior, but impossible to be implemented at the required scale.'

DO YOU HAVE ANY ADVICE FOR EIRES?
'There are lots of excellent individuals with very creative minds. But that is not enough. In order to have real impact, these creative individuals need to be aligned in large programs and this means that strategic choices need to made. EIRES is well placed to help TU/e to develop a coherent strategy on energy research and the required facilities.'



IN THE LIMELIGHT
SPOT ON SOLAR CELLS

TU/e researcher and Spinoza laureate René Janssen received his second ERC Advanced Grant. He wants to make perovskite solar cells that are up to twice as efficient as current silicon-based cells.

Chemist René Janssen aims to stack three or four different perovskite solar cells that are designed to each convert one part of the total solar light spectrum very efficiently. Collectively, this leads to higher efficiency and better utilization of the available solar energy. 'For a stacked solar cell like this to work properly, all of the cells must be able to supply the same amount of current. Small defects or instabilities have a huge effect,' he comments on the challenges ahead.
Next to the stacking challenges, there is also a major challenge in making the material stable. Perovskite has a soft structure and can exist in different phases, making the material unstable when trying to scale up. Janssen expects that it will take at least another 10 years before the technique can really be used. He therefore sees the ERC grant as a first step.

DOING YOUR BIT

'An awful lot of serious problems have already been solved through science, like HIV, acid rain, the hole in the ozone layer, and the corona virus. But the biggest problem is still ahead of us: our climate. That's a scale bigger and more unmanageable than anything we've seen so far. It's up to science to take all of the steps possible to help solve this problem. I am very happy to do my bit,' the researcher concludes.