

# PRO FILE 2020

DEPARTMENT OF ENGINEERING

RESEARCH  
TECHNOLOGY  
EDUCATION

## CHANGING OLD INDUSTRIES BY MIMICKING NATURE

Associate Professor Selin Kara aims to replicate natural bio-processes for use in the chemical industry

"This will be a huge achievement for the chemicals industry, as chemical synthesis today is very polluting"

### GENDER IMBALANCE IN ACADEMIA

Six female engineering scientists express their views

### NOTHING-GOES-TO-WASTE-TECH

Danish research to make methanol production 100% green

### OPEN-SOURCE SOLAR ENERGY

Crucial free-for-all model of global solar energy output



AARHUS  
UNIVERSITY  
DEPARTMENT OF ENGINEERING



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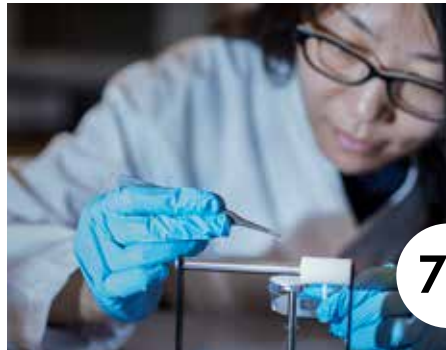
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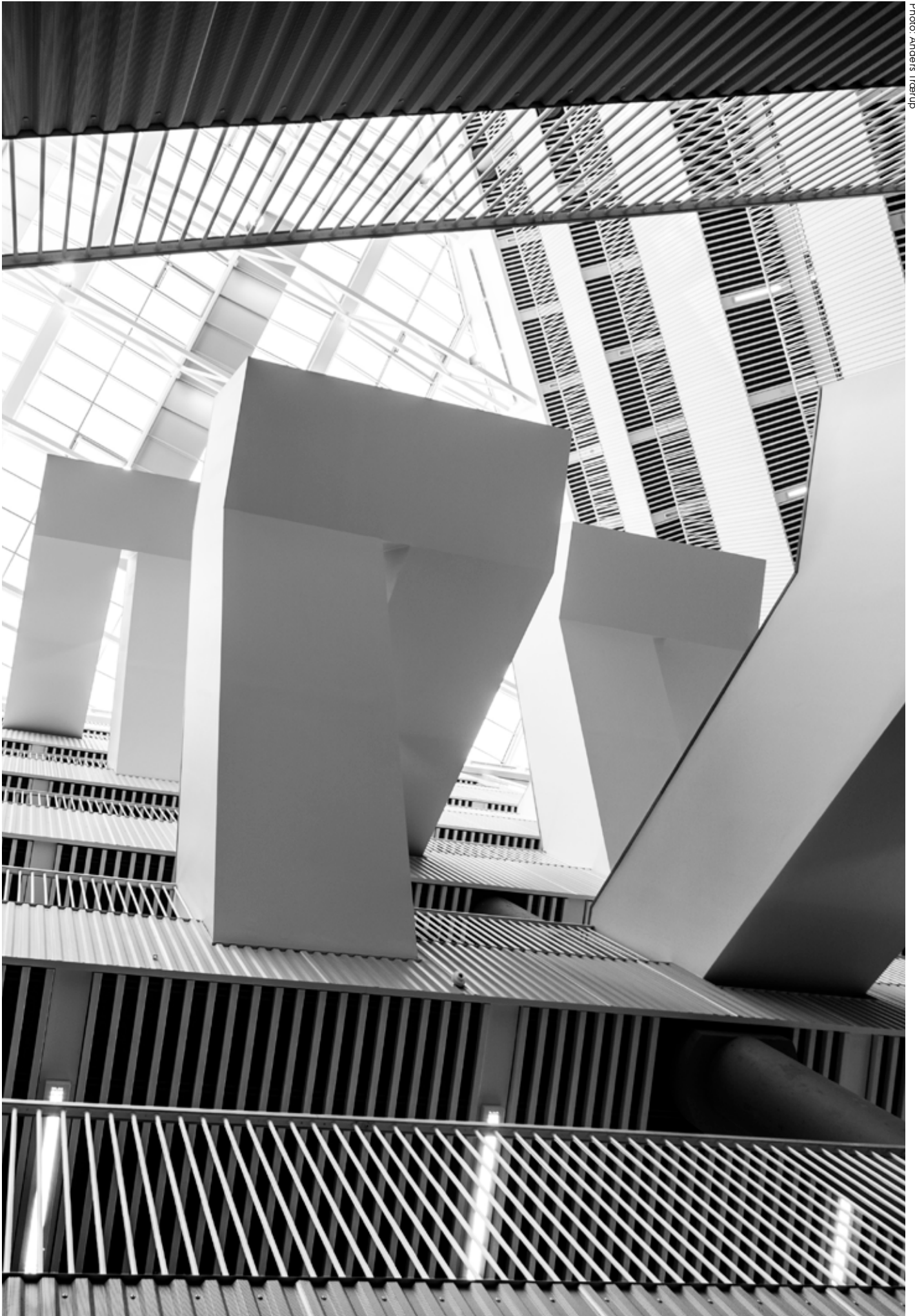
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## Forging a world for everyone

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*"Scientists discover the world that exists; engineers create the world that never was."*

The Hungarian-American aerospace engineer, Theodore von Kármán was born right in the middle of the 19th century First World industrialisation.

He saw with his own eyes what engineering science could mean for the world. How it changed the world; for better and for worse. Engineers have always been at the front of the technological revolution. It's our *raison d'être*. It's even in our name: In Latin, 'ingeniare' means 'to create, generate, contrive, devise'.

Engineers form the link between deep science and its subsequent application to human needs. No other discipline has such a strong link between the comprehension of science and its creative application. It's the engineering trademark.

And that's why Kármán's quote is so important today. We live in a time when the world is struggling with overwhelming problems such as climate change, overpopulation, food shortages and poverty. A time when human beings are using more resources than the Earth can replace.

Engineering science has to create the foundation for a sustainable tomorrow. It's the innovative, creative and research-based source code of engineers

that will help shape a possible future for humankind on Earth.

Theodore von Kármán lived at a time of exponential progress, economic growth, and the change from agrarian to industrial society; but it was also a time of war, pollution and rising Third World poverty.


Today, we live in an era when we have the ability to change all that to the better. We have the technology to initiate a disruptive change, which could have profound ramifications for all of Earth. We can battle climate change, overpopulation, food shortages and poverty. But we need engineers to do so.

That's why I'm proud to present a selection of the research going on at the Department of Engineering at Aarhus University. Because I believe this magazine is proof of my assertion above: Engineering science can help forge a greener world for everyone.

Engineers really can create the world that never was: The world we are all striving for.

**Thomas S. Toftegaard,**  
Head of Department of Engineering  
Aarhus University

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Researchers at the Department of Engineering, Aarhus University, are world leaders in unique brain measurement via a special device fitted in the ear like a hearing aid. The technology is called ear-EEG, and it measures extremely small voltage changes on the surface of the skin inside the ear caused by electrical activity in the brain's neurons. Now, the university has received a DKK 20 million grant to ensure further development of this Danish-designed method.







# Aarhus University opens the world's first centre for ear-EEG

Researchers at the Department of Engineering are world leaders in brain measurement via a special device fitted in the ear like a hearing aid. The technology is called ear-EEG, and now the university has received a new grant to ensure further development of this Danish-designed method.

Aarhus University (AU) has received DKK 20 million (EUR 2.7 million) for a new research centre focusing on a unique method of measuring electrical activity in the brain.

The method is known as ear-EEG (ear-ElectroEncephaloGraphy) and it measures extremely small voltage changes on the surface of the skin inside the ear caused by electrical activity in the brain's neurons. The protected, more discrete placement makes the method more attractive than traditional EEG measurements, which use electrodes placed on top of the head.

The generous grant was donated by the families behind WS Audiology and UN-EEG Medical and the William Demant Foundation, including Oticon.

The research group Bioelectrical Instrumentation and Signal Processing, headed by Professor Preben Kidmose from the Department of Engineering at AU, has pioneered the area for many years and is currently the world leader.

"We've been working on this methodology for the past ten years, and the new centre will ensure a significant expansion of our research activities within ear-EEG. Our research develops the measuring technology itself and explores what is possible to actually measure. We see a huge potential in ear-EEG, both in terms of research and applications. For example, you can use ear-EEG to characterise hearing loss much more precisely than what is practicable today. Ear-EEG can also be used for other things, for example to explore human sleep patterns and help provide a better understanding of various brain diseases," he says.

## **24/7 brain measurement opens new doors**

One of the great advantages of ear-EEG is that the method enables measurement of brain activity outside the laboratory in a discreet and minimally intrusive manner, over a long period of time (potentially 24/7), and on large cohorts of people.

The method enables us to construct devices to measure brain activity and adapt it to the user in a radically different way





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**William Demant Foundation**

Since its establishment in 1957, the foundation has supported charitable projects and ensured the business activities of the Demant Group. The group is the world leader in hearing health, and includes Oticon and Interacoustics, which for several years have collaborated with both Aarhus University and Widex on research and development in hearing health.  
[www.williamdemantfonden.dk](http://www.williamdemantfonden.dk)

**UNEEG medical**

Founded in 2005, UNEEG medical manufactures equipment for discrete long-term monitoring of EEG. The company has just launched an implant for long-term monitoring of EEG that can help in the diagnosis or treatment of people suffering from e.g. epilepsy or sleep disorders.  
[www.uneeg.com](http://www.uneeg.com)

**WS Audiology**

The hearing aid producer was formed in 2019 through the merger of Widex and Sivantos. WS Audiology is active in over 125 markets and employs more than 10,000 people worldwide. The company has a broad portfolio of leading hearing-related products and services.  
[www.wsa.com](http://www.wsa.com)





*Ear-EEG provides a unique opportunity to measure brain activity in our natural environment.*

than today. Among other things, Professor Kidmose hopes it will take us a step further towards understanding the human brain.

“Ear-EEG provides a unique opportunity to measure the brain in our natural environment. And that’s why we can begin to delve into things that we otherwise wouldn’t be able to measure. For example, we don’t really know much about how our sleep varies over time, and how it’s affected by our surroundings. And because we can measure sleep and patterns in the EEG that correlate with cognitive ability, we hope to get a better understanding of the correlation between sleep and cognitive ability. These are just some of the things I hope the technology will help us with,” he says.

#### Health-promoting research

The opening of the centre is very important for both the William Demant Foundation, UNEEG medical and WS Audiology, who consider their massive investment in development of this Danish technology as a matter of course.

“We’re proud to support this world-leading centre that can bring forward new knowledge about how we can record impulses in the ears, and how we can use this knowledge to benefit general health. At the William Demant Foundation, one of our main tasks is to support research and innovation that can help alleviate hearing

health,” says Lars Nørby Johansen, chair of the William Demant Foundation, and the families behind WS Audiology agree:

“We’ve been working with Professor Preben Kidmose at AU for many years, and we’ve seen many exciting results. That’s why I’m very pleased that we’ve been able to help establish a more permanent framework for his research. Ear-EEG has the potential to help people in surprisingly many areas, and I’m sure that this centre will speed up the realisation of these opportunities for the benefit of everyone,” says Richard Tøpholm, CTO of UNEEG Medical, a fellow subsidiary with WS Audiology.

#### Underpins the university strategy

The grant is also very important for Aarhus University’s digitalisation strategy, which has focus on research into next-generation technology and methods to monitor and work with the human brain, says the head of section for Electrical and Computer Engineering at the Department of Engineering, Aarhus University, Senior Professor of Engineering Jens Kargaard Madsen:

“We’re very pleased that, with this grant, we can now open the ear-EEG centre and strengthen our position significantly with a view to continuing as the world leader in this field of research,” he says. ●



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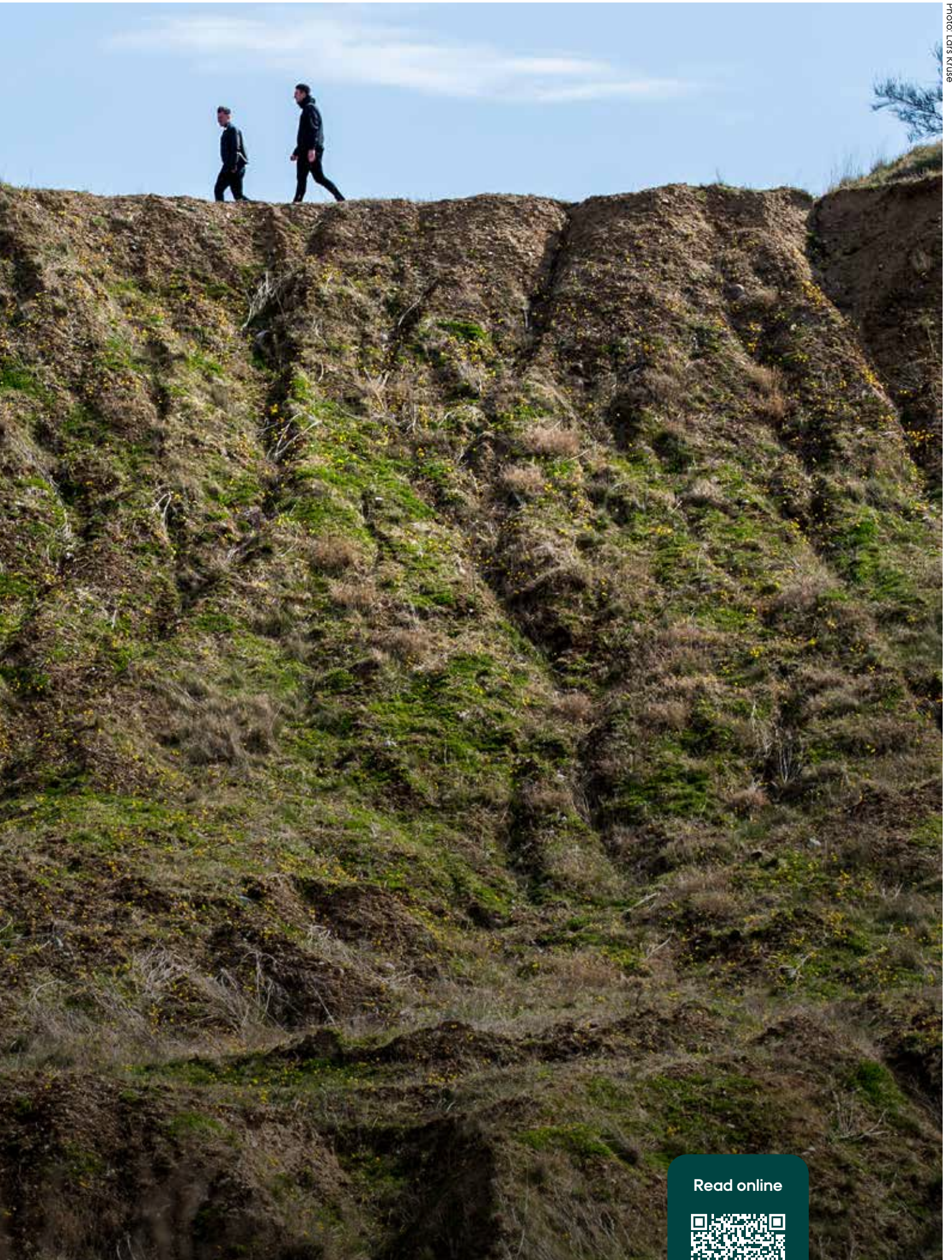
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WEB EXCLUSIVE

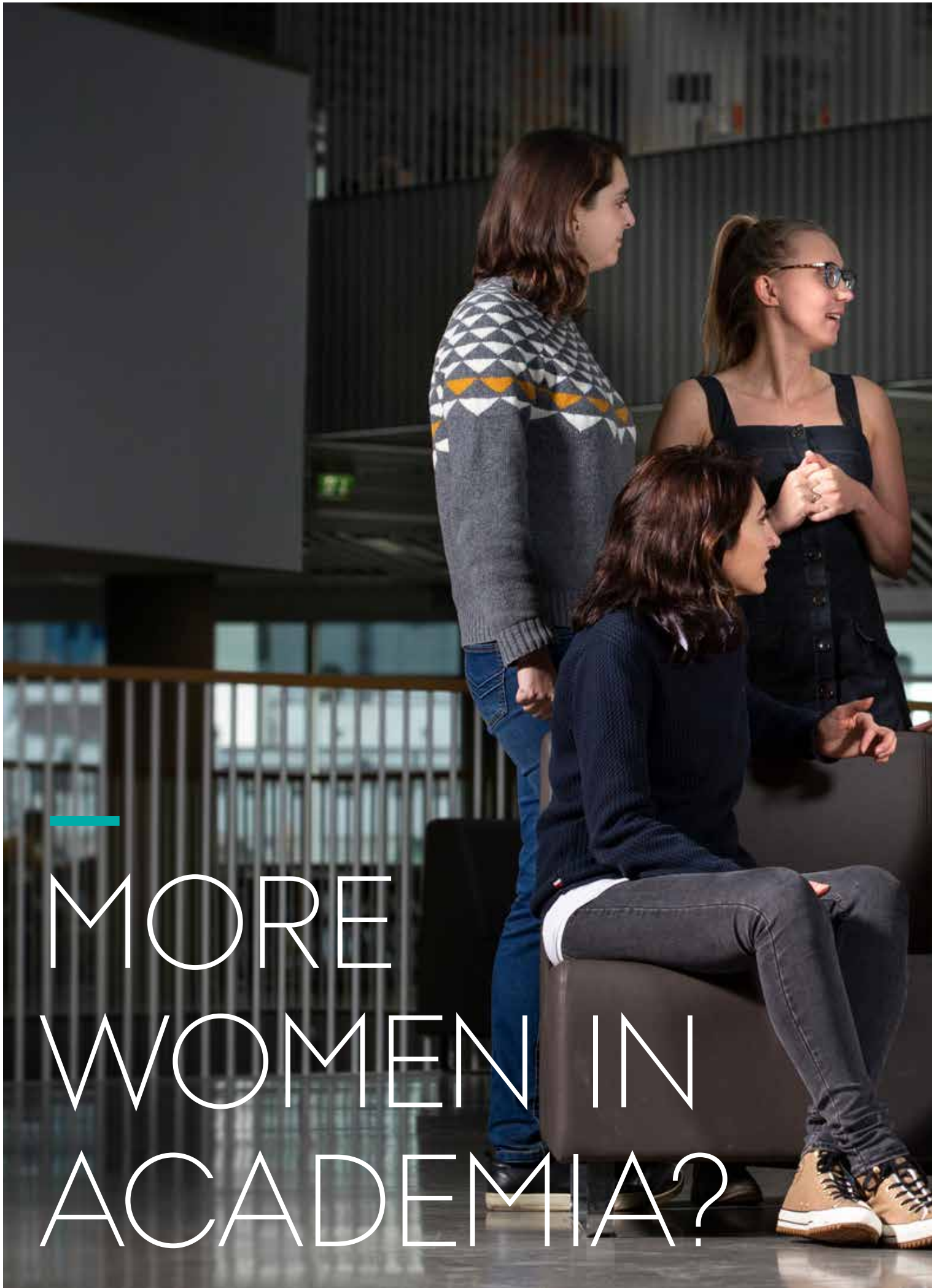
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Not only batteries can store wind energy. Two master of science in engineering students from Aarhus University are working on a project that, using a huge balloon and tonnes of ordinary soil and water, will make a giant battery for renewable energy.



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# MORE WOMEN IN ACADEMIA?





**BLOG:****How do we get more women in academia?**

*The Inge Lehmann programme is a new talent programme announced in December by the Danish Ministry of Higher Education and Science.*

*The following essay is the response to the new programme by six female scientists from the Department of Engineering, Aarhus University.*

“More women researchers,” was the cry in a press release from the Ministry of Higher Education and Science on the 16th of December. The outset was a new talent programme, the Inge Lehmann programme, which, from 2020, aims to ensure that more women join academia at Danish universities.

Currently, just 15 per cent of all professors in the natural and technical sciences are women, and a little more than one in four of all researchers are women (26 per cent). Coincidentally, a full 49 per cent of all Danish researchers are involved in the natural and technical sciences<sup>1</sup>.

Obviously, change is needed.

Researchers at universities thrive on creating innovative solutions for society. Balanced teamwork that represents diverse perspectives is paramount to ensuring optimum solution paths. It is well understood that balanced representation of both genders is crucial for academic and research output. This not only lays a democratic foundation for research, but it also ensures an unbiased and fair view of the issues we're trying to solve.

It's not wrong to say that gender diversity

forms the cornerstone of research, and it is essential to tap the intellectual power of all genders.

However, given the gap in gender diversity, it will take more than just a programme to change things. It will take a cumulative effort of changed mindsets, visible female mentors, and family encouragement to make the changes we envision.

We're female researchers in the natural and technical sciences based at the Department of Engineering at Aarhus University. We all love what we do and are proud of the choices we've made in our lives.

We solve problems. That's what engineering science is all about. For example, we're trying to imitate nature so that we can manufacture chemicals in a completely environmentally friendly way. We're researching the uses of light and communication technologies to make the internet more intelligent but less energy intensive. We're making strides in encapsulating printed electronics with bio-species for future healthcare technologies. We're developing new solar cell architectures that can absorb solar energy better than ever before. And we aren't

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doing all this alone. We're working with researchers from all over the world; collaborating across faculties and departments and fields to ensure that the results we achieve are comprehensive and universally relevant.

We work in disciplines of engineering that have been dominated by men for centuries. We have felt the same prejudice that many women feel; we have been at the receiving end of strange looks; and we have often been questioned about our choices and felt needless pressure. But here's the good news: nothing stopped us.

If you want to forge a successful career, you'll face obstacles, regardless of job

hard problems of our world. This is precisely why we all made the choices we did. We're driven by the same desire to make a difference: to make things better than they are. Today, we can actually help steer the development of society towards sustainability.

But there's no such thing as a gender-correlated job. Whatever men can do, women can do too. And vice versa.

But let's get real here: women and men are not alike. Women in general aren't risk-takers like men. We doubt ourselves more and are critical of our choices. All of us have felt the same apprehensions and doubts, but over the years, mentoring and

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*There's no such thing as a gender-correlated job.  
Whatever men can do, women can do too.*

*And vice versa.”*

and gender. The fields of science, technology, engineering and mathematics, STEM for short, are plagued with preconceptions and stereotypes, and as researchers within those fields, we feel we should voice our concerns to put an end to such misgivings.

A change of attitude is needed. And getting the younger generations excited about STEM would probably be the best place to start if we are to have more female researchers. This is because it is sad to see misconceptions thriving in the part of the population that will fundamentally determine the gender distribution of researchers in the future – those still at school, and those who are about to choose a degree programme. It would be a crying shame if the careers and futures of these young people were determined by biased attitudes.

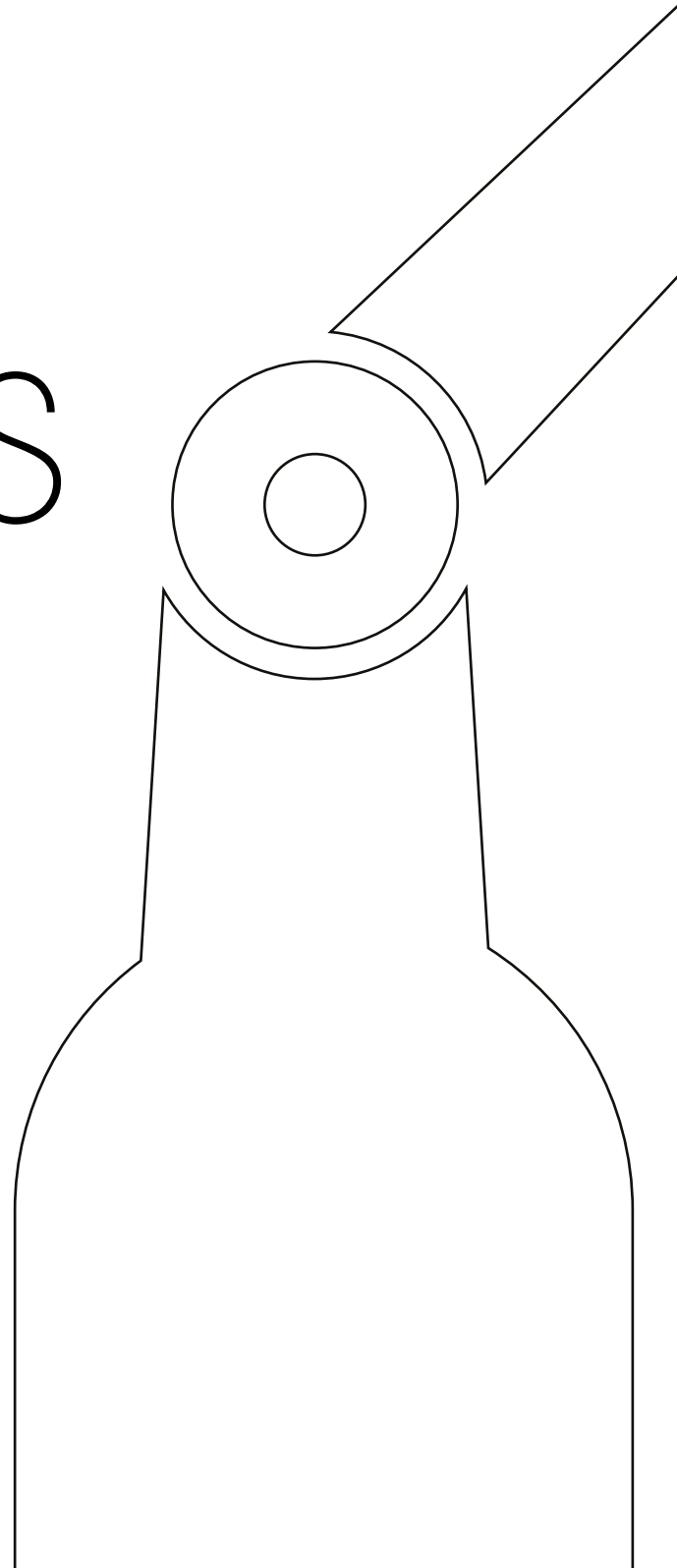
The truth is that science, technology, engineering and mathematics are highly creative, interdisciplinary and solution-oriented fields. There's no better chance to actually work with and change the die-

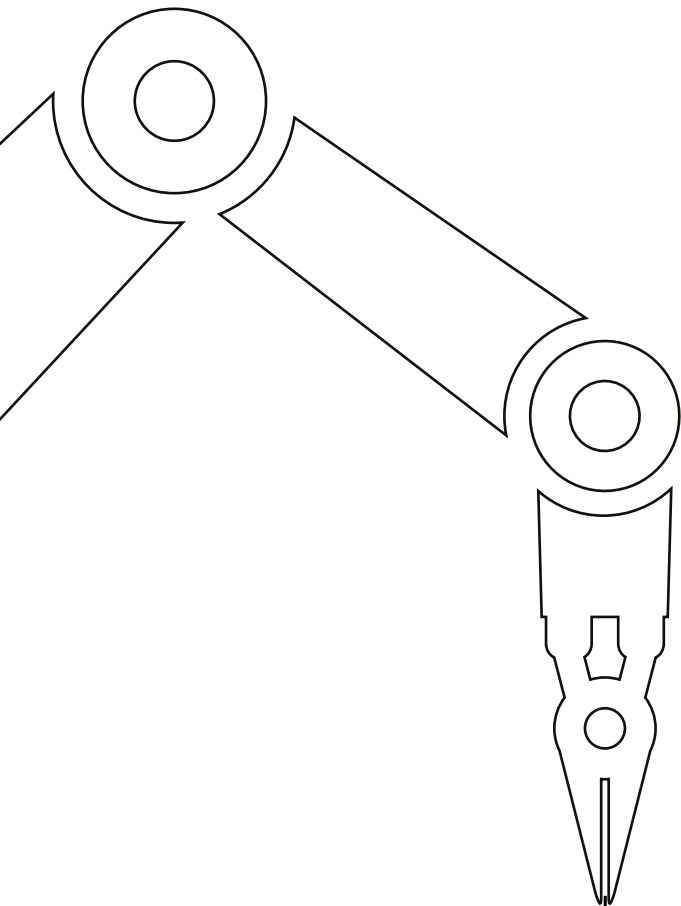
self-belief has instilled confidence, foresight and the capacity to take risks.

With that in mind it's worth remembering that interest in science, technology, engineering and mathematics is not determined by chromosomes or misperceptions. Just be passionate and believe in yourself. ●

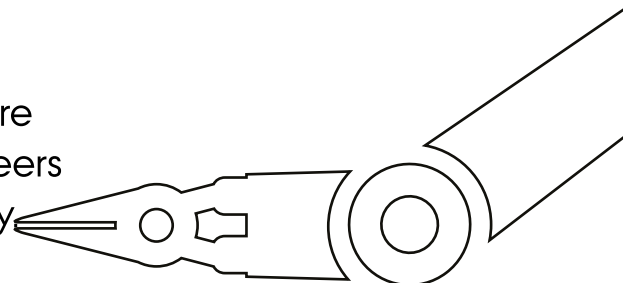
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134-YEAR-OLD  
DANISH  
FAMILY  
BUSINESS  
READY  
FOR  
ROBOTS





Jydsk Emblem Fabrik  
A/S in Malling, Jutland  
produces medals,  
trophies, emblems,  
name tags and  
accessories for uniforms.  
Now, the family-owned  
company wants to have  
collaborative robots  
working with their  
employees, and they're  
doing this with engineers  
from Aarhus University.



“I think robots could become an entirely natural part of our workforce.”

This is what Hanne Hørup, the managing director and co-owner of the 134-year-old family-owned company Jydsk Emblem Fabrik A/S, has to say about the prospect of, finally and with the help of Aarhus University, getting robots involved in their production chain.

The company, which has produced trophies, pins, medals and accessories for both private and state uniforms since 1886, has jumped aboard the university's Industry 4.0 development programme (see page 105), Smart Industry. In brief, the programme is about getting small and medium-sized Danish companies involved in the technological, computer-programmed world of the future.

“Not to replace employees, but to give them a robot workmate. To give our employees the huge boost that robots can provide. By letting robots do the most repetitive work, we can increase production and reduce the strain on our employees. I see it as a huge benefit for everyone,” says Hanne Hørup.

Initially, she was much more sceptical, when her husband and fourth-generation owner of the company, Stig Hellstern, first took her by the hand and dragged her to a trade fair on robots.

#### Reluctant Danish SMEs

Back then, she couldn't imagine how large industrial robots could ever be an efficient part of their factory. But when she saw how collaborative robotic arms can simply and efficiently be incorporated into a production line and work together with people without risking accidents, she was sold on the idea.

And when Xuping Zhang, associate professor and expert on collaborative robots at the Department of Engineering, Aarhus University, contacted her to hear whether she was ready to collaborate, Hanne Hørup and Jydsk Emblem Fabrik A/S jumped at the chance.

“The idea is to integrate cooperation between people and robots into production, so that they share their work and cooperate fully. The goal is to increase efficiency by reducing the strain injuries that often

result from monotonous, repetitive work, and to enable employees to focus on tasks with a higher value. Unfortunately, not many small and medium-sized Danish companies are willing to ride the robot wave, even though they're increasingly worried about losing competitive ground to foreign Industry 4.0 companies, and even though it's actually very easy to start a development programme with us,” says Xuping Zhang about the collaboration.

“

*It's fantastic to open up for the opportunities offered by modern technology”*

Hanne Hørup, managing director and co-owner of Jydsk Emblem Fabrik A/S

In cooperation with the machine supplier NIZE Equipment ApS, Jydsk Emblem Fabrik A/S and Aarhus University have now started a development project as part of the Central Denmark Region's Smart Industry development programme.

#### Plenty of services available

The programme focuses on innovation-collaboration and knowledge sharing, whereby researchers from the university share knowledge with companies in order to optimise processes and incorporate new technology.

“There are many of these kinds of services for small and medium-sized enterprises, but many companies don't even know that they exist. And that's a shame, because it's fantastic to open up for the opportunities offered by modern technology,” says Hanne Hørup about the project.

The development collaboration between Jydsk Emblem Fabrik A/S, NIZE Equipment ApS and the Department of Engineering at Aarhus University is called “Integrating Human-Robot Collaboration into Danish SME Manufacturing and Production” and it will run from October 2019 to December 2020. The companies only invest in the work hours spent on the programme, which is being funded by the EU Regional Fund and the Central Denmark Region with a little less than DKK 1 million (EUR 130,000). ●

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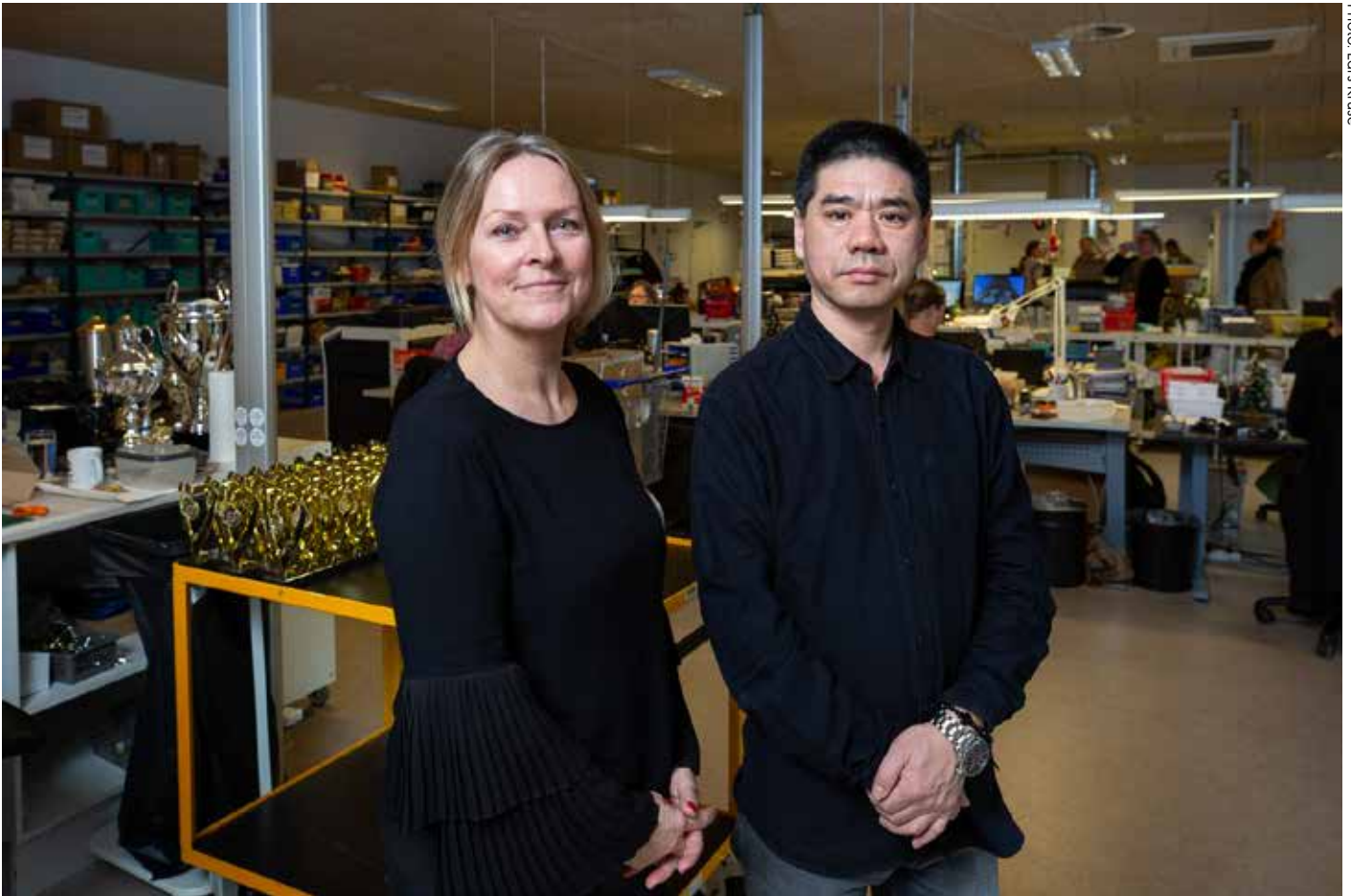


Photo: Lars Kruse

Hanne Hørup (left) and Xuping Zhang at the company Jysk Emblem Fabrik A/S located in Malling, Aarhus.

“

*The idea is to integrate cooperation between people and robots into production, so that they share their work and cooperate fully”*

**Project title:**

Integrating Human-Robot  
Collaboration into Danish SME  
Manufacturing and Production

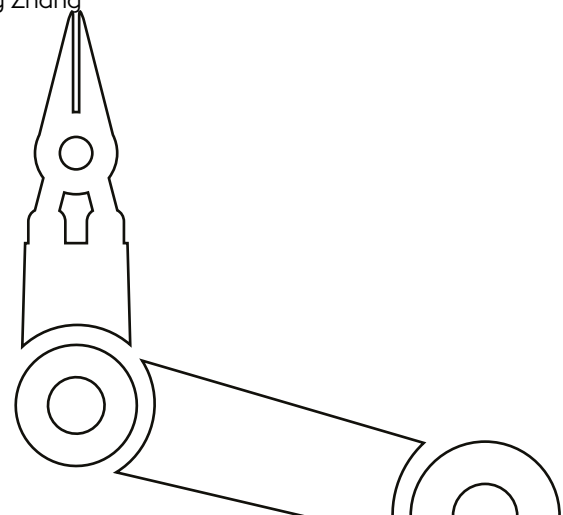
**Financial framework:**

DKK 1 million, EU Regional Fund  
and Central Denmark Region

**Partners:**

Jysk Emblem Fabrik A/S  
NIZE Equipment ApS  
Aarhus University

Associate Professor Xuping Zhang



New researcher at the  
Department of Engineering:  
Nicolas Volet





“

*We recently came across a physical phenomenon that, to the best of our knowledge, is totally unexplored. We intend to exploit it to significantly reduce the size, the weight, the cost and the complexity of laser packaging for telecommunication and for instrumentation”*

Tenure Track Assistant Professor Nicolas Volet





## **New AU researcher investigating miniaturized laser technologies with extreme stability**

Nicolas Volet is a laser expert and a new tenure track assistant professor at the Department of Engineering. He is starting a research project that may have far-reaching consequences for global data communication.

Photo: Melissa Bach Kirkeby Yildirim

The Department of Engineering, Aarhus University, has hired Nicolas Volet to build a new independent research group in Photonics. Nicolas Volet comes with more than ten years of research experience and has contributed to the development of chip-level photonic technologies in the visible, the near- and the mid-infrared spectrum.

He holds a PhD in physics from École Polytechnique Fédérale de Lausanne (EPFL), one of the world's leading technical universities.

"I currently work with lasers that are so small that you can't even see them with the naked eye. And you can't see the emitted light either, because it's infra-red. This makes visiting the laboratory a little dull, because there's simply nothing to see," grins the tenure track assistant professor when he introduces his research.

However, this does not mean that his research is any less important. Laser light is fundamental for modern global data communication, and researchers the world over are working to reduce the energy demand of lasers. This is an urgent matter, as the violent growth in Internet traffic means a rapid growth in energy demand.

The Internet is already responsible for approx. 10 per cent of global energy consumption. And traffic is increasing by 25-30 per cent annually.

"For that reason, researchers work hard to optimise the performance of products based on photonic integrated circuits (PICs) while reducing their carbon footprint. Make them smaller, more accurate, more power-efficient and more robust," says Volet, whose first PhD student will start a new research project at Aarhus University in March 2020, which he hopes will have a major impact on the semiconductor laser industries and optical telecommunication.

"One of the unique properties of lasers is the reduced spectral distribution of their optical emission as compared to other light sources. However, this laser 'linewidth' can be greatly influenced by the environmental conditions. Without saying too much, we recently came across a physical phenomenon that, to the best of

our knowledge, is totally unexplored. We intend to exploit it to significantly reduce the size, the weight, the cost and the complexity of laser packaging for telecommunication and for instrumentation. This technology has a feasible and credible path towards deployment out of the research laboratory, using mature material systems. These advanced PICs will mean much faster data communication, make it all much more energy-friendly, and moreover make the entire system more compact and cheaper to construct," he says.

Nicolas Volet came to Denmark in August and lives in Trøjborg with his wife and his two-year-old daughter.

"I am extremely grateful for this opportunity to continue my research in integrated photonics. At the university we have state-of-the art infrastructures, very talented researchers and amazing staff for support and technology transfer. I'm also happy to teach again: our Department of Engineering has a new Master's curriculum and I'm in charge of two courses in Photonics. It is a great responsibility to transmit our knowledge and passion to new generations of engineers," he says.

Nicolas Volet started his career in Switzerland with a master's degree in physics from EPFL. He wrote his master's thesis on photovoltaic solar energy at the University of Houston. He received a PhD in physics in 2014 from EPFL, for his thesis on vertical-cavity surface-emitting lasers (VCSELs). He was then awarded a post-doctoral fellowship from the Swiss National Science Foundation, and joined professor John Bowers' group at the University of California, Santa Barbara.

Before his appointment at Aarhus University, he was part of the team setting up the new R&D centre of a tech company in California.

His research interests include the physics and engineering of optoelectronic devices, and are driven to improve the precision, cost and power efficiency of industrial applications. His current projects involve the study of nonlinear phenomena to reduce the linewidth of diode lasers and the development of technologies for integrated quantum photonics. ●

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WEB EXCLUSIVE

# STUDY: URBAN NOISE DOES NOT SEEM AS LOUD WHEN WE LOOK AT NATURE

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Two engineering students from Aarhus University have set out to examine the correlation between what people see and what they hear. Using VR technology, they have discovered that looking at nature seems to dampen our hearing.

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With a DKK 60 million grant from EU Horizon 2020, a new pan-European project aims at developing a cloud-based collaboration platform to make it simple and easy for small and medium-sized enterprises to incorporate modern computer models in their development and production. The platform will be a playground for anyone who wants to try out model-based design of cyber-physical systems to find out whether it's something they can use before they spend any money.





Professor Peter Gorm Larsen.

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**Facts:**

Cyber-physical systems are collaborative computer-based networks that, via embedded sensors, direct and control physical objects or systems. A robot that reacts to sensor inputs is thus a cyber-physical system.

## New platform to help SMEs get started with cyber-physical systems

Small and medium-sized enterprises need better opportunities to exploit the benefits of computer-based models for cyber-physical systems. This is the objective of a new, large-scale, pan-European development project.

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Total funding of DKK 60 million (EUR 8 million) from the EU framework programme for research and innovation, Horizon 2020, is bringing together 17 universities and companies from seven European countries to develop a platform to make it simple and easy for small and medium-sized enterprises (SMEs) to incorporate modern computer models in their development and/or production.

This is far from simple for such companies today, says Professor Peter Gorm Larsen from the Department of Engineering at Aarhus University, who is coordinating the project:

“Cyber-physical systems are products with a physical component that is usually controlled by a cyber component (one or more computers), and these have caused a revolution in a very large number of industries. However, many SMEs don’t have any chance of keeping up with the new things happening in digitisation, and it

can be too costly just to jump aboard one thing or the other,” says the professor, adding:

“Therefore, the idea behind this project is to set up a collaboration platform in the cloud: This will include a large ‘sandbox’ for anyone who wants to try their hand at ‘playing’ with model-based design of cyber-physical systems to find out whether it’s something they can use before they throw money at it. So instead of finding tools on the Internet and installing them locally, you can test them directly in the sandbox.”

### One-stop-shop

The project is called HUBCAP and it is intended as a one-stop-shop for SMEs who want to try their hand at modelling cyber-physical systems: It is a playground where companies from all over Europe can try out intelligent IT systems for their development and/or production without having to take out their purses.



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“

*Many companies have not yet fully taken the technology to heart. This project makes this possible, and I hope that many SMEs will find it attractive”*

Professor Peter Gorm Larsen

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**Project title:**

HUBCAP

**Financial framework:**

DKK 60 million, Horizon 2020

**Schedule:**

3 years

**Partners:**

Aarhus University, Denmark  
 BEIA Consult, Romania  
 Controllab Products, Netherlands  
 Engineering Ingegneria Informatica  
 S.p.A., Italy  
 Fortiss GmbH, Germany  
 Fondazione Bruno Kessler, Italy  
 KTH Royal Institute of Technology,  
 Sweden  
 Newcastle University, United  
 Kingdom  
 Politecnico di Milano, Italy  
 Research Institutes of Sweden,  
 Sweden  
 RISE F6S Network Limited, Ireland  
 Technology Transfer Systems srl,  
 Italy  
 University “Lucian Blaga” of Sibiu,  
 Romania  
 Unparallel Innovation, Portugal  
 Validas, Germany  
 Veried Systems International GmbH,  
 Germany  
 Virtual Vehicle Research Center,  
 Austria

“We’re developing some models in the project for use as a sort of building block to make it easier for companies to get started. These models can be shared with other partners in the project, either for a fee or for free. They’re a bit like Lego bricks that make it easier to build things and get started on the game,” says Peter Gorm Larsen.

**Funds for SME projects**

As part of the project, it will be possible for SMEs to apply for funding to work on a specific project that they would like to try out using computer-based models. EUR

3 million of the EUR 8-million granted to the project has been earmarked for this purpose.

“I know that a lot of companies have already discovered the opportunities in using computer models to develop cyber-physical systems, but they have not yet fully taken the technology to heart. This project makes this possible, and I hope that many SMEs will find it attractive,” says Peter Gorm Larsen.





Photo: Lars Kruse

Professor Peter Gorm Larsen is heading the new AU Centre for Digital Twins.

## Denmark's first Centre for Digital Twins

With a donation of more than DKK 12 million from the Poul Due Jensen Foundation, the Department of Engineering at Aarhus University is opening the doors to a new centre for long-term research into digital real-time models of cyber-physical systems – so-called digital twins.

On Monday, 6 May 2019, Aarhus University officially opened the doors to its new, ultra-modern research centre: AU Centre for Digital Twins.

The purpose of the centre is to support the development of intelligent co-simulation of physical systems in real time, also called digital twins. Digital twins are one of the cornerstones of cyber-physical

systems; cooperating computer-based networks that, via embedded sensor networks, operate and control physical objects or systems.

"This is Denmark's first centre for digital twins, and it's something that is bound to cause disruption in the future. The centre will use digital models to generate real-time simulations of cyber-physical

systems, and this possibility to find out in real time when something is possible, and when something is wrong can give companies a big competitive advantage in the future," says the head of the centre, Professor Peter Gorm Larsen, Department of Engineering, Aarhus University.

### Great value for Danish companies

As well as being Denmark's first centre for



Photo: AU Photo

Director of the Poul Due Jensen Foundation, Kim Nøhr Skibsted.

digital twins, the centre is also one of the world's first attempts to work critically and academically on the topic in a research context. According to the director of the Poul Due Jensen Foundation, Kim Nøhr Skibsted this will have great value for Danish industrial companies.

"Research in digital twins is going to be very important for the industry, and therefore it's important for us to invest in long-term basic research in this area in Denmark. A good example of application could be within the service and maintenance of millions of Grundfos pump solutions around the world. If you can predict possible problems, you can target efforts and ensure that operations are not interrupted," he says.

A digital twin is essentially a complete digital copy of something physical. It can be an organism or a system, a process or a device. A digital twin is so accurate that it acts, reacts, ages and fails in the virtual world in exactly the same way as the

physical twin in the physical world.

The purpose of the digital twin is, via modern sensor technology and artificial intelligence, to simulate its physical counterpart to such an extent that it creates entirely new insight into the counterpart. This can be extremely valuable for industrial 4.0 companies, because they can improve the performance of a given product or even take it on to the next generation.

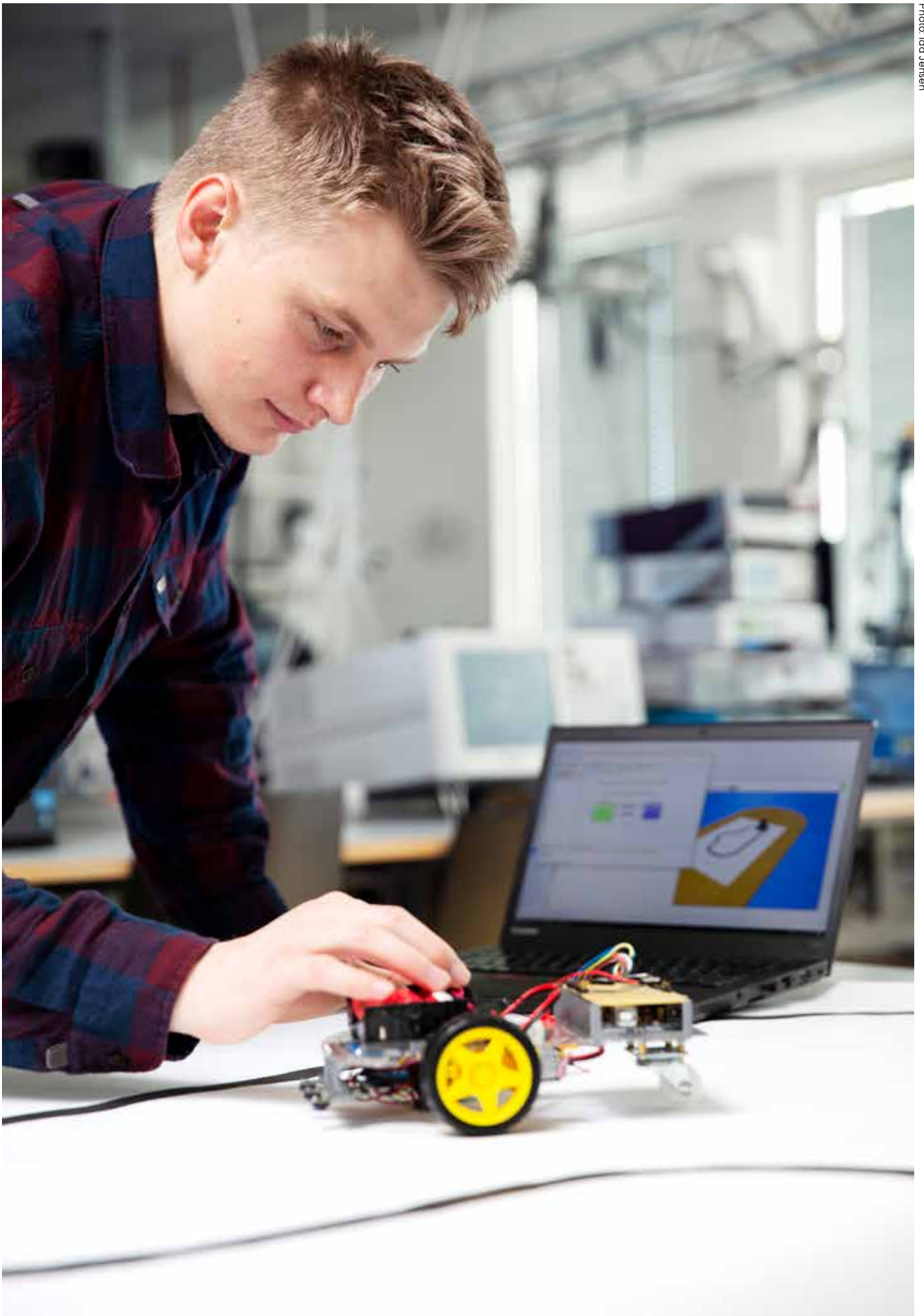
#### Digital model in real time

However, developing a digital twin is currently a very time-consuming process. Some of the first examples are extremely expensive and complex digital twins of gas turbines, aircraft engines and similar. The AU Centre for Digital Twins will be addressing this issue.

"At the Centre, we'll be reusing models that have already been built for a given system in order to create digital twins. For example, if a manufacturer is launching a new gearbox for a specific type of car, it

will be built using digital models that help the manufacturer to make the best possible gear box. We can use these models together with all the other models used for the car to make a digital twin of the entire car; a cyber-physical system in which, via smart devices, data is continually being fed into the digital model in real time. This makes it much easier to optimise the individual systems in relation to each other, constantly optimize the system, and at the same time find out what exactly is going on if, for example, something goes wrong," says Professor Peter Gorm Larsen.

The AU Centre for Digital Twins officially opened in May 2019 and provides large and small businesses with an opportunity to collaborate with Aarhus University in the area (see also page 105). The Centre is also part of the major engineering and digitisation initiatives and it will attract the world's leading engineering research and teaching talents to the University.



WEB EXCLUSIVE

## New centre for digital twins:

*“The idea of being able to design and debug the entire system before you build it is absolutely fantastic”*

24-year-old computer engineering student Christian Møldrup Legaard builds robots. Small, relatively simple robots with just one purpose: They follow a line. This may not seem particularly high-tech, but actually it is. While the robot is tumbling around following a black marker-pen line, a virtual model on a computer is behaving precisely the same way as the robot does. Fed with data from the robot in real time, the model will immediately be able to tell Christian why the robot is doing as it is doing, how it could do things better and more efficiently, and exactly why things go wrong if they do go wrong. ●

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DANISH  
RESEARCH  
TO MAKE  
BLACK-AS-COAL  
METHANOL  
PRODUCTION  
100% GREEN



Photos: Lars Kruse

Professor Lars Ottosen.

Every year, more than 70 million tonnes of methanol are produced in a process based almost exclusively on fossil fuels. A new project with Haldor Topsøe, Aarhus University and others is aiming at making production entirely green and based on biogas.

Nothing-goes-to-waste technology. This is more or less what the development project is about. With the pithy name of eSMR-MeOH, the project has just been granted support from the Energy Technology Development and Demonstration Programme, the EUDP, of almost DKK 38 million (EUR 5,1 million).

The project is being headed by the catalyst manufacturer Haldor Topsøe, and it involves Aarhus University, the Technical University of Denmark (DTU) and Aalborg University. The objective is to develop and build a demonstration facility that can convert biogas from livestock manure and biomaterial into pure green methanol by only adding renewable energy.

"In brief, the project is about producing methanol from biogas and green power. This would be a quantum leap compared to the situation today with black-as-coal production, and it would be an incredibly elegant way of creating high-value products out of the filthiest residual products from our society," says Professor Lars Ottosen from Department of Engineering at Aarhus University, who is leading the university's efforts in the project.

#### **Dramatic changes**

Methanol is an organic compound classified as an alcohol, and it is used for a wide variety of purposes. Among other things as a fuel and solvent, and as an extremely important platform chemical in the production of a wide range of other chemicals.



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“

*The ultimate goal is a society where nothing goes to waste. Where no fossil fuels are dug out of the ground, and we have an alternative for everything we dig up today. The circular bioeconomy at its best”*

Professor Lars Ottosen

Currently, the liquid is usually synthesized from fossil natural gas. You split methane into hydrogen and carbon monoxide by adding a quantity of the gas as energy input. The whole process is dependent on fossil fuels and energy sources, and this is where the new project will change things dramatically.

In the eSMR-MeOH project, the plan is to split biogas using an electrically driven catalytic converter and with additional energy injection from hydrogen produced using electrolysis technology to convert biogas into methanol.

“Haldor Topsøe is a world leader in the production of methanol, and we’re working hard to develop technology to make industrial production of methanol more sustainable in the future. Our eSMR Methanol™ technology is a strong basis for an electrified and significantly greener production process, not least because the raw material is biogas and power comes from wind turbines or solar panels. We look forward to demonstrating the process with our talented partners in the project,” says Peter Mølgaard Mortensen, a leading researcher at Haldor Topsøe.

#### Not a laboratory project

The biogas can be extracted from slurry

and sewage sludge, for example, and electricity can be obtained from renewable sources.

“The methanol coming out of the process is completely pure and green, and we know that it is possible. However, there are still a number of research and development elements to be dealt with before we get that far. Among other things, we need to find a solution to how we connect such a system to a renewable energy source, typically wind, which, by its nature, is not constant,” says Lars Ottosen.

This is not a laboratory project. At the Aarhus University research centre in Foulum, a large-scale pilot facility is to be built, from which experience and the technology developed can be translated into an industrial system, says the Professor.

“The objective is for the technology to be cost-effective at a scale suited to a large biogas plant. The ultimate goal is a society where nothing goes to waste. Where no fossil fuels are dug out of the ground, and we have an alternative for everything we dig up today. The circular bioeconomy at its best,” says Lars Ottosen. ●

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#### Project title:

eSMR-MeOH: Biogas for MeOH with electrical reformation

#### Financial framework:

DKK 38 million, EUFP

#### Schedule:

4 years

#### Partners:

Haldor Topsøe A/S (project owner)  
Aarhus University  
DTU  
Aalborg University  
Sintex A/S  
Blue World Technologies ApS  
Energinet  
Elsystemansvar A/S  
Planenergi

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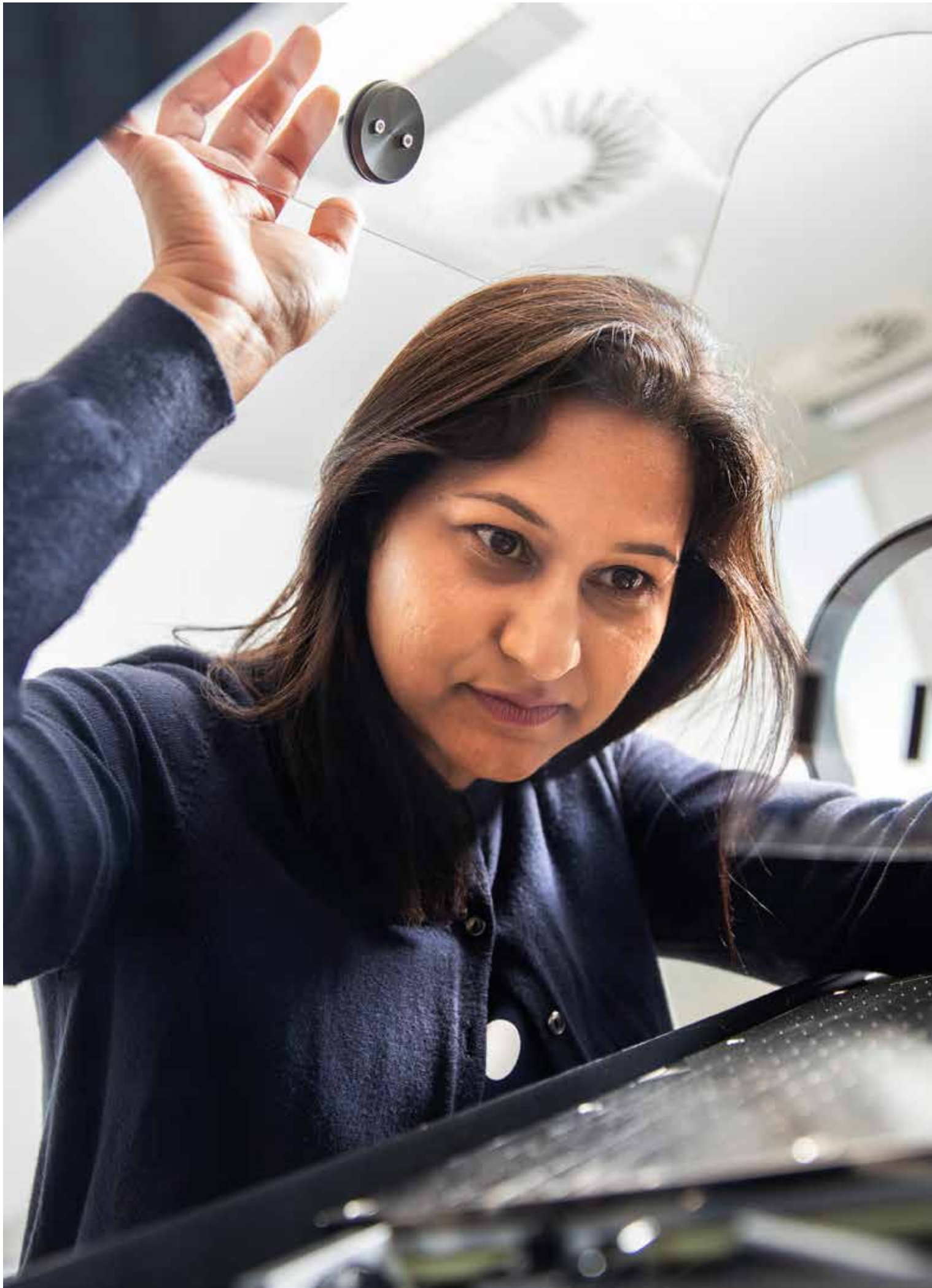
AU Engineering, Campus Navitas, Aarhus

# ENGINEERING DISCIPLINES AT AARHUS UNIVERSITY

- **Biological** Engineering
- **Chemical** Engineering
- **Civil** Engineering
- **Architectural** Engineering
- **Electrical** Engineering
- **Computer** Engineering
- **Mechanical** Engineering

Read online





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*This technology is still in its infancy, and there are many challenges to overcome, especially printing on unconventional materials such as textiles. However, for this reason there are enormous opportunities for the technology in a vast number of different areas”*

Tenure Track Assistant Professor  
Shweta Agarwala

**New researcher at  
the Department of Engineering:  
Shweta Agarwala**





### **World of opportunities with Printed Electronics in Denmark**

Shweta Agarwala, MSc in engineering from Nanyang Technological University in Singapore and PhD in electronics engineering from the National University of Singapore, is a new tenure track assistant professor at the Department of Engineering, Aarhus University. Her research focus is printed electronics catered towards finding novel healthcare solutions.

Photo: Lars Kruse

In July 2011, a group of researchers from MIT, Massachusetts Institute of Technology, succeeded in printing photovoltaic cells, or solar cells, on paper. This was a revelation in the field of printed electronics – a technology that has existed for more than half a century.

Suddenly, a completely new market opened up that had previously been expensive, cumbersome and inaccessible. As a result, a great future is predicted for printed electronics in a wide range of other applications, according to Tenure Track Assistant Professor Shweta Agarwala, who has been researching the technology in Singapore for many years, and who has now brought her expertise to Aarhus University.

“When you go to the pharmacy today, you can easily buy a plaster or headache pills or a pregnancy test. However, you can’t find out whether you’re suffering from vitamin or calcium deficiency, for example. For this, you have to visit your doctor, who takes blood tests that can take days to analyse. It’s an expensive, difficult process that you could do much better with printed electronics,” says Shweta Agarwala.

She is currently researching how to replace PCB based electronics with flexible and soft platforms. This technology could enable for example cheap plasters with a built-in sensor that can take wellness readings or skin stamps that can detect whether a wound has healed or not.

Her expertise lies in printing electronic on a variety of different substrates such as paper, textiles, plastics and biomaterials with skin and human cells.

“One of the more interesting things I’m working on is bioelectronic devices, a field where electronics and biology come together. Here we try to encapsulate biocompatible 3D printed electronic in human cells. This will make soft implantable devices possible that do not trigger an immune response when injected in the body” she says.

Printed electronics are already being used for many different applications today. The advantage is that printed electronics are cheap to produce. RFID systems are a good example of printed, modern electronics that make possible wireless iden-

tification, and printed electronics are also widely used in the production of mobile phones, for example.

“This technology is still in its infancy, and there are many challenges to overcome especially printing on unconventional materials such as textiles. However, for this reason there are enormous opportunities for the technology in a vast number of different areas,” says Shweta Agarwala.

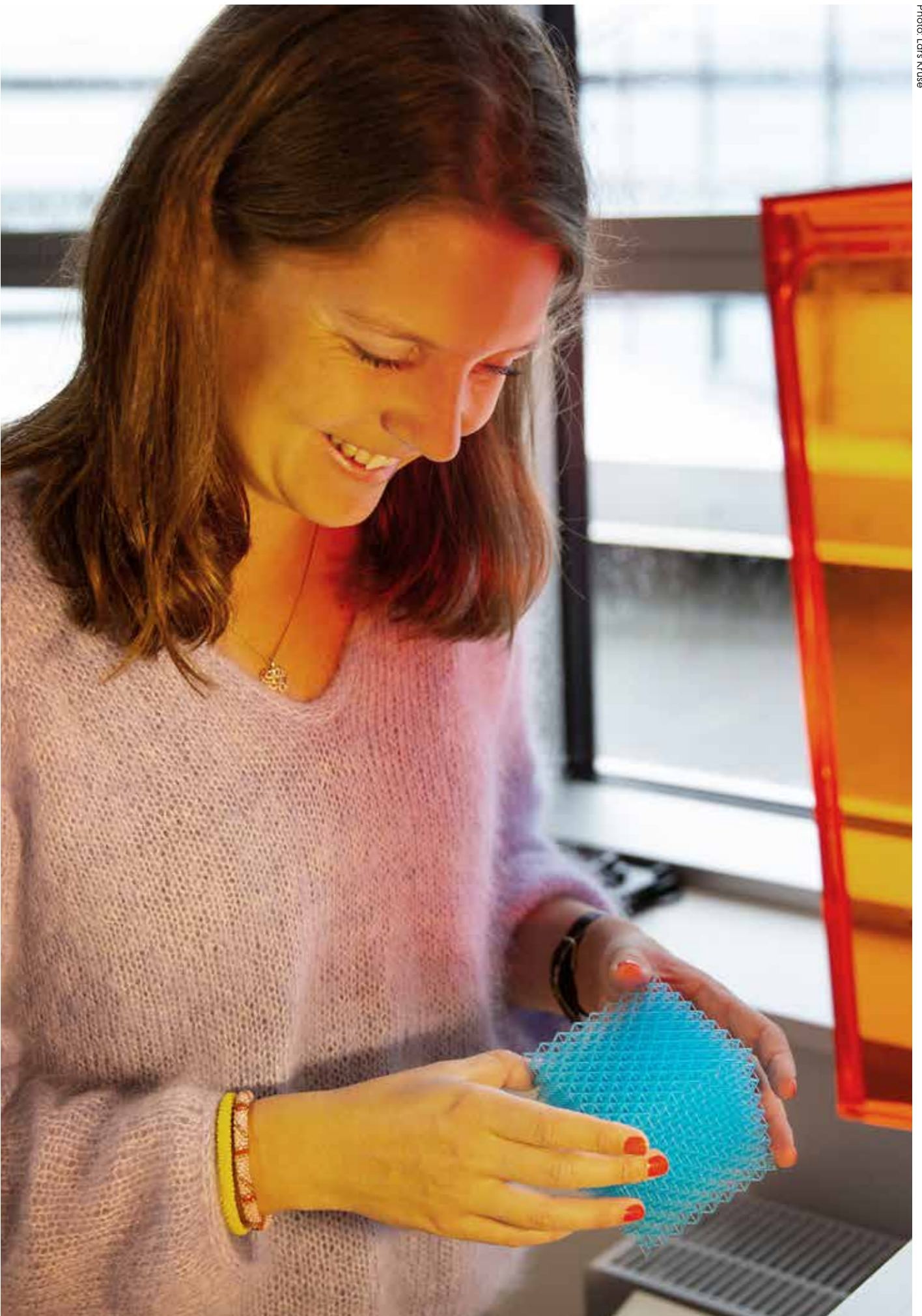
Shweta was born and raised in India and she took her Bachelor’s degree in electronics and communication engineering at M.J.P. Rohilkhand University in 2004. She then travelled to Singapore where she took her Master’s in microelectronics at the prestigious Nanyang Tehnological University. She defended her PhD at the National University of Singapore in 2012 under the title “Nanostructured Materials for Dye-Sensitized Solar cells”.

She worked as a postdoc at the Energy Research Institute in Singapore, and then went to Singapore Centre for 3D Printing to pursue research into printed electronics before travelling to Aarhus University. Shweta Agarwala is already an experienced industry project manager, and has now set up her fully functional Printed Electronics lab at the university with a PhD student employed. ●

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Camilla Dalsgaard Bloch-Jensen



## New bachelor degree programme in Mechanical Engineering opening summer 2020

26-year-old Camilla Dalsgaard Bloch-Jensen thought she was destined to a career in the pharmaceutical industry. But a chat with her mothers' friend convinced her otherwise: "I knew she was an engineer, but not that she was a mechanical engineer. I was a little surprised to be honest, because I thought that mechanical engineers were people standing around in back rooms messing with engines," she says. Read on about Camillas choices and the new programme below. ●

Read online



**BLOG:****The social housing sector is the key to achieving climate targets**

*(This opinion piece was published in the Danish newspaper Jyllands-Posten on 12 August 2019. The article was written by Senior Professor of Engineering Søren Wandahl, PhD Student Stina Rask Jensen, Aliakbar Kamari, postdoc and Johanne Mose Entwistle, head of documentation at AART Architects.)*

"The final percentage points are always the most expensive", wrote Prof. Peter Birch Sørensen in Jyllands-Posten on 20 June 2019 about the new government's negotiations on a climate target for 2030.

Since then, the Social Democrats, the Socialist People's Party, and the Red-Green Alliance have agreed that Denmark is to reduce its carbon emissions by 70 per cent by 2030.

"Insanely ambitious", said Maria Reumert Gjerding from the Danish Society for Nature Conservation – and it is! It's the equivalent of stopping all emissions from both agriculture and industry, and a good portion of emissions from the transport sector too.

Clearly, we can't do this, and the question now being energetically discussed is: where are we going to find the "final expensive percentage points"?

The answer could lie in renovating the existing housing stock. And instead of high

expenditure, we could be talking about value creation for society.

The fact is that buildings today are responsible for 40 per cent of the total energy consumption in Europe. This makes buildings one of the global community's biggest energy consumers. Add to this that 75 per cent of the building stock is energy-inefficient, and that up to 85 per cent will still be in use in 2050, and we are facing a massive problem for CO<sub>2</sub> reduction.

If we are to reach the new climate targets, energy renovation is vital.

The key factor is the social sector, which could be an important element in the government's green ambitions. One in five homes in Denmark is social housing, and the majority of them were built before the introduction of energy requirements in the late 1970s.

There is a lot to be gained from energy optimising this type of housing, and there

is a lot of low-hanging fruit. The additional cost of implementing energy improvements in social housing is relatively small for society as a whole, because Denmark is already making major improvements in the area.

Nevertheless, it is often not considered profitable to implement the deep renovation to meet the climate targets.

But what if we start thinking about the economics in a different way? Perhaps we should look at the major unrealised potentials hiding in this type of renovation. In any energy-renovation project, there is a potential for social value creation, both for the individual and for society.

Research shows that the built environment can be an important element in promoting social relations, improving security, preventing crime, improving human health, and much more.

A good example is the 200,000 m<sup>2</sup> former

“

*Is it possible to imagine that we can move away from just referring to renovation as a ‘cost’, and rather talk about it as an investment in the environment and in a better indoor climate, lighting conditions and social communities?”*

ghetto of Rosenhøj in Aarhus, which, from 2014 to 2017, underwent major renovation with focus on physical and social-housing initiatives. The percentage of residents feeling insecure has now halved compared with 2008, and the area has become much more attractive: There are fourteen-times as many people on the waiting list today as there were in 2010.

A good physical environment provides a number of advantages, especially in the long term, and in fact we can start to talk about actual economic benefits for society. This opens up new perspectives for what, at society level, we perceive as ‘costs’ or ‘revenues’.

Is it possible to imagine that we can move away from just referring to renovation as a ‘cost’, and rather talk about it as an investment in the environment and in a better indoor climate, lighting conditions and social communities?

Together with a large number of partners,

the Department of Engineering at Aarhus University started the ReVALUE research project three years ago. The objective of the project was to identify the potential for added value in energy renovation, and to develop tools to strengthen a holistic process in the early design phases of a building renovation project, to focus on the potentials for environmental, economic and social added value.

The project is now in its final phase, and we now have new knowledge and tools to help achieve the ‘final percentage points’, without these being the most expensive. On 21 August 2019, we shared this experience at an open symposium at Navitas in Aarhus.

The ‘final expensive percentage points’ that the new government is currently struggling with are just what the project has been working on over the past years. Our final hope is therefore that both the new housing minister and the new climate minister will find inspiration in our

work and that they will invest in energy renovation projects with added value when they make their plans for the Denmark of the future. ●

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The three-bladed single-rotor wind turbine has become a well-known spot on the horizon. It might not be the most optimal energy-harvesting design however, as research from Durham University and Aarhus University here demonstrates.





## Computer models show clear advantages in new types of wind turbines

Researchers have modelled the fluid dynamics of multi-rotor wind turbines, and how they interact in wind farms. The research demonstrates a clear advantage for a turbine model with four rotors.

With their 220-metre diameter, the wind turbines at the future Dogger Bank wind farm in the North Sea are the world's largest yet. But large, larger, largest is not necessarily the best when it comes to wind turbines.

Researchers from Aarhus University and Durham University in the UK have modelled the fluid dynamics of multi-rotor wind turbines via high-resolution numerical simulations, and it turns out that wind turbines with four rotors on one foundation have a number of advantages.

A wind turbine harvests energy from the incoming wind, but when the wind passes through the blades of the turbine, a region with lower wind speeds and higher turbulence is created called wind turbine wake. A second wind turbine downstream is affected by this turbulence in several ways. First of all, it produces less energy, and secondly, the structural load is increased.

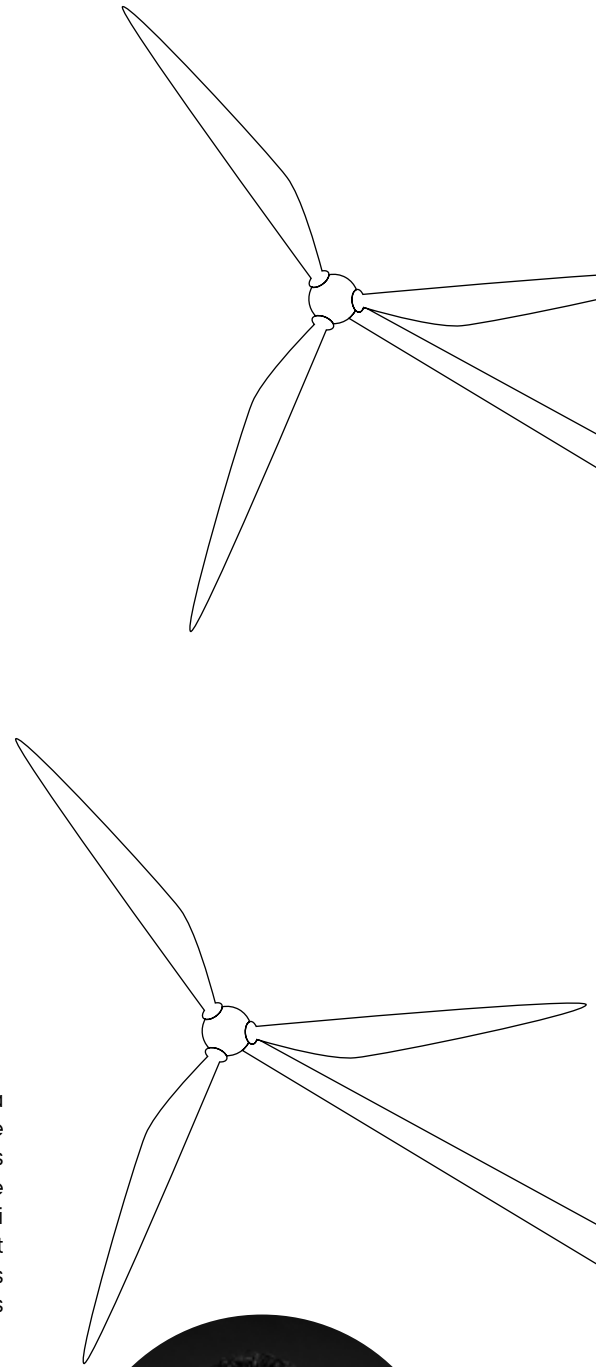
"In the study, we found that turbulence and currents in the wake of the turbines recover much faster with multi-rotor tur-

bines. This means that, with multi-rotors, a second turbine downstream will produce more energy and will be subjected to less load and stress, because the turbulence is correspondingly smaller," says Mahdi Abkar, tenure track assistant professor at the Department of Engineering, Aarhus University and an expert in flow physics and turbulence.

### Less cost, less hassle, more energy

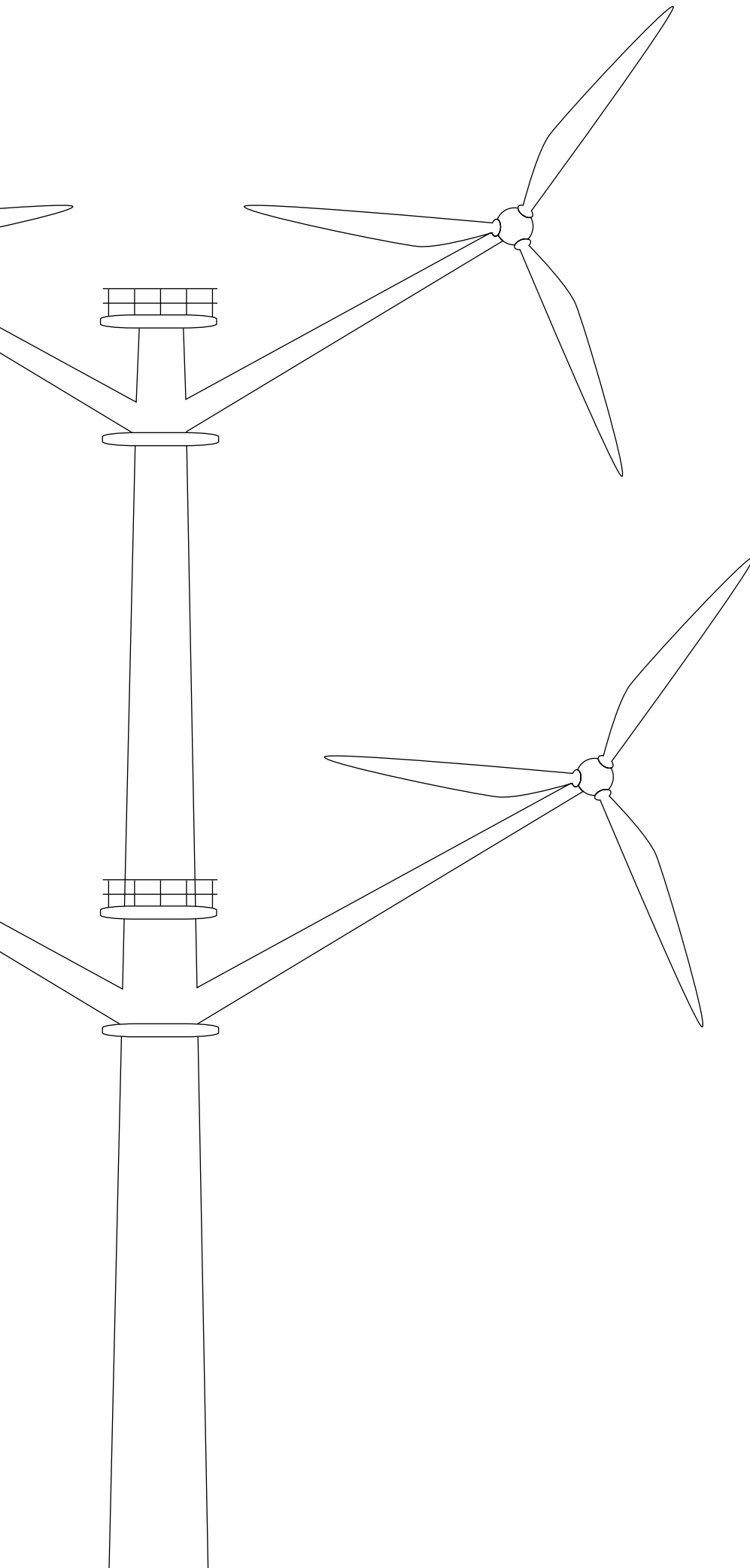
A wind turbine with more than one rotor creates less turbulence, and the wind is "restored" faster, which means a higher energy output. And this is important knowledge at a time when wind turbines are becoming increasingly larger, and thereby also increasingly expensive.

"You can always increase your energy output by increasing the diameter of the rotor blades, but there are major structural challenges in building these massive constructions with diameters exceeding 150 metres. The material requirements increase, the transport of the structures is cumbersome and expensive, and it becomes more costly to maintain the wind turbines," says Mahdi Abkar.



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“

*The optimum construction is a turbine with four rotors as far apart as possible. The latter results in less downstream turbulence and a faster stabilisation of the wake behind the wind turbines”*

Tenure Track Assistant Professor  
Mahdi Abkar

A turbine with four rotors costs approx. 15% less to construct than a turbine with one rotor, even though the blades cover the same area in total. At the same time, a construction with four rotors is much lighter and therefore easier to transport. And if one of the rotors stops working, the rest of the turbine will still produce energy, unlike ordinary wind turbines.

In addition, the researchers have found that individual multi-rotor turbines actually produce slightly more energy than single-rotor turbines: approx. 2% more.

“We’ve explored several different geometries and dynamics of multi-rotor turbines and have found that the optimum construction is a turbine with four rotors as far apart as possible. The latter results in less downstream turbulence and a faster stabilisation of the wake behind the wind turbines,” says Tenure Track Assistant Professor Mahdi Abkar. ●

A photograph of a rooftop solar panel array. The panels are dark blue with a grid of white lines. In the background, there is a modern building with a grid of windows. The sky is overcast. The text "FREE-FOR-ALL WORLDWIDE SOLAR ENERGY MODEL" is overlaid in white, sans-serif font. A small teal horizontal bar is at the top left, and a teal teardrop shape is at the bottom left.

# FREE-FOR-ALL WORLDWIDE SOLAR ENERGY MODEL





Solar cells are currently the world's most talked-about renewable energy source, and for any future sustainable energy system, it is crucial to know about the performance of photovoltaic systems at local, regional and global levels. Danish researchers have set up an historically accurate model, and all the data has been made available for anyone who wants to use it.

Solar energy is advancing in earnest throughout the whole world. Over the past three years, more photovoltaic (PV) installations have been installed globally than any other energy source, and the annual growth rate between 2010 and 2017 was as high as 24%.

In global terms, it has been predicted that solar energy will play a similar role to wind energy in the sustainable energy systems of the future, but this requires precise models for how much energy PV systems produce.

Danish researchers have developed these models in a major research project at the Department of Engineering, Aarhus University and the results have been published in the journal *Progress in Photovoltaics*.

#### Global, regional and local scale

"We've collected 38 years of global solar radiation, weather and temperature data with a spatial resolution of 40 km x 40 km for the entire globe, and compared this with historical data for photovoltaic installations in Europe. Based on this, we've made a very accurate model that, at global, regional and local levels, can tell you about the performance of PV installations in a given geography, depending on the type of facility being used. This

means we can look at not only a single installation, but energy production in entire countries or continents from PV installations. This is extremely important for the way in which the energy systems of the future can be combined to function optimally," says Tenure Track Assistant Professor Marta Victoria, who has been responsible for the project.

She continues:

"Generating cheap green energy is no longer a challenge. The price of PV installations has tumbled over the last 10-20 years, so we're now seeing huge investments in this particular energy source. The challenge is to link energy production from myriads of small installations across the landscape with a country's total energy demand and energy production from other sources, some of which is also linked across national borders."

#### Huge impact on future systems

The problem is also that the green energy system of the future depends on renewable energy sources, which in turn depend on the weather. This is why, according to Marta Victoria we need very accurate and detailed knowledge about energy production.

"PV installations will have a huge impact on the energy systems of the future, and

planning systems based on models that do not take into account the outages in relation to the norm simply won't work. Therefore, this project has gathered very detailed data over time for the last 38 years for the entire globe, so that the model can be used anywhere," she says.

All the data in the model has been made readily available to everyone via Open Licence.

The project is part of the RE-Invest project, which is being funded by Innovation Fund Denmark, and which brings together a large number of Danish and international universities and companies to create the energy system of the future. ●

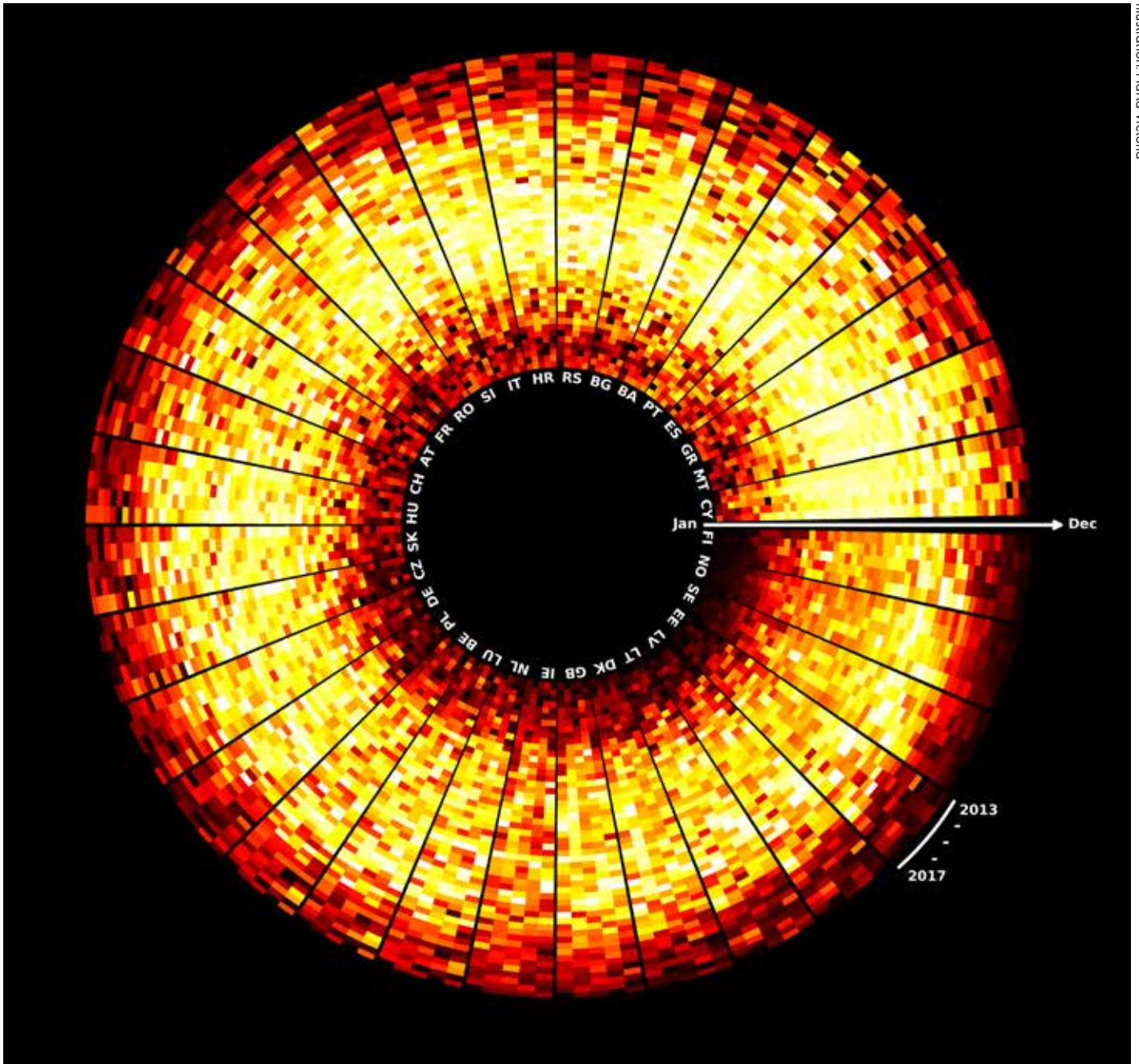
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*PV installations will have a huge impact on the energy systems of the future, and planning systems based on models that do not take into account the outages in relation to the norm simply won't work”*

Tenure Track Assistant Professor Marta Victoria



Not the eye of Sauron but the weekly total solar energy output of every European country from 2013-2017.

A photograph of a library or study area. In the foreground, there are stacks of books and a printer. In the background, there are bookshelves filled with books, a whiteboard, and a potted plant. The lighting is soft and focused on the central area.


WEB EXCLUSIVE

You know what it's like when you have a teacher who just loves their subject? Someone who's captivating, inspirational and yet empathetic when they talk? Sara does. And more than anything, that's why Sara chose a programme she otherwise hated.



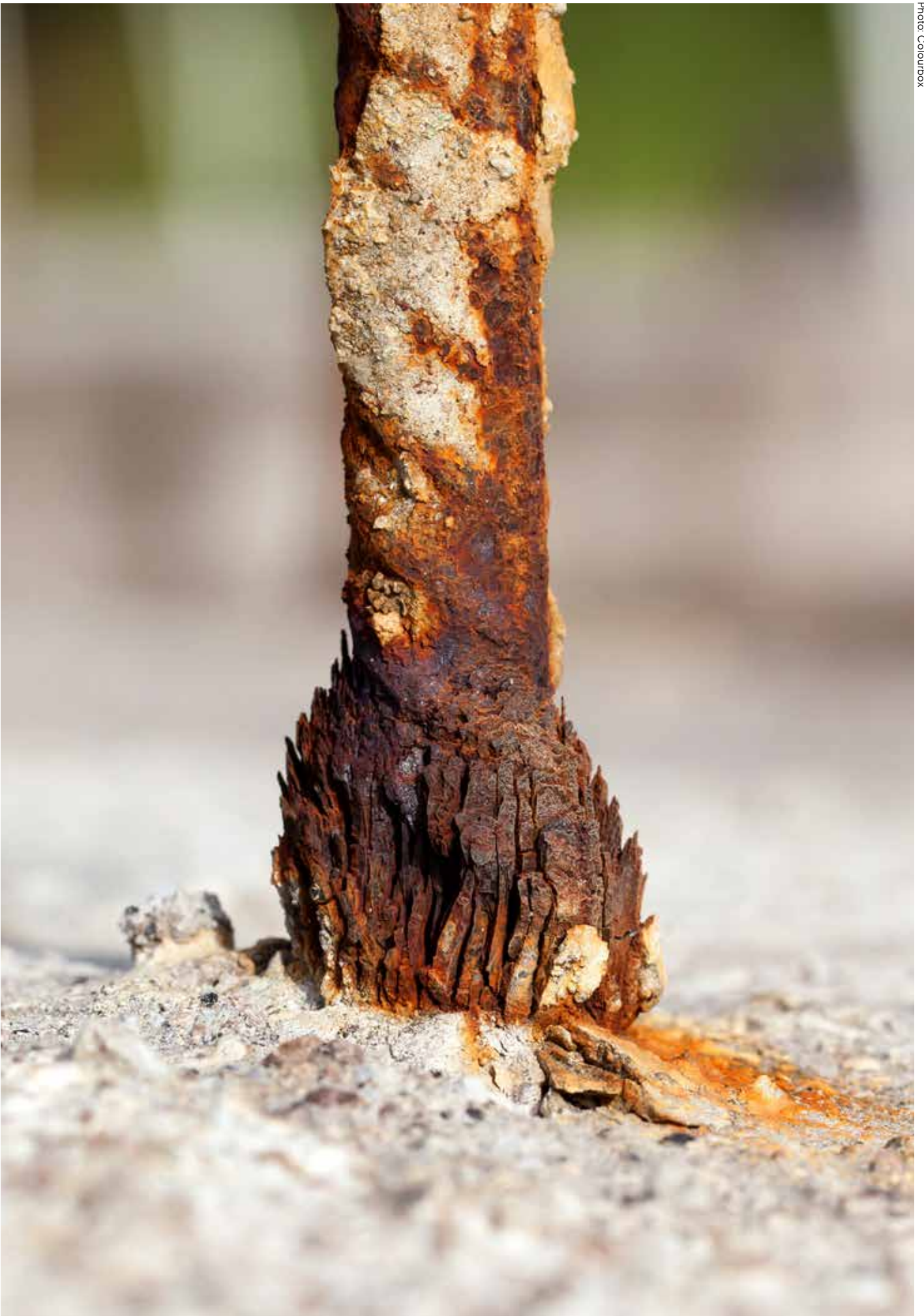
Read online





Globally, corrosion is an enormous problem. It is estimated that approx. DKK 17 trillion is spent annually on remediating rust problems, amounting to about 3-4 per cent of the GWP. Researchers are now developing a cheap, intelligent, self-powered, built-in patch that continuously monitors corrosion and steel reinforcement integrity in concrete structures. The goal is simple and cheap structural health monitoring everywhere.





*Rust is a gargantuan problem in construction worldwide. Health monitoring could potentially lower the astronomical annual remediation costs.*

# Smart, self-powered patches to put an end to DKK 17 trillion bill caused by rust worldwide

The cost of corrosion runs to 3-4 per cent of the gross world product (GWP) annually, and therefore there is increasing international focus on monitoring infrastructure projects. A smart patch now being developed can cut huge amounts off the costs of rust.

In August 2018, the once-proud engineering legacy of Italy was dealt a major blow when the one-kilometre-long and 45-meter-high Morandi bridge collapsed and killed 43 people. 600 were left homeless.

While the exact cause of the collapse has yet to be determined, investigators have found evidence that undetected corrosion and structural deterioration were to blame for the tragic event.

The Italian case of the Morandi bridge is not unique. Corrosion can be a huge safety hazard all over the world if not properly managed and monitored. But despite the major global challenges with corrosion in steel-reinforced concrete structures, there are currently only few possibilities to actually monitor the problem: the sensors being used for rust monitoring today are indicative, can be error-prone and are based on slow, energy-demanding technology that is more than half a century old and which costs up to EUR 5,000 per measuring point.

## Energy-harvesting tech

Researchers from Aarhus University are aiming to change all this. In a collaboration project with the technological service company FORCE Technology, they

are developing a brand new, intelligent and self-powered sensor.

"The aim of this project is to develop a plaster sensor which is placed on the reinforcement and moulded into the concrete construction. The sensor and interfacing electronics are powered by means of energy-harvesting technologies to ensure continuous monitoring of the condition of the steel," says Jaamac Hassan Hire, industrial PhD student on the project.

The data collected is sent to a central computer where it is processed. The project, named DIGIMON, is being headed by Associate Professor Farshad Moradi, Department of Engineering, Aarhus University:

"Within this project, we will use ultrasonic waves generated locally in a self-powered sensor inside the concrete to monitor the corrosion. We want to be among the first – probably the first-ever – to develop a self-powered corrosion sensor," Farshad Moradi adds.

## Great potential

The project has been funded by Innovation Fund Denmark as a collaborative industrial project between ICELab at Aar-



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Photo: Michele Ferraris

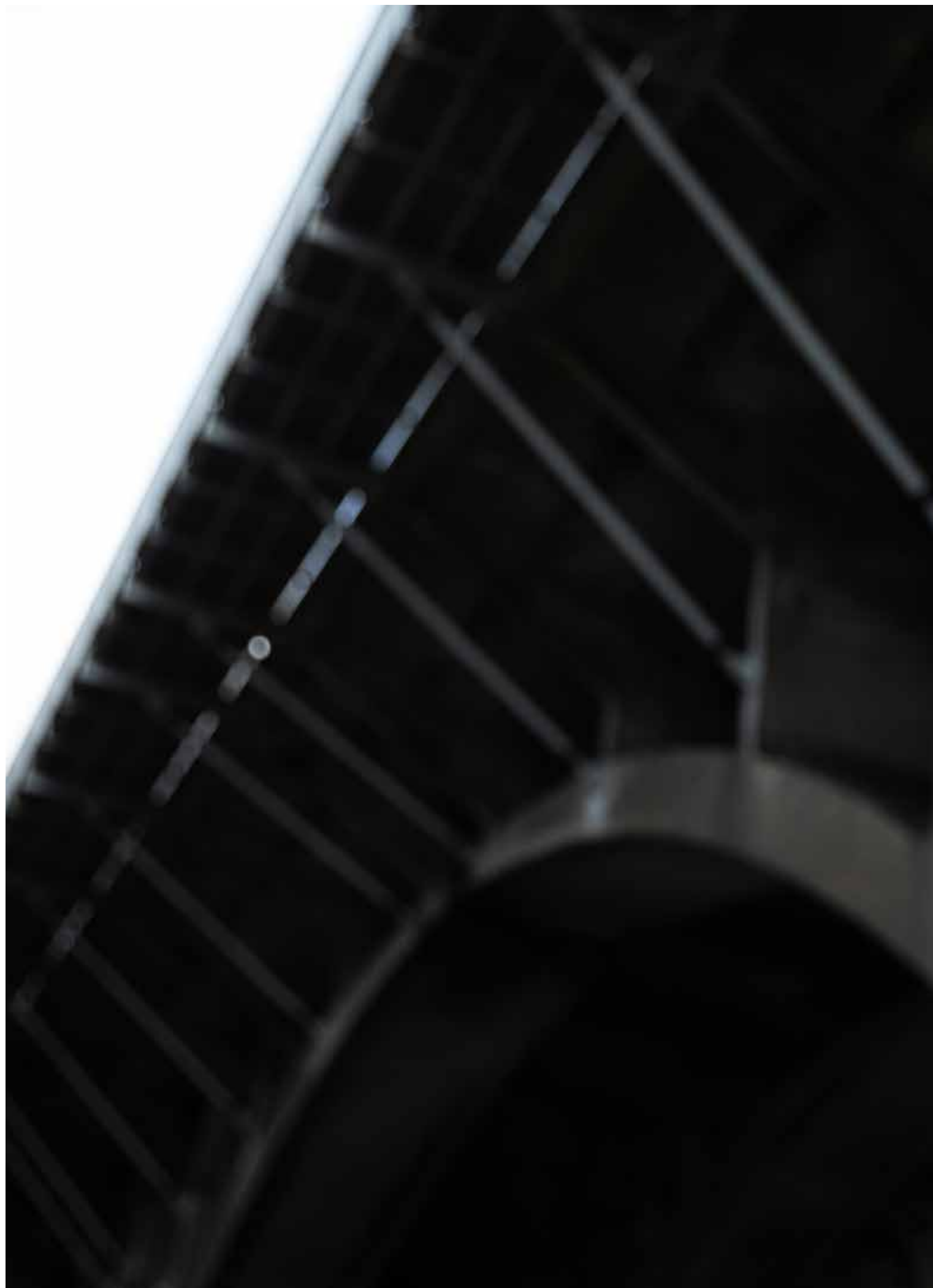
The collapse of the Morandi bridge in Italy.

“

*DIGIMON is a great example of mobile and energy-efficient modern technology that's at the very front of the technological revolution, and I hope it can play its part in making structures safer in the future”*

Morten Wagner, head of department at FORCE Technology









*Corrosion is a very expensive problem throughout the world.*

---

“

*Structural health monitoring is a new and improved way of doing traditional non-destructive testing. It involves the integration of sensors, smart materials, data transmission and processing”*

Jaamac Hassan Hire, industrial PhD student

hus University and IdemoLab at FORCE Technology.

“We’re happy to be a part of this project. We’re working with monitoring today, and we see a lot of potential in being able to continuously monitor large constructions, even in harsh environments. This would provide us with a clearer picture of the state of the construction or building. DIGIMON is a great example of mobile and energy-efficient modern technology that’s at the very front of the technological revolution, and I hope it can play its part in making structures safer in the future,” says Morten Wagner, head of department at FORCE Technology.

Globally, corrosion is an enormous problem. It is estimated that approx. DKK 17 trillion (EUR 2.3 trillion) is spent annually on remediating rust problems, amounting to about 3-4 per cent of the GWP.

However, there is no getting away from rust. The harsh marine environment to which steel-reinforced bridges are exposed, for example, causes a spontane-

ous electrochemical process known as oxidation.

#### **Structural health monitoring**

The problem has attracted increasing international focus and has created a huge need to increase monitoring of newly constructed infrastructure.

“It’s extremely interesting to work on this project. Structural health monitoring is a new and improved way of doing traditional non-destructive testing. It involves the integration of sensors, smart materials, data transmission and processing. It’s currently receiving great technical and scientific interest, since awareness of structural integrity and safety, planning of repair works and the associated costs have become a focus area for owners. We hope that, through this project, we can bring the technology into a viable industrial application, benefitting society both in terms of safety and economically,” says Jaamac Hassan Hire. ●

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#### **Project title:**

DIGIMON

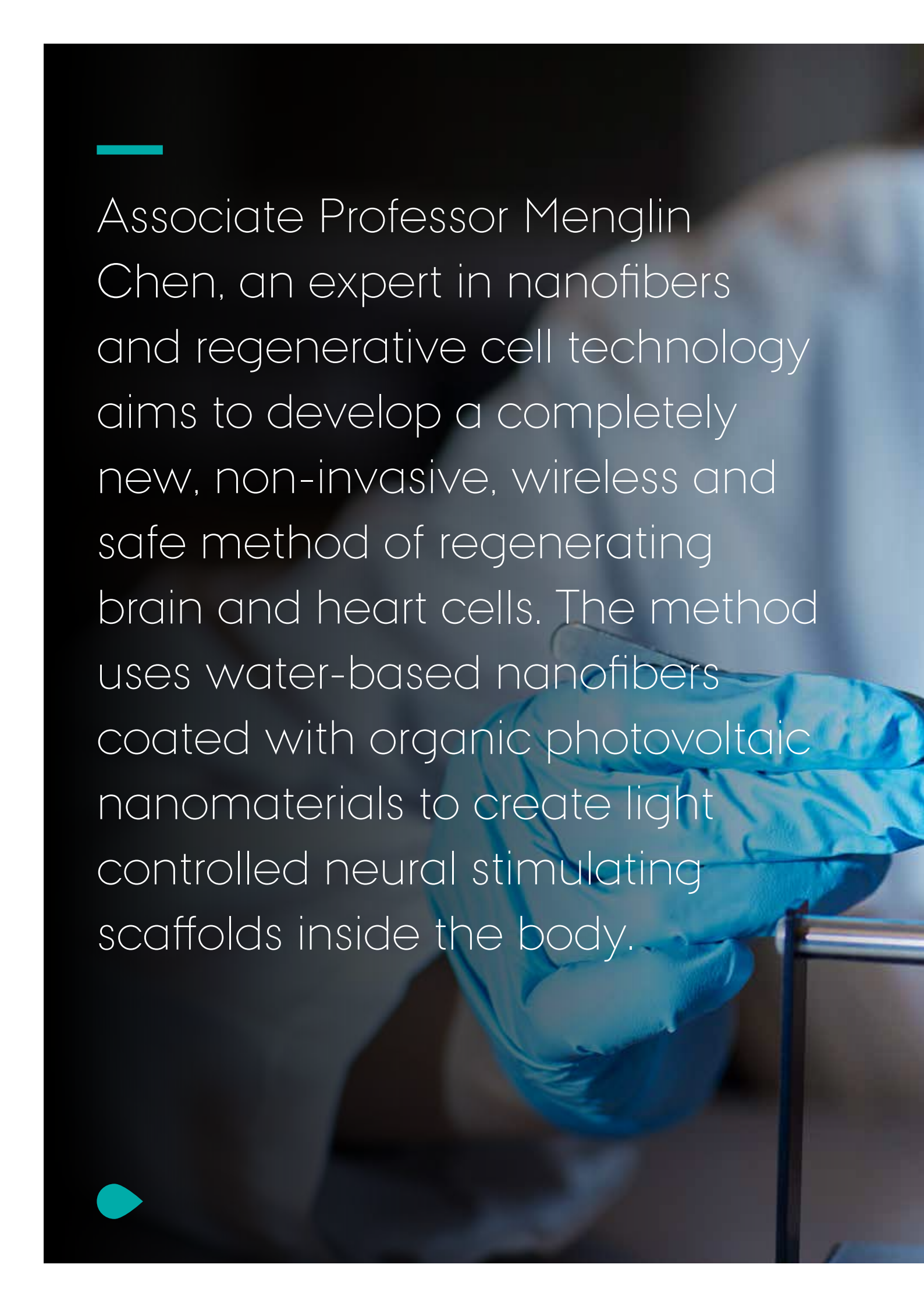
#### **Financial framework:**

DKK 1.1 million, Innovation Fund Denmark

#### **Partners:**

FORCE Technology  
Aarhus University

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A person wearing a white lab coat and blue nitrile gloves is working in a laboratory. The person is holding a small, clear, cylindrical object, possibly a microfluidic device or a small container, and is looking down at it. The background is slightly blurred, showing other laboratory equipment and a clean, professional environment.

Associate Professor Menglin Chen, an expert in nanofibers and regenerative cell technology aims to develop a completely new, non-invasive, wireless and safe method of regenerating brain and heart cells. The method uses water-based nanofibers coated with organic photovoltaic nanomaterials to create light controlled neural stimulating scaffolds inside the body.





## She's injecting 'solar cells' into the body to regenerate brain cells

Associate Professor Menglin Chen has received a major grant from the Carlsberg Foundation to develop a completely new method of regenerating brain and heart cells. The method uses water-based nanofibers coated with organic photovoltaic nanomaterials to create light controlled neural stimulating scaffolds inside the body.

With a grant from the Carlsberg Foundation of DKK 4.2 million (EUR 0.6 mill.), Associate Professor Menglin Chen, an expert in nanofibres and regenerative cell technology at the Department of Engineering, Aarhus University, can start her OptoMed project on a somewhat untraditional form of cell therapy.

In contrast to optogenetics, which uses light to selectively control neurons by genetically modifying them, Menglin Chen's group, in collaboration with American partners, has introduced a non-genetic, light-mediated method that can locally stimulate cells electrically.

### Point-specific treatment

The method uses an organic semiconductor nanomaterial, that works just like a solar cell, and that has already proven to have a regenerative effect on neural model cells.

"We want to develop a wireless, non-invasive, safe, and very accurate therapeutic treatment method that can regenerate heart and brain cells by means of an external light source. There is a great need for such point-specific forms of treatment to relieve symptoms in a great many people all over the world," says Associate Professor Menglin Chen.

The technology works by injecting water-based nanofibres coated with a biological photovoltaic substance (the semiconductor nanomaterial) into the damaged tissue. The photovoltaic effect means that the substance creates an electrical voltage when it is exposed to light.

When the body is exposed to sunlight or near-infra-red artificial light, some of the light will penetrate the tissue and fall on these nano semiconductors, thereby converting the light into electricity.

### Major impact for future treatments

In this way, it is possible to locally stimulate electrically excitable cells, such as neurons in the brain, and via bioelectric signal transduction, to modulate a specific cell reaction; in this case a regenerative response. Research has already demonstrated that electric stimulation can get neurons to regenerate, and the novel, wireless method may also be interesting for use on heart cells.

"The project makes it possible to create better cohesion between the natural tissue and the rigid world of microelectronics, which so far has not been able to target individual cells and their circulation, and describe their underlying mechanisms. Using nanofibers as flexible, injectable scaffolds that allow cell growth, we can now integrate the nervous system or cardiovascular system with nanoelectronics and thereby stimulate regeneration. If we're successful, this will have a major impact on implementing new treatment methods for various brain and heart conditions in the future," says Associate Professor Menglin Chen.

The grant of DKK 4.2 million is part of the Carlsberg Foundation's 'Young Researcher Fellowships', which are awarded to young associate professors with particularly visionary research ideas and projects.

A total of 30 researchers at Aarhus University received funding for new research projects from the Carlsberg Foundation in November 2019. The Foundation has awarded a total of DKK 204 million to 134 young researchers. The 30 researchers at Aarhus University have together received more than DKK 47 million. ●

### Project title:

OptoMed: Injectable nanofibrous optoelectronics as regenerative medicine

### Financial framework:

DKK 4.2 million. Carlsberg Foundation

### Schedule:

3 years



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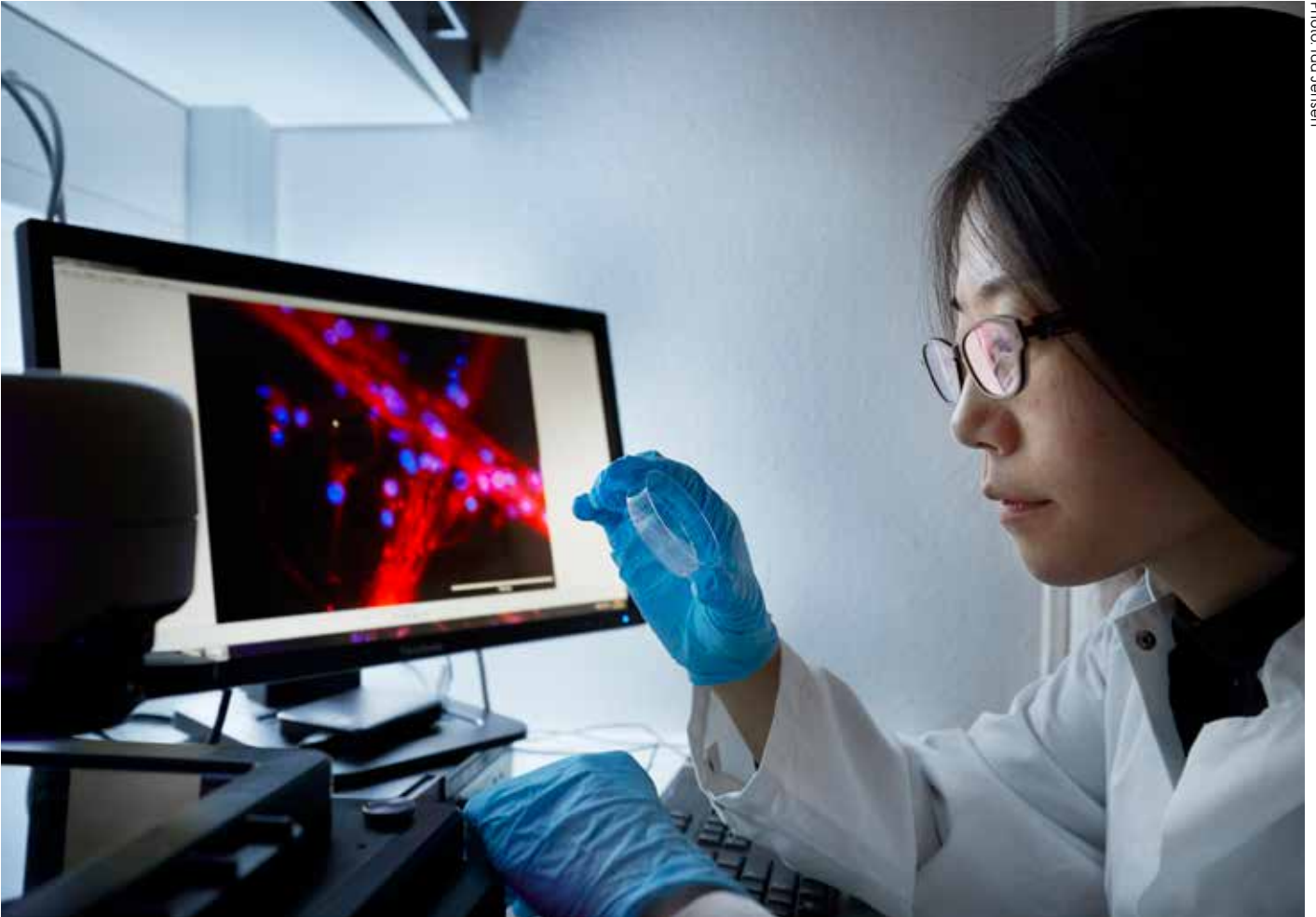


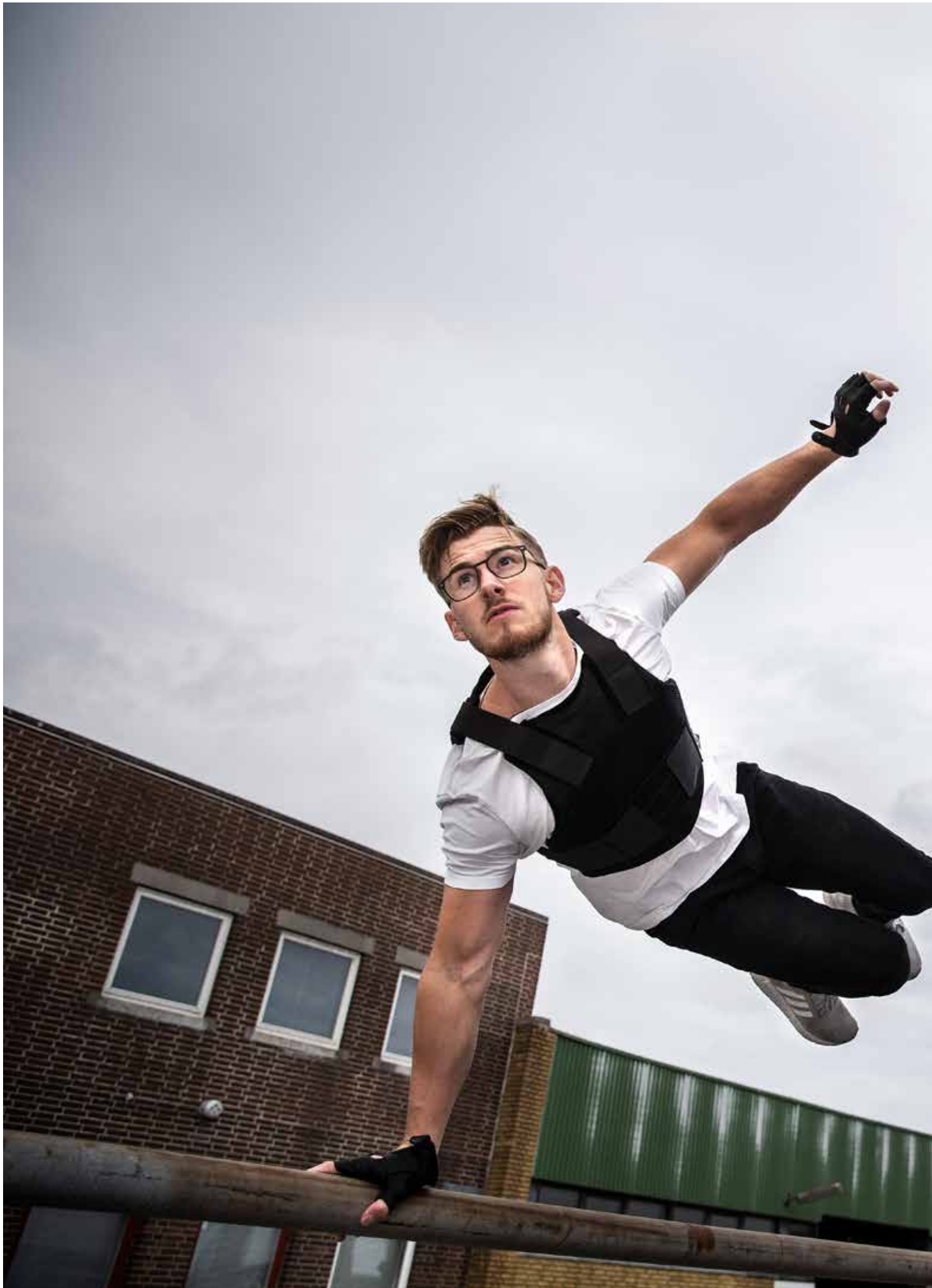
Photo: Ida Jensen

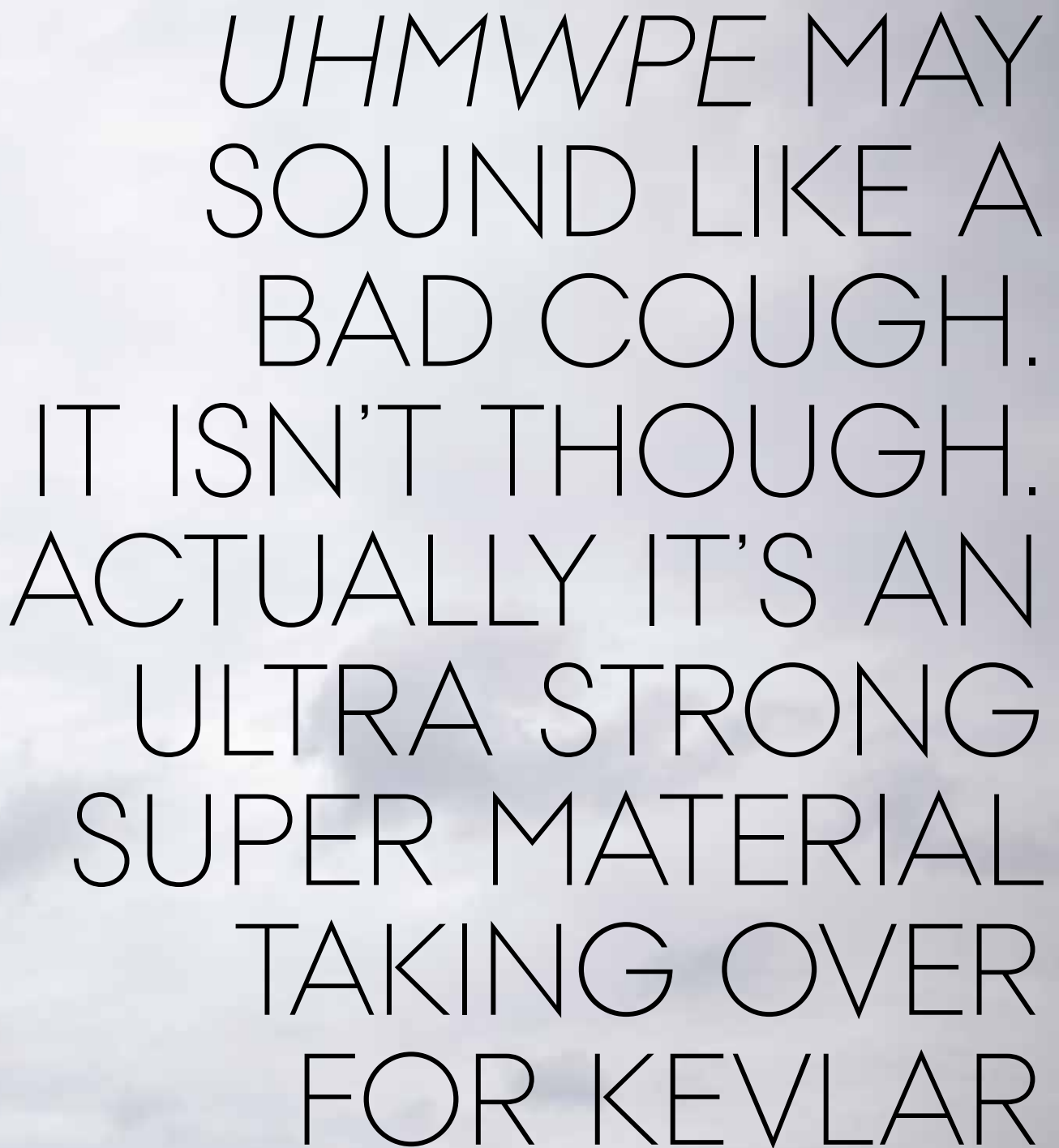
Associate Professor Mengling Chen introduces a non-genetic, light-mediated method to locally stimulate cells electrically.

“

*If we're successful, this will have a major impact on implementing new treatment methods for various brain and heart conditions in the future”*

Associate Professor Mengling Chen





UHMWPE MAY  
SOUND LIKE A  
BAD COUGH.  
IT ISN'T THOUGH.  
ACTUALLY IT'S AN  
ULTRA STRONG  
SUPER MATERIAL  
TAKING OVER  
FOR KEVLAR

## Scientists from Aarhus University and the University of Cambridge are the first to measure and set guidelines for bolted joints using the upcoming replacement for Kevlar: the ultra-strong material with the catchy name ultra-high molecular weight polyethylene

Imagine a velvety, soft material that is extremely light, but also strong enough to stop a bullet. This is close to a description of ultra-high molecular weight polyethylene (UHMWPE), a super-plastic material commercially known as Dyneema or Spectra, which is already taking over from the para-aramid fibrous material, Kevlar, in e.g. bullet-proof jackets.

There is also much need for the super material in many other applications than body armour, and therefore researchers have now set up guidelines and failure maps for use of the material in joints with steel bolts. The research team is being led by Simon Skovsgård, PhD and MSc in engineering at the Department of Engineering, Aarhus University, and Professor Norman Fleck at the University of Cambridge.

The results have been published in the International Journal of Solids and Structures.

“The tests we’ve done showed that the material began to deform at the joints, but the fibres weren’t broken. This is interesting in relation to other popular composite materials, such as carbon fibre composites, which snaps suddenly. Here, although we can tear the material, it’s really difficult to actually break the fibres,” says Simon Skovsgård.

UHMWPE consists of extremely long chains of polyethylene (PE). And these long chains strengthen the intermolecular interactions of the substance and enable the material to transfer stress loads effectively to the polymer skeleton.

This means that UHMWPE fibres have an incredibly high tensile strength compared to many other thermoplastics, and this also means that the material is much stronger than steel in the fibre direction. The tensile strength of high-strength steel is approx. 900 MPa, but in order to break the fibres in UHMWPE, you need approximately 3000 MPa.

“UHMWPE fibre plates are a collection of these incredibly strong fibres. It’s almost impossible to extend and break the fibres, but if you twist or shear the material, it is soft. This combination makes it easy for the material to absorb energy,” says Simon Skovsgård.

The new research results are good news for the commercial use of UHMWPE, which is increasingly being introduced in the shipping industry in containers, ropes and nets, as well as armour for vehicles and personnel and in the textile industry. So far, there has been no experience with using the material combined with other materials. ●



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Photo: Simon Skovsgård

Test conducted by Simon Skovsgård on the super material.

“

*It's almost impossible to extend and break the fibres, but if you twist or shear the material, it is soft. This combination makes it easy for the material to absorb energy”*

PhD Student Simon Skovsgård



WEB EXCLUSIVE

## Drug recycling and 'banapples': Engineering innovation captures Aarhus



AU Engineering's new research facility, the Deep Tech Experimental Hub in Skejby, Aarhus, was crammed with engineering students when the "invention pitch 2019" kicked off.

Photos: Ida Jensen





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*“The world is full of problems; an awful lot of them in fact. In a way this is a good thing, because it forces us to think differently and be innovative. It’s important to focus on innovation and entrepreneurship, and it’s fantastic to see the eagerness of the young engineering students. Some of them have some really good ideas to solve problems that are changing the world”*

Henrik Larsson,  
CEO of the Centre for Industry



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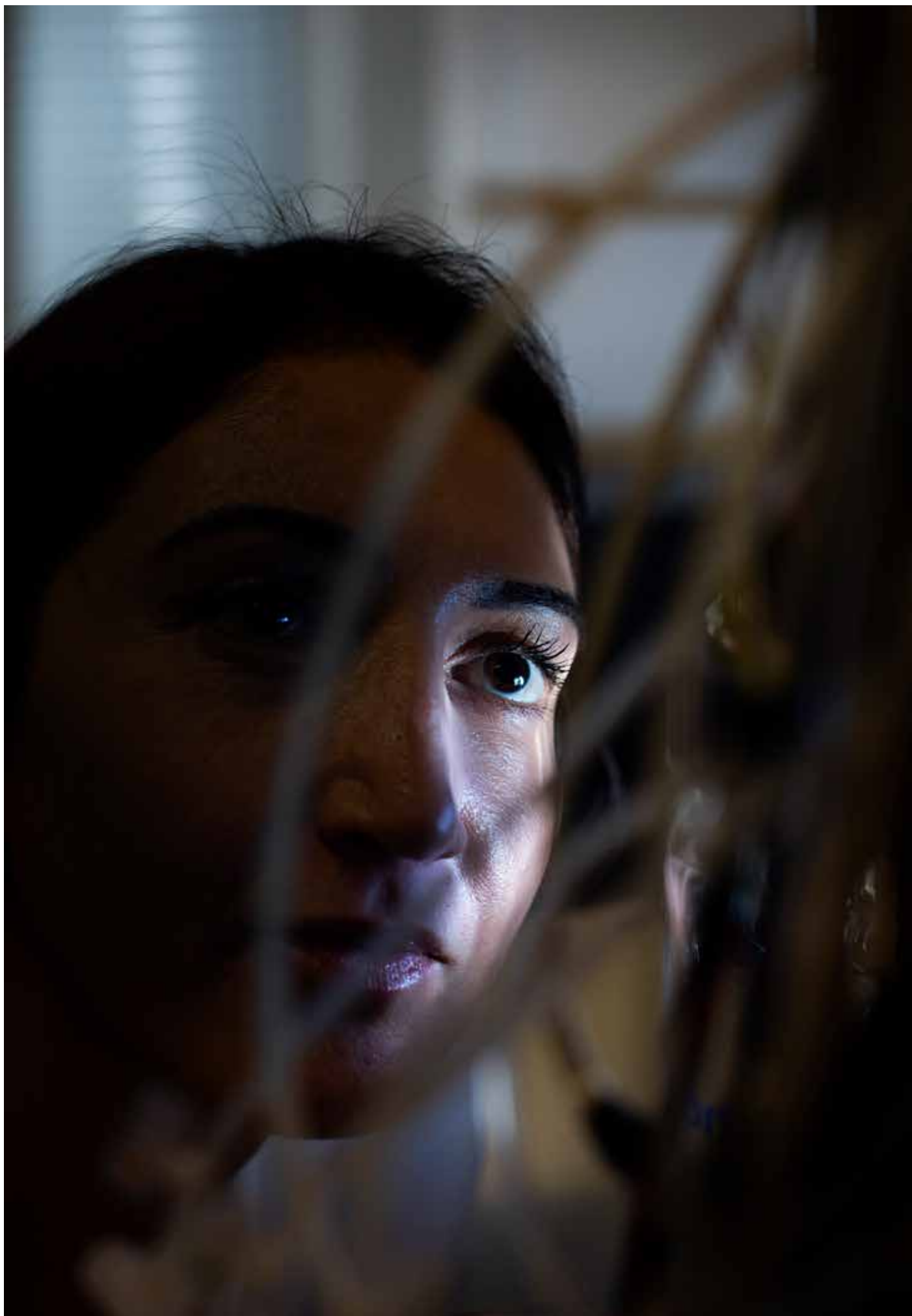


Associate Professor Selin Kara, an expert in biocatalysis and bioprocess development aims to replicate completely natural bioprocesses for use in the chemical industry.

The following articles highlight her latest grants for new engineering research projects.







*Sustainable clean production of chemicals could be attained by completely natural processes, Selin Kara explains.*

## She uses mushroom enzyme and light to create green chemicals

By combining nature's own reactions, Associate Professor Selin Kara aims to develop a fully green and sustainable production process for chemicals.

With a total of DKK 6.2 million (EUR 0.8 mill.) of prestigious Sapere Aude funding from the Independent Research Fund Denmark (DFF), Associate Professor Selin Kara, chemical engineer and expert in biocatalysis and bioprocesses, is launching a new research project which could eventually secure completely environmentally friendly production of chemicals.

Selin Kara will use entirely natural enzymatic reactions to synthesize chemicals in a continuous flow: Imagine small tubes (around a few millilitres) into which you put one product in one end, and get a high-value product out from the other.

"The idea is to link photo-catalysis with bio-catalysis in miniaturized, tubular bioreactors operated with continuous flow. The system will be multi-phasic where the photobiocatalyst – an enzyme found in normal chestnut mushrooms – will be in a solid form and the reaction media

will be liquid. Due to the low solubility of the substrate, also a second liquid phase is needed for bioprocess development. Overall, I will deal with a multi-parameter challenge," says Selin Kara.

### Building blocks for the industry

The photocatalytic part of the system is constantly exposed to light, which is necessary in the process of creating the desired core substrate. The enzyme converts that core substrate (now an intermediate) into the final target product, a pharmaceutical compound.

"The goal is photobiocatalytic synthesis of various active pharmaceutical ingredients which can be used as building blocks to create other chemical substances," says the associate professor.

The final goal of the project, called PHO-TOX-f, Photobiocatalytic oxyfunctionalization in continuous flow, is highly productive photobiocatalysis in continuous



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*A completely environmentally friendly production of chemicals. That's the goal for Associate Professor Selin Kara, Aarhus University, who've received a prestigious Sapere Aude grant of DKK 6.2 million from the Independent Research Fund Denmark. In the project, Selin Kara will merge photo-catalysis with bio-catalysis in miniaturized, tubular bioreactors in the hope of continuously synthesizing chemicals using only natural enzymatic reactions.*

flow, which may have a major impact on the pharmaceutical industry.

"If we can utilize bio-catalysis and photo-catalysis together to develop very productive enzymatic reactions, hopefully we'll make the enzymatic synthesis more attractive in future chemicals production. This will be a huge achievement for the chemicals industry as a whole, as chemical synthesis today is very polluting," says Selin Kara.

#### **Mini models first**

There are, however, some major challenges to be overcome first, which is also why the project is starting with miniature bioreactors:

"The entire system needs refining to the smallest detail to ensure the optimum flow and conditions. The photo- and bio-catalysts have to be perfectly balanced to work together effectively, and that's why we're starting by focusing on

the spatial spread between the two types of catalysis," she says.

Sapere Aude grants are awarded by the Independent Research Fund Denmark to talented early career researchers to enable them to develop and strengthen their own research ideas and establish themselves as research directors with the foundation's financial assistance.

In 2019, the Independent Research Fund Denmark awarded Sapere Aude grants to 35 researchers on the basis of 346 applications. Of these, 11 recipients are from Aarhus University.

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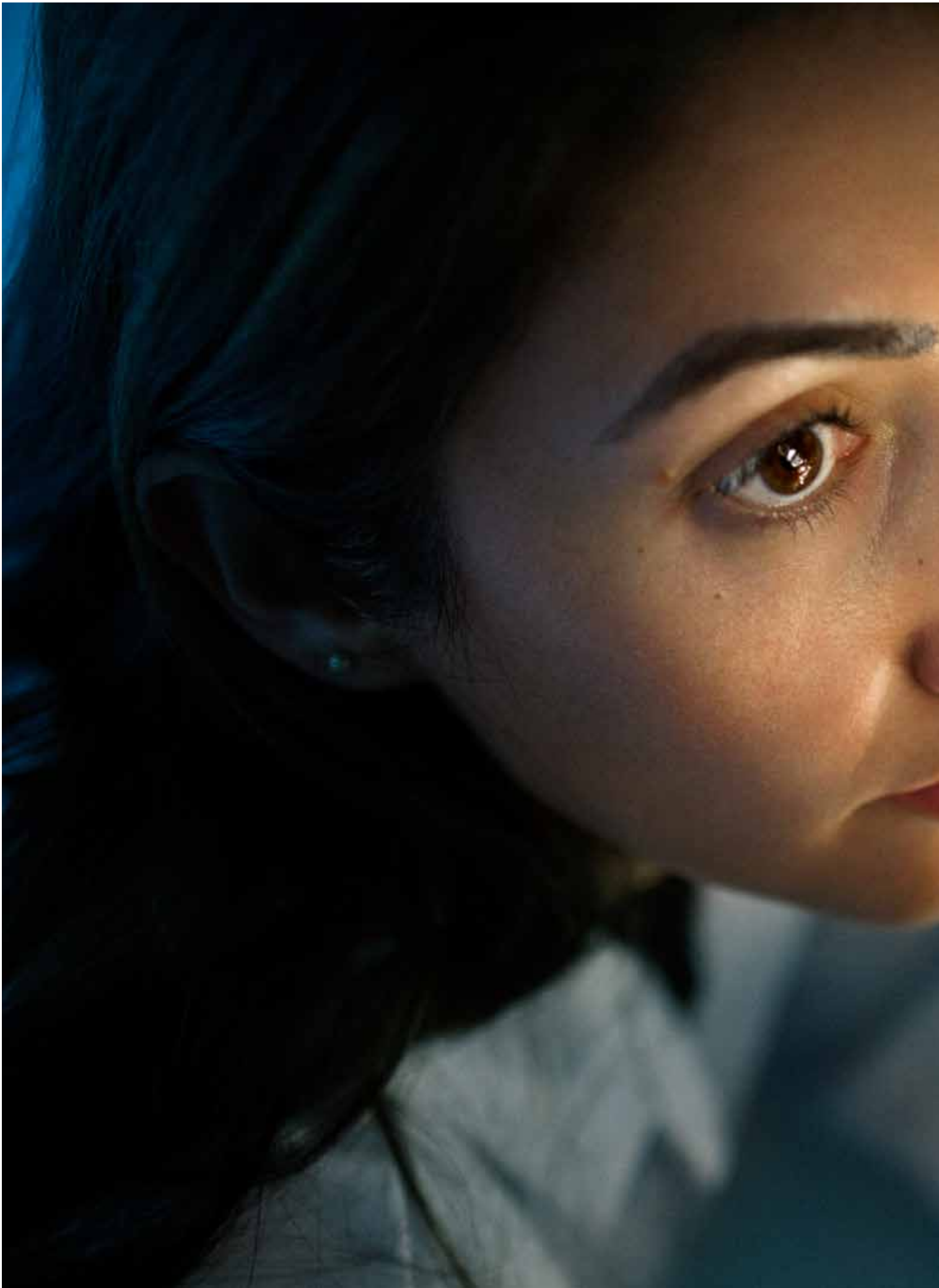
#### **Project title:**

PHOTOX-f, Photobiocatalytic oxyfunctionalization in continuous flow

#### **Financial framework:**

DKK 6.2 million, Independent Research Foundation Denmark







*An unusual, light-dependent enzyme is the focal point of a new research project. A team of engineers will utilize the rare properties of the enzyme in a photo-bio-catalytic continuous flow system to produce drop-in biofuels from waste oils and fats.*

## Rare algae enzyme to convert cooking oil into ready-to-use biofuel

Researchers have found an unusual, light-dependent enzyme in microalgae. A new project will use the enzyme in a system to produce drop-in fuels from waste oils and fats.

A grant of DKK 3 million (EUR 0.4 mill.) from the Novo Nordisk Foundation will kick-start a new research project at Aarhus University aiming to develop a system that, via completely natural processes, converts organic waste into sustainable biofuel we can pump directly into our cars.

It may sound too good to be true, but it's not.

The focal point is a special light-dependent enzyme, which was first discovered about two years ago. The enzyme is found in microalgae and it has the particular characteristic that, with light as the only source of energy, it can decarboxylate fatty acids into alkanes, and thereby synthesize biofuel.

### Compatible with society

"The project covers all stages of the process, from selection of the best mutant of the enzyme to development of the flow system itself, which, via photobiocatalysis, will convert organic waste oils and fats into different biofuels in a continuous

flow," says Tenure Track Assistant Professor Bekir Engin Eser from the Department of Engineering at Aarhus University.

These are the so-called drop-in biofuels, which are functionally equivalent to fossil fuels and are fully compatible with the existing petroleum infrastructure used in society.

In other words, this means that the sustainable biofuel extracted in this process can be used more or less directly in existing engines, so ordinary petrol and diesel vehicles can begin to run on a largely carbon-neutral green fuel.

Production has to be in a single, continuous flow in which waste stream is added at one end and, via enzymatic photobiocatalysis with the algae enzymes, is converted into fuel that comes out at the other end.

### Mutation portfolio

However, before we get that far, a great many processes have to be linked together.

At the moment, the enzyme produces alkanes of different lengths. The goal is to develop variants of the enzyme by protein engineering, so that we can adjust the individual production of alkanes to a kind of portfolio:

"So far, no one has tried to specialise the enzyme to create the product portfolio we want. For this reason, part of this project is to build a mutation library of the enzyme, so that, using different systems, we can make either diesel, petrol or jet-fuel in one process," says Associate Professor Selin Kara, who is heading the project.

As biofuel based on waste oil and fat could become a significant part of the energy market of the future, the technology will have to be scaled up:

"The system has to be very, very efficient, because enormous amounts have to be produced if we are to get the industry interested in this transition," says Associate Professor Selin Kara. ●



Tenure Track Assistant Professor Bekir Engin Eser and Associate Professor Selin Kara.

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**Facts:**

The project will develop a multi-enzymatic reaction sequence that can produce drop-in biofuel from waste oils and fats, and which has the potential to reduce the use of fossil fuels.

Using a light-dependent enzyme found in microalgae, it is possible to decarboxylate fatty acids to hydrocarbons of different lengths. By selecting natural enzyme mutations, the researchers expect to be able to develop enzyme variants that are specific to short, medium or long-chain hydrocarbons to meet different fuel needs.

“

*So far, no one has tried to specialise the enzyme to create the product portfolio we want. For this reason, part of this project is to build a mutation library of the enzyme, so that, using different systems, we can make either diesel, petrol or jet-fuel in one process”*

Associate Professor Selin Kara

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**Project title:**

Light-dependent multi-enzymatic synthesis of biofuels from sustainable resources

**Financial framework:**

DKK 3 million,  
Novo Nordisk Foundation

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WEB EXCLUSIVE


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Protein concentrate extracted from grass via green biorefining at the Department of Engineering's demonstration plant in Foulum, Denmark. The concentrate contains more than 50 per cent crude protein with a reasonable content of essential amino acids and can be used as fodder or processed further into food protein.



Read online





CURING  
EPILEPSY  
WITH  
ARTIFICIAL  
INTELLIGENCE





*A new ground-breaking treatment method could potentially cure epilepsy. Here, Associate Professor Farshad Moradi.*

The Department of Engineering at Aarhus University is part of a new international research team with an EU grant of DKK 60 mill. (EUR 8.5 mill.). The aim is to try to find a cure for epilepsy with a ground-breaking treatment method.

With a grant of approx. DKK 60 million from the prestigious Future Emerging Technology (FET-Proactive) pool under the EU research and innovation programme, Horizon 2020, Danish researchers from the Department of Engineering are working with 11 other European organisations to find a cure for epilepsy.

The research project introduces a paradigm shift in the treatment of brain diseases because the goal is to insert a so-called biohybrid neuronics device in the brain itself, which, by means of both a biological and an artificial component, regenerates damaged brain tissue by means of artificial intelligence.

It is potentially ground-breaking, explains Associate Professor Farshad Moradi, who is an expert in nanoelectronics:

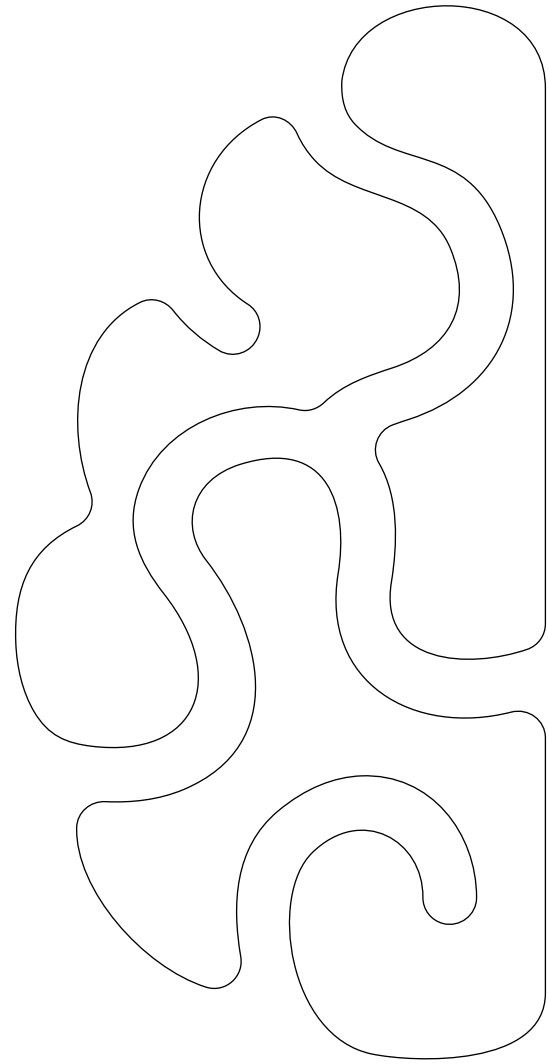
“We are putting effort into building a mi-

cro-scale, brain-like computing chip to train the brain on how to behave in case of a failure with help from Artificial Intelligence. This project is going to be carried out in close collaboration with neurobiologists in order to research and develop a reliable brain-like circuit in hardware enabled by neon-scale devices. Building such a brain-like chip potentially enables the healing of any damaged brain circuitry in the future, if successful,” says Farshad Moradi.

#### **Strong need for cure**

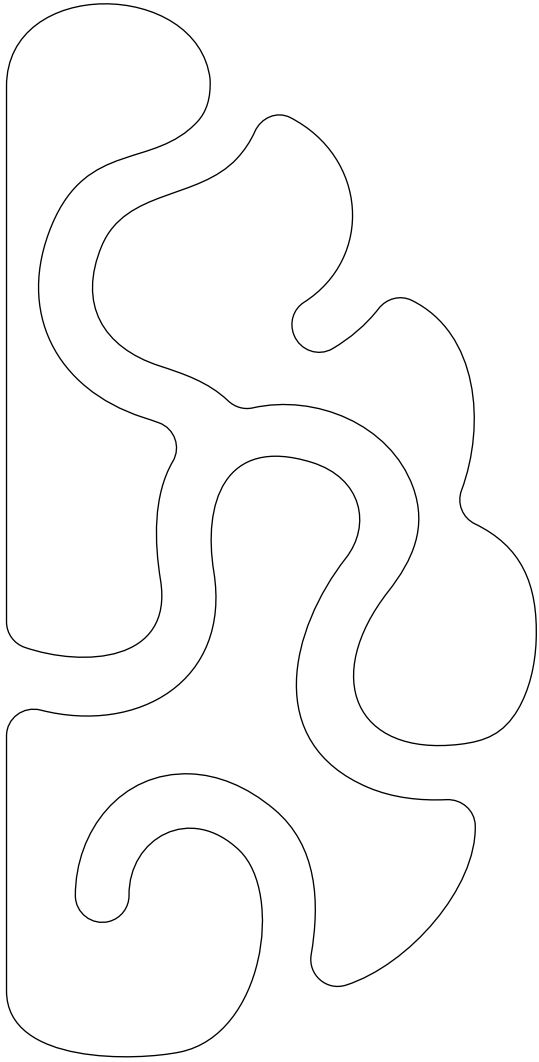
The research project, known as HERMES (Hybrid Enhanced Regenerative Medicine Systems), primarily involves studying epilepsy, a chronic neurological condition which manifests with recurrent seizures.

50 million people suffer from epilepsy globally, 8 million in Europe alone. That makes it one of the most frequent neu-



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“

*Building such a brain-like chip potentially enables the healing of any damaged brain circuitry in the future, if successful”*

Associate Professor Farshad Moradi

rological diseases. Today, many epilepsy patients live with it for the rest of their lives, thus there is a strong need for a cure. Researchers from the HERMES consortium will study temporal lobe epilepsy, the most frequent epileptic syndrome and the least responsive to anti-epileptic medications.

Temporal lobe epilepsy destroys the area in the brain called hippocampus, and the purpose of the project will be to rebuild this area using so-called 'biohybrid neuronics' (neural electronics) based on the functional symbiosis between biological and artificial counterparts. The researchers will create hippocampal tissue in the laboratory and couple it with an electronic device that mimics the normal functioning of the brain.

#### **AI component shuts down automatically**

Biohybrid neuronics will be implanted in the brain of epileptic rodents, where the

electronic device, equipped with artificial intelligence, will be used to guide the correct integration of the biological component within the brain. The electronic device will be used to train the transplanted tissue until the damaged area has been fully regenerated and is functioning normally, after which the artificial component will shut down.

The HERMES project was launched in 2019 and will run for five years. ●

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#### **Project title:**

HERMES: Hybrid Enhanced Regenerative Medicine Systems

#### **Financial framework:**

DKK 60 million, Horizon 2020

#### **Schedule:**

5 years

#### **Partners:**

Istituto Italiano di Tecnologia (Italy)  
 Università degli Studi di Modena e Reggio Emilia (Italy)  
 Università degli Studi di Verona (Italy)  
 Agencia Estatal Consejo Superior de Investigaciones Científicas (Spain)  
 Politecnico di Milano (Italy)  
 University of Glasgow (UK)  
 Tampere University (Finland)  
 Fundación Instituto de Estudios de Ciencias de la Salud de Castilla y León e Universidad de Salamanca (Spain)  
 Eurokleis S.r.l. (Italy)  
 Radboud Universiteit (Netherlands)  
 Den Institute (Belgium).  
 Aarhus University (Denmark)

The project is coordinated by Istituto Italiano di Tecnologia (Italy)

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# Danish researchers develop artificial intelligence to expose stock-market fraud

Aarhus University is heading a project to put an end to stock-exchange fraud and market manipulation. The researchers will use artificial intelligence (AI) to clean up the extensive fraud taking place, where control is currently implemented via manual sampling.

A team of researchers from Aarhus University (AU) has received a grant of DKK 2.8 million (EUR 0.4 million) from the Independent Research Fund Denmark for a project that may impact share trading throughout the world.

The team is being headed by Alexandros Iosifidis, an associate professor at the Department of Engineering and an expert in machine learning. The project aims to develop a system that can identify suspicious trading on all of the world's stock exchanges – something that is currently being done through manual samples.

"The AI solutions we're looking for require far less manual work, they reduce costs, and they're much more effective than today's controls," says Alexandros Iosifidis.

## Billion-dollar problem

As yet, no one knows the extent of stock-market fraud globally, but the US Federal Trade Commission (FTC), has estimated that, in the US alone, the problem amounts to between USD 10-40 billion a year.

There are many different types of stock-market fraud, which is a ticking bomb under the whole philosophy behind the market-economy principle of supply and demand.

"A reliable, automatic safeguard against market manipulation could therefore be crucial for transparent stock markets," says Alexandros Iosifidis.

## Detect and predict

The project will design entirely new methods which, using machine learning, will be able to conduct systematic analyses of stock-exchange activity, recognise irregular transactions, and identify patterns in share-price data. This will make it possible to detect, and even predict, market manipulation in share trading across the entire world.

"We're working on the assumption that trading in one share affects future trading in other shares in specific patterns that can be recognised using data-driven analyses. We're focusing on recording trading activity based on jumps in average share prices, and we will detect these in actual stock-exchange data in order to identify relationships between share transactions and irregular trading activities," he says.

The project is called 'Data-driven Inter-Stock Predictive Analytics' or 'DISPA', and it will run for three years, coordinated by Associate Professor Alexandros Iosifidis.

## Project title:

DISPA: Data-driven Inter-Stock Predictive Analytics

## Financial framework:

DKK 2.8 million, Independent Research Fund Denmark

## Schedule:

3 years



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Photo: Lars Kruse

Stock-market fraud amounts to between USD 10-40 billion a year in the US alone.

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*A reliable, automatic safeguard against market manipulation could be crucial for transparent stock markets”*

Associate Professor Alexandros Iosifidis

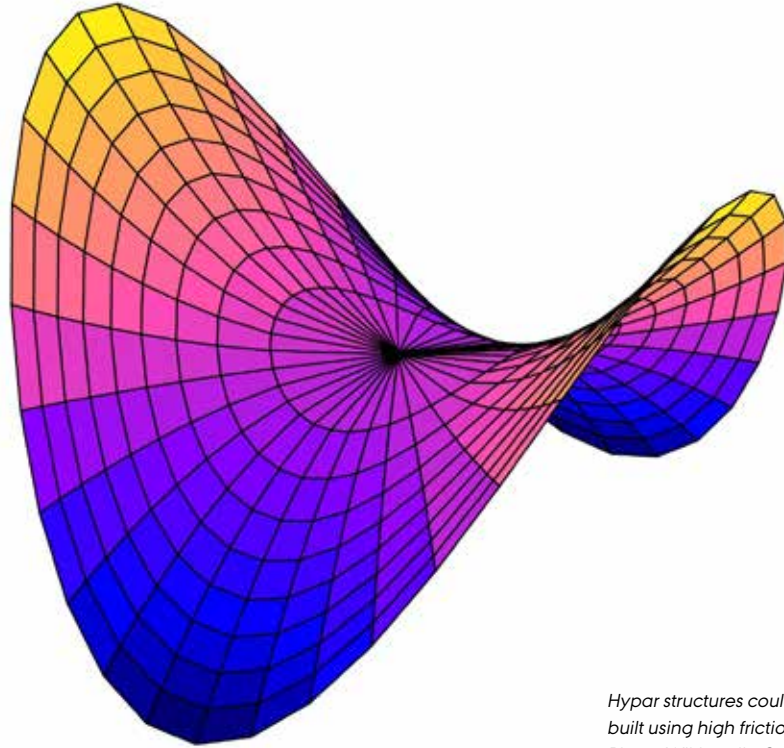


### **Creating anticlastic architecture using Newton's laws**

Valentina Beatini, architect from the University of Genoa and PhD from the University of Parma, is a new tenure track assistant professor at the Department of Engineering, Aarhus University. Her research is focused on building strange shape constructions using high friction masonry.

Photo: Lars Kruse





*Hypar structures could theoretically be built using high friction masonry alone.  
Photo: Wikimedia Commons*

On a small hilltop in north-central Italy, right in the middle of Tuscany, lies a small village. Known as “the town of fine towers”, the place is famous for its more than 500-year-old high-rise architecture.

The skyline dates back to the Middle Ages, when two competing families built ever taller houses culminating in 72 towers up to 70 metres tall.

The village is called San Gimignano and is an ancient jewel of building design held together by one thing: masonry. And like so many other brilliant pieces of medieval built Italian history, it played a major part in why Valentina Beatini – the newest addition to the civil and architectural engineering research team at the Department of Engineering, Aarhus University – became an architect.

ty, which has been lived in and left unchanged for centuries because it worked. And still works. That is quite amazing in my mind, that people were able to create cities and streets and spaces a thousand years ago that is still appealing to the modern community today,” she says.

Valentina Beatini is a new tenure track assistant professor at the Department of Engineering. Today, her research is focused on anticlastic architecture using high friction masonry and zero mortar and on innovative modular structures able to add meaning and value to the contemporary building landscape.

She is currently working on a hyperbolic paraboloid (hypar) shaped structure. But any structure can theoretically be achieved, she explains:

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Tenure Track Assistant Professor  
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“In Italy, wherever you go – even in the smallest village hidden in the most remote location – you are surrounded by architectural beauty. Diffuse block-built beau-

“The idea is to use friction and compression to create spatial structures with no mortar. Simply blocks that are held together by the laws of physics,” she says. ●



## WEB EXCLUSIVE



Focus was on entrepreneurship, the City of Aarhus' climate strategy, the latest engineering research, and interdisciplinary collaboration, when the Department of Engineering filled Incuba's Pier Venue for 2019's last Science Lunch in December.

Science Lunch is an ongoing informal academic programme at which researchers, the business community, the industry and students openly share ongoing projects and research with each other.

Photos: Zane Hartmane





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A person wearing a dark jacket is working in a laboratory or industrial setting. They are holding a long, thin metal rod or tool, possibly a probe or a sample holder, and are focused on their task. The background is slightly blurred, showing various pieces of equipment and structures. The overall scene suggests a research or technical environment.

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Revolutionising the way  
we manage waste:  
A Danish researcher is  
developing a pioneering  
new technology  
able to e.g. recover  
all phosphorus from  
manure and sludge.





An engineer from Aarhus University has received EU funding for the launch of a new research project, which can have far-reaching and ground-breaking significance for the environment throughout the world. The project promises to completely revolutionise the way we manage liquid waste today.

The DKK 11.2 million (EUR 1,5 million) grant from the prestigious ERC Starting Grant under the EU Framework Programme for Research and Innovation (Horizon 2020) sets in motion a project promising to deliver far more sustainable liquid waste management to benefit the environment around the world.

The project is headed by chemical engineer and Tenure Track Assistant Professor at the Department of Engineering, Aarhus University, Patrick Biller, who will use state-of-the-art technology known as continuous hydrothermal liquefaction (HTL) to recover phosphorus and carbon from manure and sewage sludge (carbon in the form of so-called biocrude, which can be refined e.g. into aviation fuel).

The project is ground-breaking because it will allow for almost 100% recycling of valuable resources in liquid waste management. In addition to biocrude, the end product consists of nothing more than clean freshwater, hydrogen and CO<sub>2</sub>.

"I'm very grateful to have been awarded this grant, which makes it possible to develop this exciting new technology that will enable us to recover valuable phosphorus from waste otherwise difficult to manage," says Tenure Track Assistant Professor Patrick Biller.

Today, phosphorus is a valuable and scarce resource, which is ranked among the top 20 most critical raw materials by the EU. Europe does not have its own phosphorus reserves, and is therefore primarily imported from North Africa where it is retrieved from mines as phosphate rock.

Mining for as well as refining and trans-

port of phosphate rock for fertiliser is associated with considerable greenhouse gas emissions (3.1 kg of CO<sub>2</sub> per kg of phosphoric fertiliser), and it has been assessed that phosphorus resources are so scarce that they will only meet our demands for a further 50-100 years; and when they are depleted, it will have dire consequences for humanity.

Every year, Danish agriculture imports 50,000 tonnes of phosphorus, because it is absolutely necessary to apply phosphoric fertiliser to crops if you want to be able to maintain the yield that is normal for modern agriculture.

Denmark's approx. 13 million pigs also produce large amounts of phosphate rich organic manure, which is difficult to reuse as fertiliser without harming the environment.

To recycle the phosphorus, farmers apply manure to fields as fertiliser, and in many countries this leads to environmental problems such as contamination of the aquatic environment, groundwater and air. The problem is that manure can contain large amounts of antibiotics, which can cause problems with antibiotic resistance when the slurry is dispersed in the fields.

The same problem applies to sewage sludge. Here, e.g. residues from microplastic, oestrogens, pathogens and pharmaceutical products, including antibiotics, make it very difficult to directly recycle the sludge.

"Due to the relatively high temperatures and pressures in the HTL reactor, all environmentally hazardous substances are destroyed, so that the phosphorus



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HTL facility at Aarhus University

we eventually recover is clean, safe and plant-available," says Patrick Biller.

The project, which is called REBOOT, and which is headed by Patrick Biller from the Department of Engineering, Aarhus University, officially starts on 1 January 2020, at which point Patrick Biller will set up a research group for the project. The project will be run at pilot scale at the department's Centre for Biorefining Technologies at Foulum, which is already home to one of the world's largest HTL reactors.

The aim is to create a single cohesive system that is fed with sewage sludge and manure at one end, and which supplies the valuable raw materials at the other

end. Patrick Biller will make it possible to do so e.g. by developing new solutions and technologies within catalysis, water purification and filtration.

If the project is successful, it will have a huge and positive effect on the environment across the world, as it will make mining for phosphorus redundant and will provide us with sustainably fuel, recovered directly from our wastewater. At the same time, it will have great significance for the problems associated with lack of sewage treatment in many developing countries, such as the spread of disease and other adverse health effects. ●

**Project title:**  
REBOOT

**Financial framework:**  
DKK 11.2 million, Horizon 2020

**Schedule:**  
5 years





# WORK WITH US

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The Department of Engineering at Aarhus University cooperates with a wide range of organisations and companies on research and development projects. For example, we help large and small businesses to join the Industry 4.0 wave, we establish innovative partnerships for exploring technological challenges and we cooperate internationally to create insight into international trends. We work with the latest technologies to help companies build or develop new products or components and to process-optimize production chains.

Are you interested in working with the region's leading knowledge institution? We offer various cooperation models.

#### **Collaborative R&D projects and programmes:**

Our researchers are involved in a large number of national and international research projects in collaboration with companies and universities throughout the world. Therefore, your company can tap into the latest technological knowledge within the engineering sciences and the opportunities this offers your industry. If your company has an idea or a need you want help with, you can collaborate with our researchers on developing your company's technology.

#### **Scientific and innovation networks:**

Aarhus University is active in almost every innovation network in Denmark, and in many other scientific, technical and business-related networks. It may be advantageous for your company to learn more about these networks and what they can

offer. You can solve your business problems in collaboration with others, and this is an excellent way to profile your company. You can also develop long-term strategic collaborations with other companies or knowledge institutions.

#### **Innovation collaborations:**

We have (The Department of Engineering at Aarhus University) launched a number of initiatives to help companies, especially SMEs in Denmark. For example, our "Smart Industry" programme targeting SMEs with the potential to develop new smart products, services or processes. This is a specific initiative to strengthen growth and innovation for SMEs through more teamwork between companies and knowledge institutions. We also offer cross-disciplinary cooperation combining engineering expertise with researchers from other departments in Aarhus University's strategic research centres. Combined with a strong and proven approach in applied innovation, we lead and facilitate processes to create new possibilities and new needs. We transform the latest research findings into useful knowledge, products and methods for a huge variety of different companies in different branches and of different sizes, ranging from entrepreneurs to SMEs, and from medium sized companies to large organisations.

#### **Get involved**

If you would like to explore the opportunities of working with us, contact Business Relations and Partnerships for further information about how we can connect relevant researchers and your interests. ●

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Business Relations and Partnerships  
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## WEB EXCLUSIVE

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Denmark aims to be independent of coal, oil and gas by 2050, and in parallel with increasing electrification of its infrastructure and heating sector, this means that Denmark is facing future multi-billion investments in conversion and expansion of the energy system.

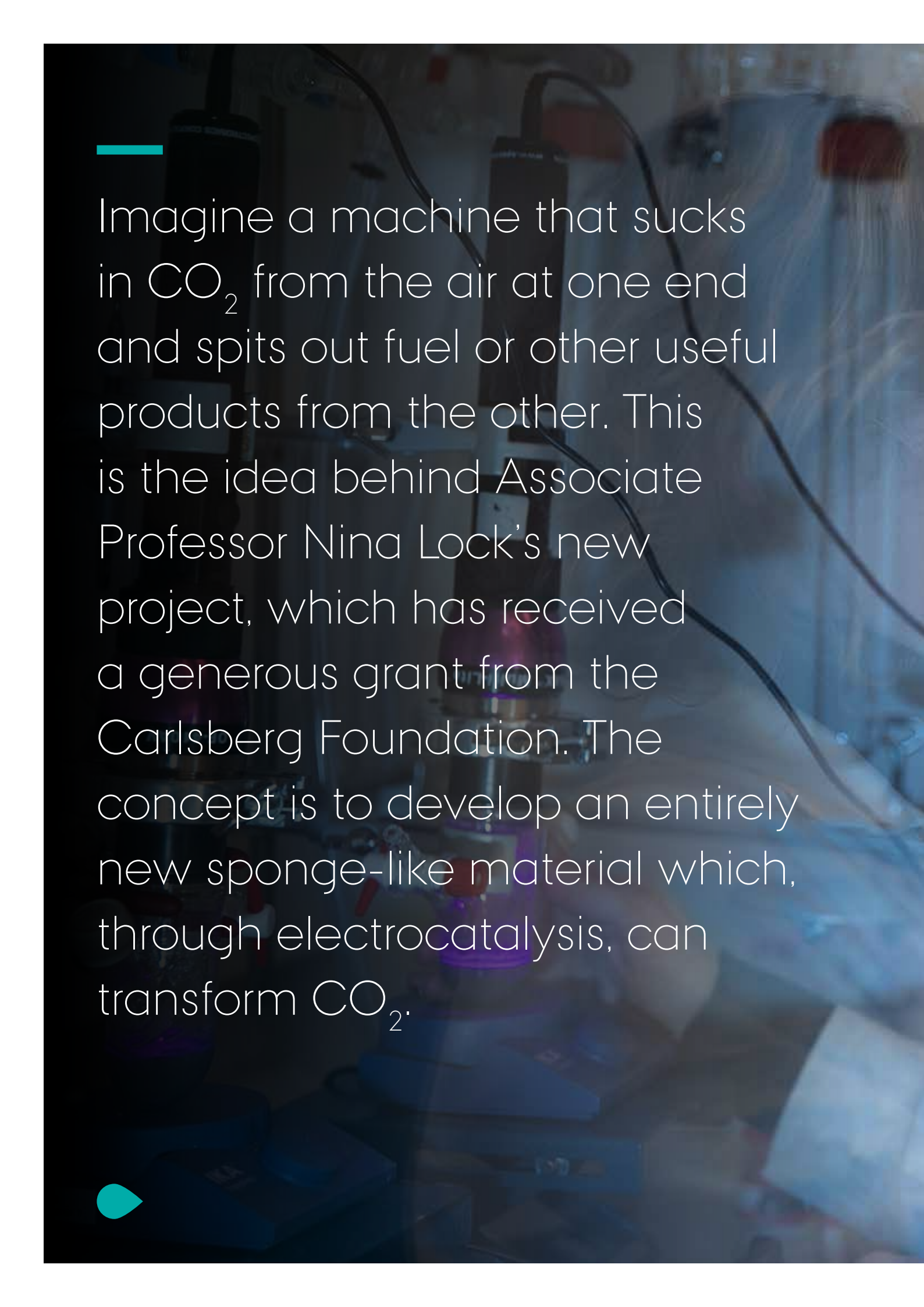
A four-year research project, in which Aarhus University and the three other Danish technical universities have joined forces with the utilities sector, will focus on whether, by using among other things artificial intelligence, it is possible to remove a significant percentage of this investment need.

“In the near future, I can well imagine that the design of energy-efficient buildings will also entail weighing investments in energy flexibility against investments in, for example, energy savings,” says Associate Professor Steffen Petersen, who is head of Aarhus University’s part of the project.



Read online





Imagine a machine that sucks in CO<sub>2</sub> from the air at one end and spits out fuel or other useful products from the other. This is the idea behind Associate Professor Nina Lock's new project, which has received a generous grant from the Carlsberg Foundation. The concept is to develop an entirely new sponge-like material which, through electrocatalysis, can transform CO<sub>2</sub>.





# Metal-organic sponge to convert CO<sub>2</sub> into fuel

Associate Professor Nina Lock has received a grant of DKK 4.3 million (EUR 0.6 mill.) from the Carlsberg Foundation to develop an entirely new material which, through electrocatalysis, can transform CO<sub>2</sub> into useful products.

Imagine a machine that sucks in CO<sub>2</sub> from the air at one end and spits out fuel or other useful products from the other. This is the idea behind Associate Professor Nina Lock's new project, 'Rational development of inexpensive and scalable electrocatalysts', which has received DKK 4.3 million from the Carlsberg Foundation as a 'Young researcher Fellowship' grant.

"Humanity is facing a huge problem in relation to both climate change and limited carbon-based resources. We need to find other sources of carbon, and if we can convert CO<sub>2</sub> from a waste product into something useful, we can help solve both issues at the same time," says the associate professor about the overall motivation behind the project.

"On a more personal note, I also have to admit that it's just a really exciting project," she continues.

Associate Professor Nina Lock is an expert in hybrid materials, and much of her work is on reduction of CO<sub>2</sub>. Her idea in this project is to develop new metal-organic materials that work a bit like a sponge.

"We want to create a metal-organic network composed of metal centres connected to organic molecules that together form a porous network – a bit like a sponge with pores in which CO<sub>2</sub> can diffuse," says Nina Lock.

## Cheap system for industrial use

After the CO<sub>2</sub> has been diffused inside the 'sponge', by means of an electro catalysis it will be converted into another product, e.g. fuel such as methanol or methane, or building blocks for the chemicals industry, after which the product can diffuse out of the pores again.

"The aim is to develop scalable catalysts so that we can use this industrially. This means that we need to create a system based on cheap elements and not, for example, precious metals," says the associate professor.

The project also includes a study of how electro-catalysis takes place at atomic level.

"We also want to investigate what happens to the structure of the catalyst during the process. What's happening at atomic level when we run electricity through our catalyst? We actually know very little about this today. We need to find a material where this works, and then we need to find out exactly why it works," she says.

"Therefore, the research team will take a sort of X-ray of the process itself, so that we can see exactly what's happening."

In November, the Carlsberg Foundation granted DKK 204 million (EUR 27.2 mill.) to 134 young up-and-coming researchers and young newly appointed associate professors with visionary research ideas and projects. Thirty researchers from Aarhus University have received grants totalling more than DKK 47 (EUR 6.3 mill.) million.

With the grants, Aarhus University has received more than DKK 121 million (EUR 16 mill.) from the Carlsberg Foundation on the basis of applications submitted to the Foundation in 2019. Total grants from the Carlsberg Foundation amounted to more than DKK 400 million (EUR 53.3 mill.) based on calls in 2019. ●

## Project title:

Rational development of inexpensive and scalable electrocatalysts'

## Financial framework:

DKK 4.3 million, Carlsberg Foundation

## Schedule:

3 years



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Photo: Ida Jensen

Associate Professor Nina Lock in her research lab at Aarhus University

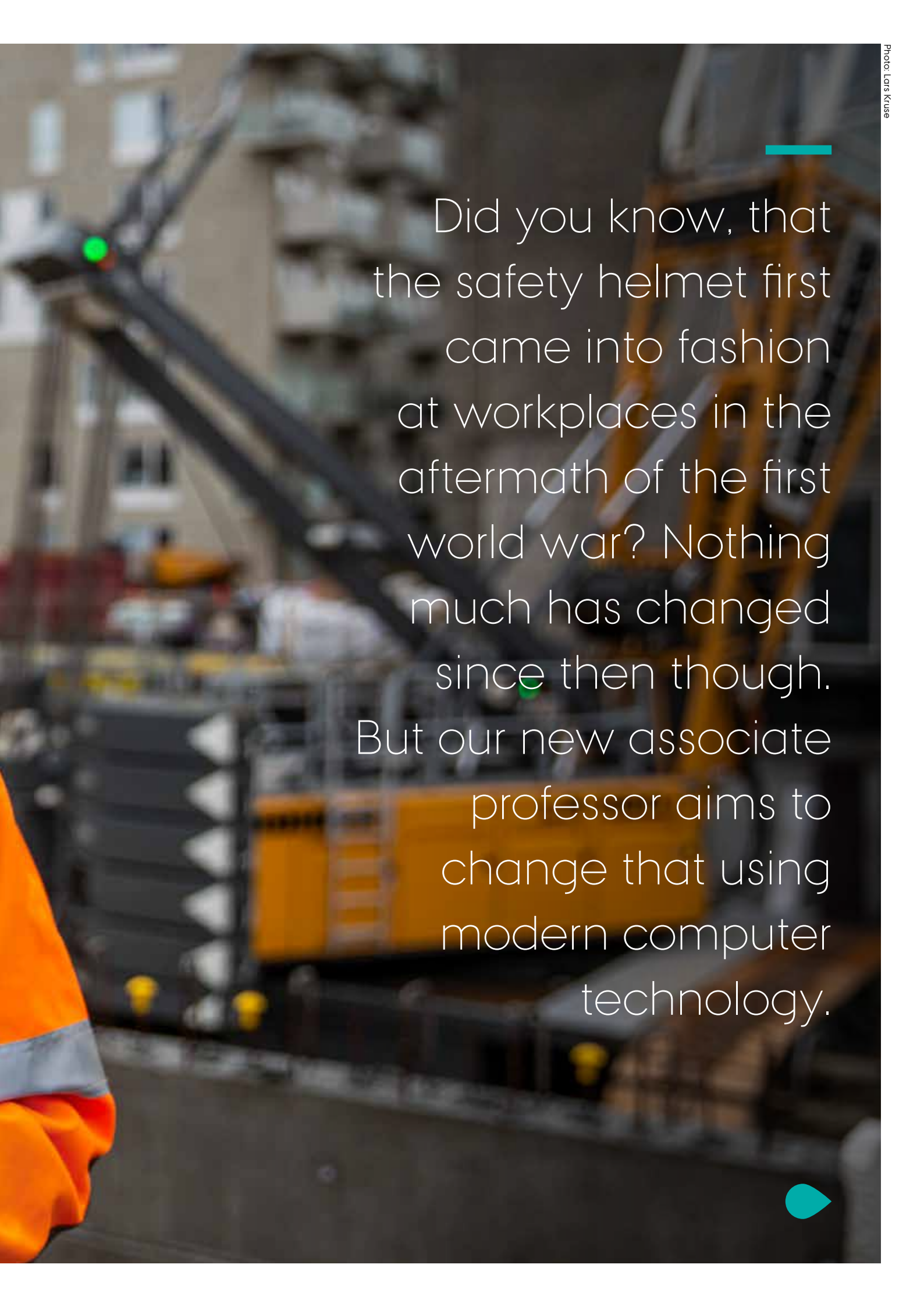
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*Humanity is facing a huge problem in relation to both climate change and limited carbon-based resources. We need to find other sources of carbon, and if we can convert CO<sub>2</sub> from a waste product into something useful, we can help solve both issues at the same time”*

Associate Professor Nina Lock







Did you know, that the safety helmet first came into fashion at workplaces in the aftermath of the first world war? Nothing much has changed since then though. But our new associate professor aims to change that using modern computer technology.



## New AU researcher aims to make workplaces safer with computer technology

Nothing much has changed since the safety helmet came into fashion at workplaces all over the world in the aftermath of the First World War. Associate Professor Jochen Teizer wants to do something about that. He uses digital twins, Internet of Things (IoT), and Mixed Reality to pro-actively prevent accidents at the workplace, alert workers of dangers in real-time and personalize education and training.

Tens of thousands of workers die and millions are injured every year at workplaces throughout the world as a result of accidents. And many of these take place on building or infrastructure sites. In the US alone, construction-related accidents are responsible for more than one in five deaths, and approximately 25 per cent of these involve large machines.

And even though deaths and injuries can have severe consequences for the persons, their family and relatives, businesses and even society, there aren't many countries that think about safety as much as the Scandinavians.

This is a pity, according to Jochen Teizer, a new associate professor at the Department of Engineering, Aarhus University, who has devoted his professional career to improving safety and productivity at workplaces, in particular in dynamic and complex construction sites.

"Every cent you invest in safety will earn itself back three times through achieving additional improvements, and that's

why I think it's a shame that more countries aren't following the Scandinavians' strong focus on safety. That's why safety and productivity go hand in hand! I have seen several businesses go unnecessarily bankrupt due to accidents and poor work practices. Much of this could be avoided with stronger focus on safety in the first place," he says.

Associate Professor Jochen Teizer is an award-winning German engineer, who has now settled in Denmark to pursue his research career at Aarhus University. He's won several industry and academic prizes, one of which for the SmartHat 4.0 – a safety helmet equipped with sensor technology that, among other things, pro-actively warns workers of immediate dangers in real-time.

However, Teizer hasn't only worked with personal protective equipment (PPE) like helmets. He tries to incorporate modern technology in all aspects of a project's lifecycle phases. In order to design out hazards already at the planning phase, he successfully invented automatic safe-



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Associate Professor  
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Photo: Jochen Teizer

Personalized education and training is paramount for optimal safety on workplaces. Here, the training is done virtually.

“

*Every cent you invest in safety will earn itself back three times through achieving additional improvements, and that's why I think it's a shame that more countries aren't following the Scandinavians' strong focus on safety.”*

Associate Professor Jochen Teizer

ty rule checking for Building Information Modeling (BIM). By introducing IoT-based services built into building elements, workwear and shoes, he measures, analyses and visualizes unsafe behaviour in a workplace objectively and in real-time. He designs and tests virtual construction games for more effective, personalized education and training.

“Human capital should be prioritised above everything else, and this is why

safety is so important. We all work best in a safe and secure environment, and I hope that more countries will begin to adapt new technologies to the same extent as they do here in Denmark, for example. It's important to understand that, in this context, technology is not an enemy, but a helper. An assistant that can give us a number of benefits,” he says.

Jochen Teizer was born and raised in Karlsruhe, a stone's throw away from the

fabled Black Forest. As the son of a construction manager, Jochen himself started his engineering studies at the Karlsruhe Institute of Technology and subsequently went to the US, where he took his PhD at the University of Texas. He has taught and researched for several years at the Georgia Institute of Technology, the Technical University of Munich, Osaka University, and Ruhr-Universität Bochum. ●



AU Engineering, Campus Navitas, Aarhus

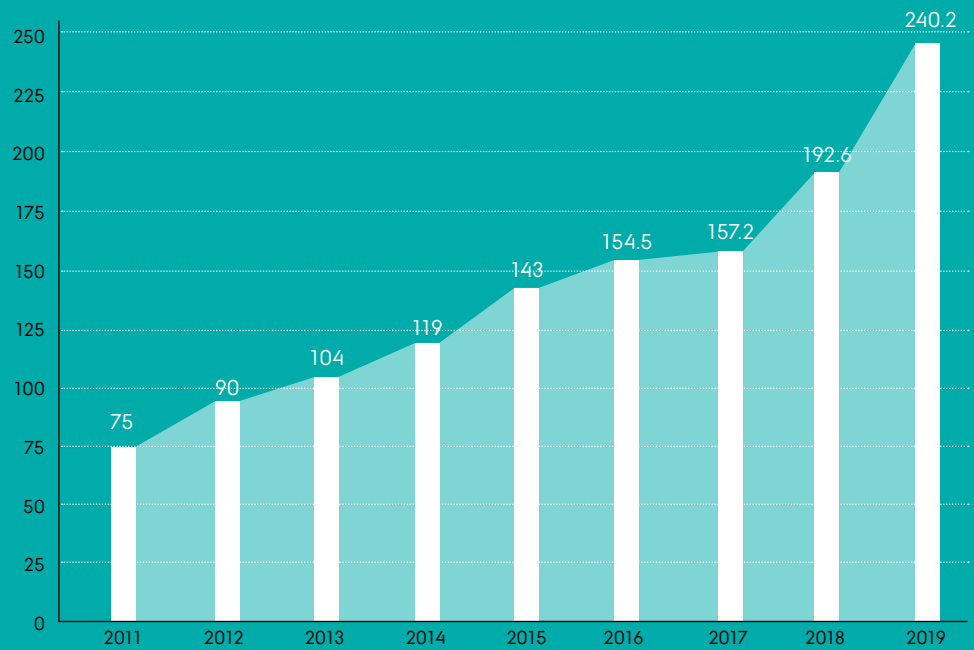


Photo: Maria Rendina

# KEY FIGURES

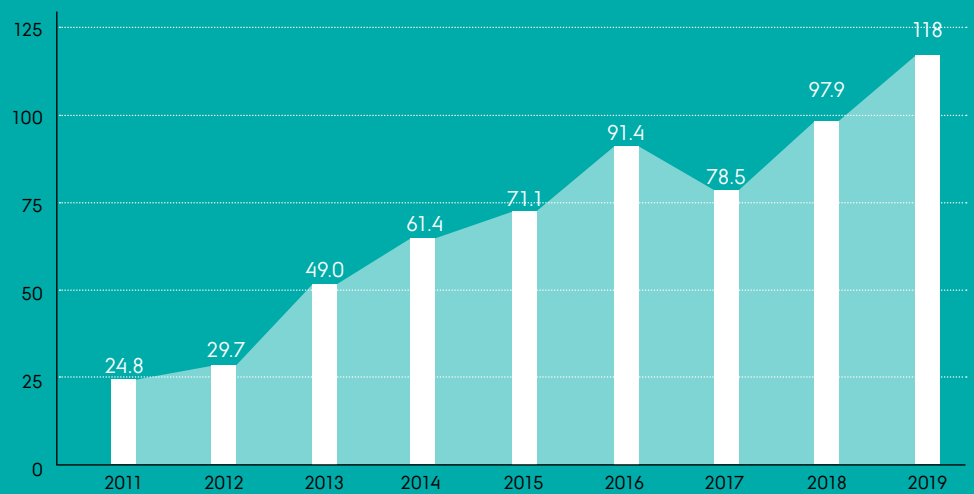
## TOTAL ENG TURNOVER (M DKK)

Based on annual FC3 budget

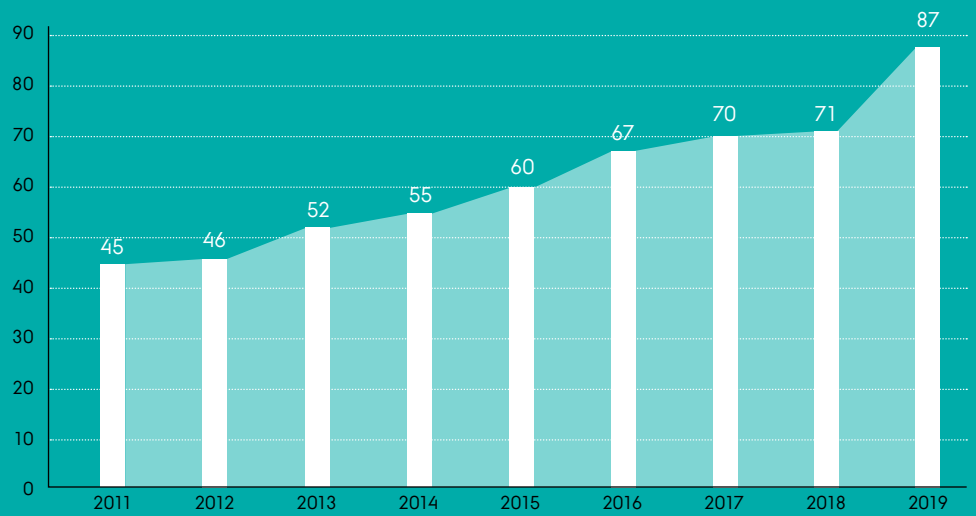


## EXTERNAL FUNDING TOTAL (M DKK)

Based on annual FC3 budget

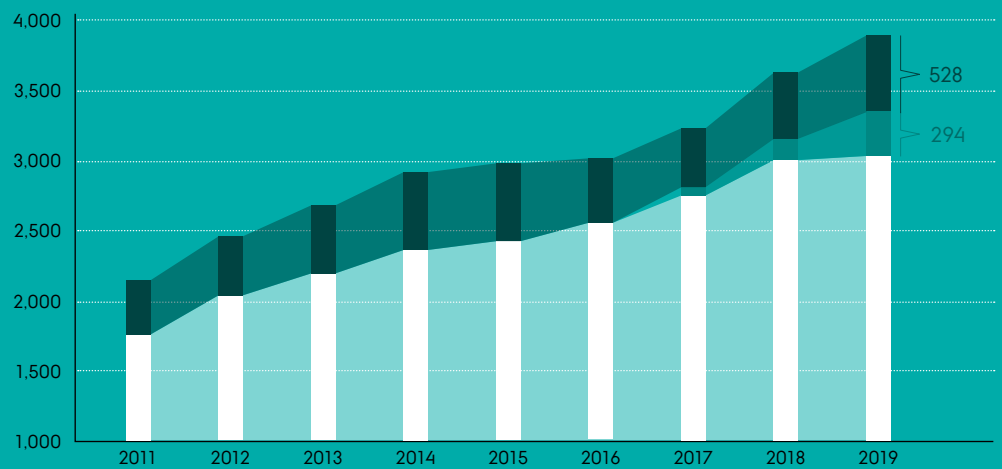


ENGINEERING PHD STUDENTS



ENROLLED ENGINEERING STUDENTS

- MASTER OF SCIENCE IN ENGINEERING
- BACHELOR OF SCIENCE IN ENGINEERING
- BACHELOR OF ENGINEERING



WEB EXCLUSIVE

There is an increasing global need for a standardized, documentable 3D printing filament of high and stable quality from recycled plastics. Now, we're developing exactly that.





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