PROFILE 2016
DEPARTMENT OF ENGINEERING

RESEARCH
TECHNOLOGY
IMPACT

AARHUS
UNIVERSITY

Innovation through engineering

Engineering is all about taking deep science and using it for innovation. It is about translating theoretical research into new solutions and applications that can benefit individuals, businesses and society.

During the short history of engineering at Aarhus University, we have aspired to a standard of excellence that has required a strong innovation culture. This has been essential to the development of research activities within technological fields that address some of the global grand challenges the world is facing today.

Our early multidisciplinary focus has enabled us to initiate an impressive number of new projects at both national and European levels, ranging from basic engineering science to applied strategic research, and funded by public institutions as well as private companies.

These projects have in common that each one focuses on technological innovation while also creating value, whether it be social, cultural or financial.

In 2016, we are attempting to advance to the next level with increased possibilities and opportunities to enable our research activities to support society. In near future new inventions and technology-driven innovation will accelerate a major societal shift and disrupt the way businesses operate and people live their daily lives.

These changes are not without challenges for engineering universities. We are going to break new ground, but we are going to do it with due care and consideration. We strive for increased commercialisation of research and for economically viable knowledge transfer to industry. Above all, however, we would like to lay the foundation for a better world where technology stands for positive intervention.

I am proud to highlight some of our latest engineering projects. They are all examples of innovation in the heart of the global megatrends that drive the transformation of society.

Sincerely yours,

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

"Department of Engineering at Aarhus University creates innovative and sustainable solutions to some of the major problems facing humanity. We keep a strong focus on technology's impact throughout all our engineering activities – in deep research, applied and strategic research, partnerships with industry, education, development of PhD programmes, and in our public sector consultancy services."

Thomas S. Toftegaard,
Head of Department of Engineering

ENGINEERING DISCIPLINES

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

COM PUTER INTELLI GENCE

We meet intelligent systems each and every day. Digitalisation has made a radical impact on the lives of individuals and competitive conditions for companies. Researchers play a key role in the work involved in utilising technological opportunities in a good, safe and responsible way in fields such as Artificial Intelligence, Internet of Things and Big Data.

Earth antennas
to find groundwater

Researchers will develop antenna technology in a new project to locate and measure groundwater without expensive drillings.

Our groundwater resources are under pressure all over the world due to overexploitation, pollution and climate change. In some places – the most severely affected areas – the groundwater table is sinking more than one metre per year, and major problems are often seen in coastal areas due to salt water intrusion.

The traditional methods used to measure groundwater levels via drillings are expensive, and it is hard to predict precisely how much water can be extracted without emptying subsurface reserves. Researchers will therefore design a new technological instrument to spot groundwater from the ground surface in a way that is both sustainable and inexpensive.

More precise detection of groundwater
The idea is to use an antenna on the ground surface to create an electromagnetic field that affects the water.

"We know that water respond to electromagnetic fields at a certain frequen-

cy and, by analysing how it reacts, we can draw very detailed groundwater maps," says Assistant Professor Jakob Juul Larsen.

In the next three years, the researchers will develop the antenna so it can very precisely locate and characterise access conditions to the groundwater without any drillings at all. This will make it easier to acquire knowledge about the size, distribution and quality of the groundwater resources, according to Dr Larsen.

"If we're to continue to have access to sufficient amounts of groundwater in the future, we must ensure a sustainable transformation of the way we exploit the resources. For this purpose, we need new instruments that can spot groundwater quickly and more precisely," he says.

New computer models of the subsurface
The aim is to prepare a geophysical measuring method that determines not only the water content in the subsur-

face, but also the porosity of the soil layers. This will make it possible to very precisely analyse the subsurface conditions and thereby the potential for transporting water.

"Once we've acquired detailed knowledge of the location of the water and the soil layer characteristics, we'll be able to build computer models of the groundwater and predict how much water we can pump up," says Dr Larsen.

The antenna consists of a 400-metre-long cable laid out on the ground surface in a 100 x 100 metre square, and this will provide the researchers with extremely valuable data.

"We can use the data about the subsurface to build computer models of the groundwater. This will make it much easier to find, and we can also get more precise information about the amount of groundwater we can pump within sustainable limits," says Dr Larsen.

Photo: Colourbox

Researchers will use new technology to measure groundwater from the ground surface via electromagnetic signals from an antenna. This could prove to be an efficient, inexpensive and sustainable alternative to traditional drillings.

project facts

TITLE
Faster surface NMR groundwater measurements with new receiver technology

SCHEDULE
2016-2017

FINANCIAL FRAMEWORK
DKK 300,000

PARTNERS
COWI A/S

CONTACT
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New patent on drones that spray predator urine

Drones equipped with thermal cameras and predator urine will help to reduce the number of fawns killed by farm machinery on agricultural land.

Every year in June, thousands of fawns are killed in the fields when they get run over by large farm machinery at harvest time. The accidents mostly occur during the summer when the animals migrate to the edge of wooded areas.

"The problem today is that during the first week or two, the newborn fawns usually lie flat on the ground when an agricultural machine is approaching. This makes it extremely difficult to detect the animal and prevent a collision. Even for a hunter with a trained dog, it is an almost impossible task since fawns have no scent," says Senior Researcher Rasmus Nyholm Jørgensen.

But according to the first results from a research project to monitor deer and fawns, the problem may be greatly reduced by using drones equipped with thermal cameras and predator urine.

Urine makes the mother call out to the fawn

The idea is that the drone identifies specific fields where fawns are hiding and then sprays urine in precisely this area. The smell of the predator urine alarms the mother deer which then calls out in the twilight.

"Fawns protect themselves by hiding, pressing themselves against the earth, and lying perfectly still. The only thing that can get them to come out of the field is when the mother calls," says Senior Researcher Jørgensen.

He is one of the main designers of the drone and he has already carried out the first test flights with different predator scents. Canadian lynx urine has proved to have the greatest deterrent effect to date.

Can improve food safety

Aarhus University has taken out a patent on the technology to spot animals and spray the fields with urine, and will apply for funds in the coming time to further develop the spray method.

"We'd like to reach an altitude of right up to 40 metres, and we therefore need to find out whether we can use an additive so the urine doesn't blow in all directions when we spray," says Senior Researcher Jørgensen.

Photo: Colourbox

A drone with thermal cameras identifies game in the fields. It then sprays lynx urine over the area. The smell alarms the mothers, who call out to the fawns, clearing the way for the farm machinery within a short time. Researchers will use it to significantly reduce the number of accidents involving animals on agricultural land.

He estimates that the drone technology has great commercial potential both in Denmark and abroad, partly because it can boost food safety. Dead animals in the field may contaminate the food, which can lead to bacterial poisoning for whoever ends up eating it.

The researchers goal is to be able to develop a complete workable solution, ultimately reducing the number of animals killed on agricultural land.

"Many farmers experience these fatal situations. We'd very much like to help them and believe that we can do so," says Senior Researcher Jørgensen.

project facts

TITLE
Game-friendly harvesting methods

SCHEDULE
2016

FINANCIAL FRAMEWORK
Public sector consultancy

PARTNERS
Danish Hunters' Association, Natur &
Landskab Aps (Nature and Landscape), LMO

CONTACT
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Quantum cryptography on the standard fibre network

One of the most secure encryption methods is quantum cryptography, where the key is built one photon at a time. However, this is both difficult and expensive. Researchers are working to make it easier and cheaper – by transmitting quantum encrypted data via standard fibre networks.

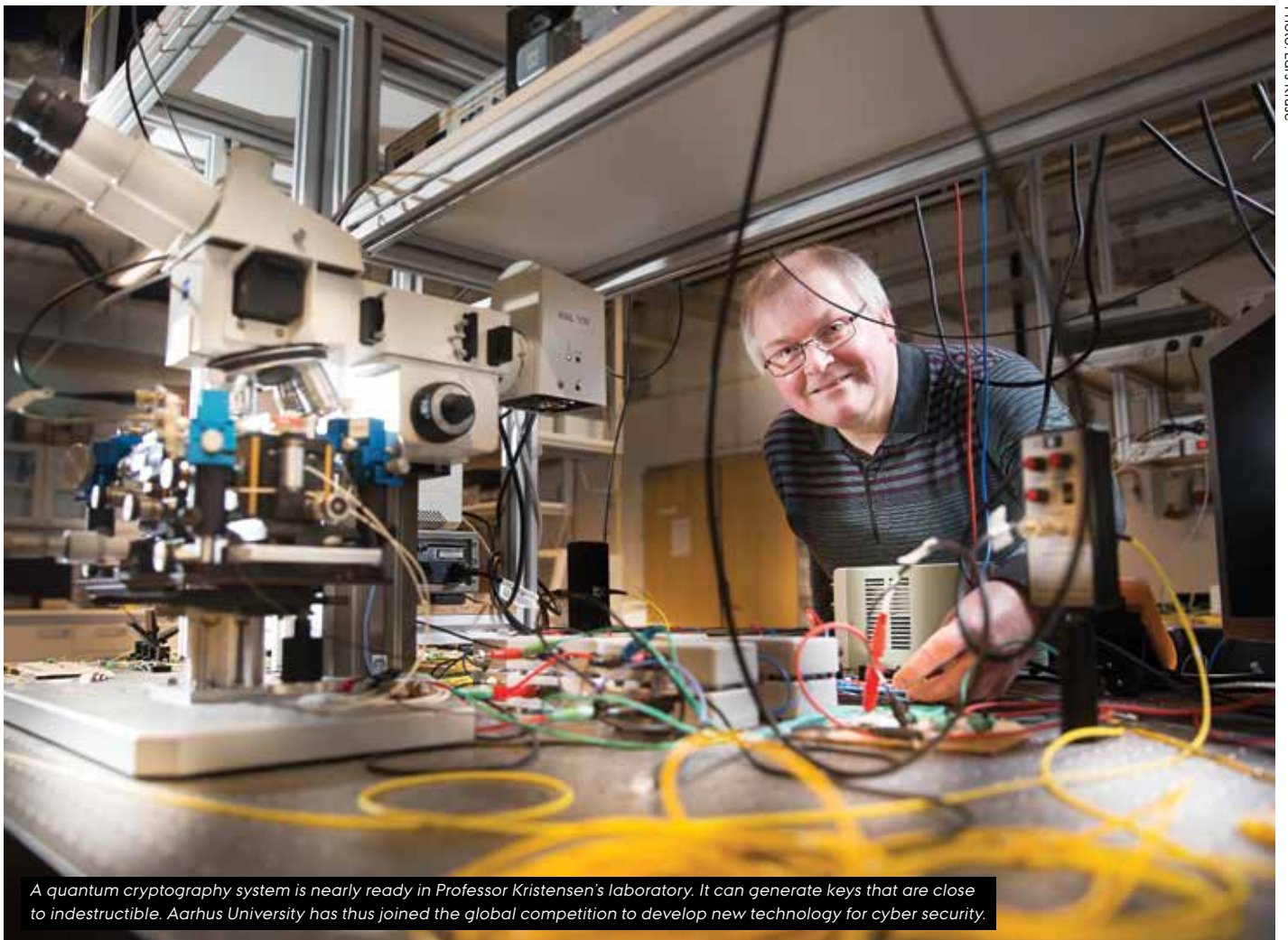Photo: Lars Kruse

A quantum cryptography system is nearly ready in Professor Kristensen's laboratory. It can generate keys that are close to indestructible. Aarhus University has thus joined the global competition to develop new technology for cyber security.

What could be worse than having an unauthorised person finding out how to decrypt your encrypted communication? That you do not discover this and continue to send confidential information that is no longer confidential, in fact.

The German military learned this the hard way during World War II when they used the Enigma encryption machine without realising that the British forces had cracked the code and were thereby peeking over their shoulders.

"The advantage of quantum cryptography is actually that outsiders are unable to intercept the key to the encrypted data without the legitimate transmitters and receivers of the information noticing it," says Professor Martin Kristensen.

Quantum cryptography is mainly about sending to a receiver a stream of individual photons, each of which is randomly encoded via a fibre optic cable. The photons can be encoded by either polarising them in different ways or giving them different phases.

When the transmitter has sent a sufficient number of photons that can be used as an encryption key, he or she tells the receiver how to set up their apparatus in order to 'read' each photon correctly.

Technology can detect eavesdropping
Should an unauthorised person try to intercept the code by measuring the phase of each photon passing through the fibre optic cable, it will be discovered immediately. It is actually a fundamental condition of quantum mechanics that it is impossible to measure photons without disturbing them.

And it is worth mentioning that any attempt to eavesdrop will be discovered while the key is being distributed – i.e. before the encrypted information begins to flow through the cable.

"By combining quantum mechanics with the theory of relativity, you can work out where the eavesdropper is located. Based on the number of bit errors, the pattern of the errors and the absolute time of arrival, you can locate the eavesdropper with an accuracy of one centimetre on a 50-kilometre cable," says Professor Kristensen.

And it is impossible for any eavesdroppers to hide when listening in on long cables. Quantum cryptography actually works on relatively short distances because the photons are lost in transit in the fibre optic cable. It is impossible to insert amplifiers along the way because exactly the same thing happens as when you are eavesdropping – the signal is distorted.

Global race for encryption distances
Until now, quantum encryption has not succeeded in working at distances of more than 120 kilometres, and only on special high-quality cables that are directly laid between the users.

This has sparked a global race to make quantum encryption more widely accessible – both by extending the 'shelf life' of the photons and by using standard fibre networks.

A fully developed system is nearly ready in Professor Kristensen's laboratory today, and it can be used in standard fibre optic cables, based on phase encoding. The advantage of this system is that it can very quickly generate secure encryption keys over a distance of more than 100 kilometres and store them on a standard computer chip.

Not ready for home computers
Even though Professor Kristensen's system works on standard fibre networks, it is too early to expect to use it for home online banking services just yet.

To start with, the end user must have a chip installed in the box where the fibre optic cable enters. Secondly, the Internet provider must allow quantum communication and reserve channels for it in the fibre optic cables, so that standard data traffic does not act as a jammer.

project facts

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Sound zones on the way to the living room

Aarhus University has entered into a three-year collaborative agreement with one of the world's major manufacturers of speakers. The aim is to fully develop a new technology that can make it possible to divide our homes into sound zones.

Dad sits on the sofa listening to jazz, mum streams her favourite radio programme and junior turns up cartoons on TV while baby sleeps undisturbed in a cot. This all takes place in the same room and can become a reality with the help of sound technology that is now on its way to the living rooms of private consumers.

In the acoustic laboratory at Aarhus University, researchers have been experimenting with dividing rooms into sound zones and defining the direction of the sound waves from the speakers so precisely that they do not disturb each other.

This means in practice that the sound zones can be located side by side in even a very small room. It is all made possible by means of advanced signal processing, according to Assistant Professor Jakob Juul Larsen.

"In principle, we do it by calculating exactly how much sound needs to be delayed in each of the room's individual speakers in relation to the sound from the other speakers. This makes it possible to create both quiet zones and sound zones side by side."

Researchers cancel out sound in the laboratory
In recent years, the researchers have been experimenting with directing sound waves from the speakers so they criss-cross each other in different directions. They use the same technology we are familiar with at museums or supermarkets, where the sound is directed towards a particular position.

This could be a museum visitor contemplating a work of art and getting audio-based information about the exhibition, or a customer receiving a message about a special offer.

However, the major engineering challenge is not pointing the sound in a specific direction, but getting it to cut off again.

This is crucial for ensuring the technology will work in a small room with sound zones that interface with each other.

"In a room with a number of sound zones, we must be able to control the sound very precisely in all directions, and we must also be able to stop the sound very suddenly so that it can't be heard in the next sound zone. This means that we have to work with a concept called antiphase, where one sound wave can cancel out another," says Dr Larsen.

Two sound waves in perfect antiphase cancel out each other and provide complete silence. The researchers will use this principle in their work with sound zone speakers for the home.

Who will be first with sound zones for the home?
For the time being, the technology is not sufficiently advanced that any companies dare risk providing sound zones for the private customer segment. However,

Using advanced signal treatment, researchers at Aarhus University can divide a room into sound zones that do not disturb each other. In the coming three years, they will collaborate with the Chinese acoustic company GoerTek Inc. and develop the technology so it can be commercialised and thereby moved out of the laboratory and into our living rooms. Pictured here are PhD student Xiahui Ma (left) and Assistant Professor Jakob Juul Larsen in the anechoic laboratory at Aarhus University.

Photo: Lars Kruse

research into signal treatment has now reached the stage where a Chinese sound technology company has chosen to invest in a three-year development project in collaboration with researchers at Aarhus University.

"Our aim is to improve our speaker technology with a new form of strong signal treatment in the course of the coming years, so we can be the first with sound zone speaker systems for homes," says Jan Abildgaard Pedersen.

An extremely difficult task

A number of speaker manufacturers have previously launched commercial products with zoned audio systems for cars, but nobody has yet found a solution to how the technology can be used in rooms where the listener does not remain in one particular position in relation to the speakers but, on the contrary, moves around.

The researchers will continue working on the signal treatment so that the new speaker technology will be safe from errors and able to be moved from the laboratory into the living room.
Provided all goes well, of course, according to Dr Larsen.

"We've set ourselves an extremely difficult task, which nobody yet has managed to solve perfectly. The speakers are permanently mounted on metal tracks in the laboratory, the researchers are familiar with the room, and the listeners sit with their heads virtually in a vice. But how will this set-up work in the home, where the geometry of the rooms and the sound reflection conditions vary? The sound zone technology must be able to adapt to individual rooms and work in real time, even when consumers move their furniture around," he emphasises.
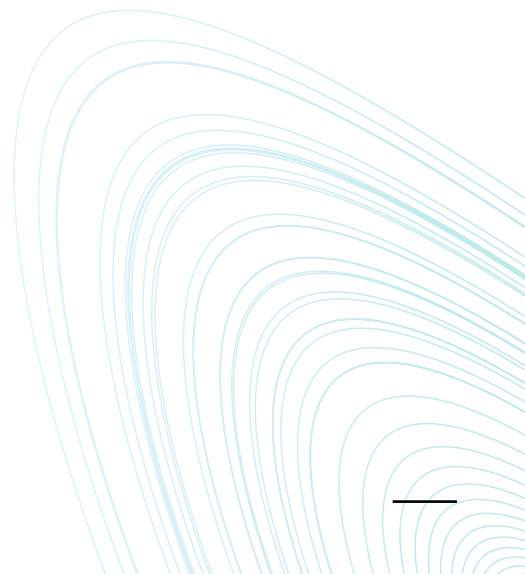
ADVAN CED MATE RIALS

New materials with properties that we hardly dare dream of today will see the light of day in the near future. We are on the threshold of yet another industrial revolution technology will pave the way for completely new inventions and advances in a considerable number of areas, such as space travel, medicine and 3D printing.

Superplastic with graphene provides industry with new opportunities

In an industrial postdoctoral project, researchers will study opportunities to develop a new form of reinforced two-component plastic with graphene.

The aim is to use a 3D printer to produce prototypes in specific shapes. The technology has great potential in the wind and plastic industries, and will be demonstrated in full-scale production.

Graphene is a single layer of carbon with some unique properties that make it the thinnest and strongest material in the world. It will now come out of the research laboratories and enter the industrial world, where researchers and companies will join forces to demonstrate the value of graphene and 3D printing in connection with developing advanced technology products.

"Graphene is a material with an enormously large theoretical potential. We'd like to investigate how to use graphene in the plastic industry to manufacture new products and develop new produc-

tion processes," says Industrial Postdoctoral Fellow Bettina Brøgger Jensen.

Strong industrial collaboration
The researchers are collaborating with SP Group A/S, a major manufacturer of two-component plastic products, and Vestas Wind Systems A/S, the world's largest wind turbine manufacturer. The parties expect that the graphene-reinforced plastic will provide new options for a greatly improved starting material for use in a number of advanced technology products.

"A very important element in our strategy for product development is that we're capable of delivering unique solutions to our customers. We need to get together in the laboratory and take part in the development and testing of new materials and production methods. Combining

two-component plastic with graphene and 3D printing opens up for completely new opportunities to make engineering plastics with a very modest start-up cost," says R&D Director Jens Hinke, SP Group A/S.

Vestas Wind Systems A/S must be able to continually ensure that all materials in their wind turbines have optimal conditions between properties, weight and cost, and this makes 3D printing with graphene an interesting technology.

"Until now, 3D printing hasn't been used in the wind turbine industry. We'd like to take the 3D printing process and materials with new properties out of the laboratory environment altogether and put the prototypes into full-scale production," says CTO Anders Vedel, Vestas Wind Systems A/S.
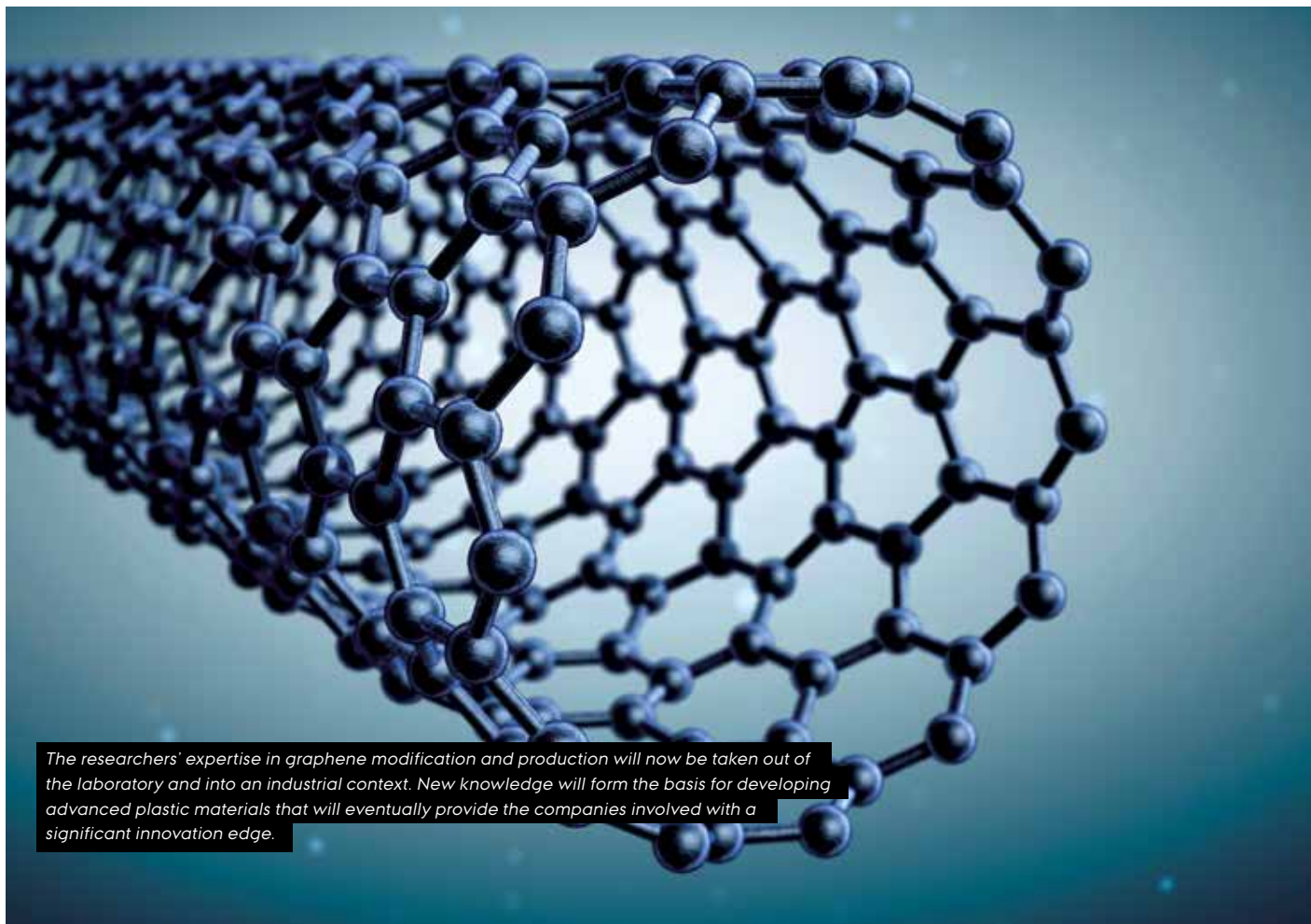
The researchers' expertise in graphene modification and production will now be taken out of the laboratory and into an industrial context. New knowledge will form the basis for developing advanced plastic materials that will eventually provide the companies involved with a significant innovation edge.

project facts

TITLE
3D printing of graphene reinforced PUR

SCHEDULE
2015–2016

FINANCIAL FRAMEWORK
DKK 1 million

PARTNERS
SP Group A/S, Vestas Wind Systems A/S

CONTACT
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Mobile machine tool and the giant wind turbines

Researchers and companies have come up with an idea that could have far-reaching implications for the wind turbine industry. They will design a portable machine tool that can process the giant components on site. If successful, it could save billions in transportation costs and thereby significantly reduce energy consumption in the production chain.

Photo: Anders Trærup

As components grow in size, the production of giant wind turbines is facing major challenges. In a few years, cast iron structures such as the hubs that are part of large-scale offshore wind turbines will increase from 3x3x3 metres and a weight of 15 tons to at least double these figures. This will make it near impossible to transport the components to the machines that process them, yet alone to make these processing machines that generate the accurate surfaces necessary for assembly.

On site processing improves logistics
Researchers working on this project are developing a flexible machining system for processing the giant wind turbine components of the future. The challenge is to make the mobile machining system so accurate that the components can be processed on site while maintaining the same level of accuracy and productivity currently possible using stationary machining systems.

"One of the greatest challenges in the project is to gain constant knowledge of the current stiffness and vibration level in the overall processing system. It involves controlling the cutting forces that arise when we're working with the components. We're trying to solve this by combining mathematical models of the material's mechanical properties and dynamics of the flexible structure with continuous process monitoring of forces and vibrations to detect and correct possible deviations of machining performance in real time," says Professor (Docent) Ole Balling.

The approach followed by the project consortium encompasses an innovative design of the machining system in smaller, mobile units.

Transporting giant wind turbine components many kilometres between factories in different countries could soon be a thing of the past. A new mobile machine tool will be able to process so accurately that it can replace some if not all of the work done today in stationary machinery.

Molecular nanoglue with great potential

In recent years, researchers have been working on the production of different types of nano-adhesives that can bond two different materials and, in principle, turn them into one. They will now develop one that can be dissolved again. In both cases, these are laboratory inventions that can be very important for industry.

A superglue that bonds rubber to metal can solve problems in the food industry where leaky valves in the process plants gather bacteria. Professor Mogens Hinge is the main architect behind the new nanomaterial and co-founder of the spin-off company Radisurf.

Photo: Anders Trærup

Super valves for food companies

A new chemical substance can help industry with super valves in which rubber coatings remain intact and thereby prevent the gathering of dirt and bacteria.

A new chemical compound that can bond rubber to metal can be the solution to problems for the food and water industries with process plants that collect dirt and bacteria in their valves.

In any case, researchers have come up with different types of adhesives or nanoglue, and the chemistry appears to be very promising if it can be implemented in an industrial context, according to Associate Professor Mogens Hinge.

"Valves in large production plants for water and food supplies are hard to clean and maintain, and they therefore need to be replaced very frequently. This happens when the rubber coating in the valve becomes loose so that it gradually

loses its function and provides access to bacterial growth. Our concept is to use our knowledge about nanomaterials to develop new and more sterile valves with very long durability," he says.

The idea is to use a chemical nano-adhesive on the metal surface of the valve, which bonds to the rubber coating when it hardens. From a chemical point of view, the valve becomes one single piece, which means bacteria are unable to penetrate.

Associate Professor Hinge and his colleagues have already taken out a patent on a similar chemical binder that can join materials such as plexiglass and steel.

project facts

TITLE
MoAd: Molecular Adhesive for Strong and Durable Bonding of Rubber to Metal

SCHEDULE
2016–2019

FINANCIAL FRAMEWORK
DKK 12 million, Innovation Fund Denmark

PARTNERS
AVK Gummi A/S
Radisurf ApS

CONTACT
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What do you do with outdated wind turbine blades and aircraft made of expensive fibreglass? Scrap them? Or possibly in the future, you add a chemical substance that can separate the glass from the plastic fibres so they can be recycled. This is the common goal for researchers and companies in the DreamWind project.

Wind turbine blades of the future will be recyclable

In the DreamWind project, researchers develop a chemical substance that will make it possible to separate composite materials from each other. This means that the large and expensive fibreglass components from wind turbines will be recyclable.

What do you do with a wind turbine that is no longer operational? This question is becoming more and more relevant as the expiration date is getting closer and closer for the wind turbines that were erected early on in the 1970s.

The first old wind turbines have already been scrapped, and this takes place at enormous 'graveyards'. The components are crushed and buried in the ground because it is virtually impossible today to recycle the material, according to Associate Professor Mogens Hinge.

"Components made of fibreglass have to go through a difficult procedure before they can be reused. This entails separating the glass from the plastic, and you can only do this if you heat the material for a long time at 600 degrees Celsius, which is far from profitable – from both an energy and an economic point of view," he says.

Along with his research team and industrial experts, Associate Professor Hinge has specialised in developing nanobinders. The acute problem in the wind turbine industry inspired them to develop a solvent that can separate composite materials chemically with limited or no heating at all.

New bonding agent for fibreglass

The researchers are initially focusing on designing a bonding agent for fibreglass, and the first laboratory results are promising.

The idea is that the glass should be re-used when it has been cleaned – for new fibreglass components for structures such as wind turbines, aircraft or cars.

"This way, we can retain the value of the material instead of just discarding it. The technology holds great potential for optimising the value chain," says Associate Professor Hinge.

And this can save industries such as the wind turbine sector a considerable amount of money at the same time as reducing carbon dioxide emission.

"It's expensive to manufacture fibreglass that can't be recycled. It's expensive to drive round with blades when they have to be scrapped. And it is expensive to scrap them. Chemical research can provide the industry with an enormous boost of innovation," he says.

Chemical research paves the way for more recycling

Innovation Fund Denmark has invested a total of DKK 17.6 million in the project which, in the long run, can influence the recycling of composite materials outside the wind turbine industry.

"We now have an opportunity to develop smart new materials that can change shape or separate as required when they're no longer in use. This is an important project that could have a major impact on the way in which materials are recycled in the future," says Associate Professor Hinge.

In the DreamWind project, Aarhus University will collaborate with partners including Vestas Wind Systems A/S and the Danish Technological Institute to develop new composite materials for wind turbine blades.

The parties expect to be ready with a chemical compound for separating fibreglass within four years.

project facts

TITLE
DreamWind – Designing REcyclable Advanced Materials for WIND energy

SCHEDULE
2016–2020

FINANCIAL FRAMEWORK
DKK 26.7 million,
Energy Technology Development and Demonstration Programme (EUDP)

PARTNERS
Vestas Wind Systems A/S
Danish Technological Institute

CONTACT
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A new ingredient for miraculous anti-age products? Perhaps. Bianca Perez carries out research into lipids, and she has developed novel lipids for more effective skin care lotions. This can have great significance for the effect of the moisturisers of the future.

New skin cream formula

Lipid researchers at Aarhus University have developed a new ingredient in the laboratory, that can make creams more effective. They are collaborating with one of the world's largest producers of skin care products, which has now taken out a patent for the invention.

Mainly two basic types of skin cream are available on the market. One formula is based on water-absorbing molecules and the other is based on lipids that lie outside the skin as an extra protective layer.

These formulas are used by the cosmetic and pharmaceutical industries to generate skin care lotions that can treat dry and sensitive skin.

Under the skin with new lipids

For years, researchers have been hunting for different new ingredients that can make skin creams more effective. In the search for novel skin care ingredients that mimic the lipid matrix in the epidermal skin barrier, a research team has found a lipid capable of improving skin care lotion efficiency, potentially leading to healthier and younger-looking skin.

Postdoctoral Fellow Bianca Perez is developing new types of lipids for skin creams that help prevent transepidermal water loss.

"Our aim is to identify new types of lipids that mimic the lipids in the outermost layer of the skin and act as a kind of extra protective barrier. These lipids must be able to pack in a very tight molecular structure preventing water loss from the body," she says.

Some lipids have actually already been found and are currently being used in skin care moisturisers, but they are relatively expensive to produce.

The university's lipid researchers have therefore been invited to work in close collaboration with the multinational pharmaceutical company GlaxoSmith-Kline to develop effective new low-cost skin lotion ingredients that can thus benefit more people.

Patent for new ingredient

After several hundred hours of laboratory work, Bianca Perez has now discovered a novel lipid that appears to be so promising that GlaxoSmithKline has applied for a patent.

"It looks as though we've discovered an ingredient that can generate a highly occlusive skin care lotion providing an extra barrier to the outermost layer of the skin. At the same time, the lipids are cheap to produce and can also be manufactured in one single process that protects the environment," says Dr Perez.

The lipid researchers at Aarhus University are among the best in the world, and Dr Perez has specialised in characterising the physicochemical properties of lipids as potential ingredients to generate highly occlusive skin care lotions.

In her research collaboration with Glaxo-SmithKline, she has also been working on developing a new synthetic pathway to yield other lipids potentially relevant to achieve improved moisturising properties.

However, Dr Perez is not yet able to promise whether or not the results of her lipid research can lead to new beauty products in the cosmetic industry.

"Whether we can hope for miraculous anti-age products? I can't really say. However, we can expect creams with really good moisturising properties. And as dry skin is prone to ageing, it's definitely a step in the right direction," she says.

project facts

PARTNERS
GlaxoSmithKline

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Sulphur-free biogas for fuel cells

Fuel cells can convert methane from biogas into electricity with a high utilisation rate. However, it requires removing all the sulphur compounds in the gas. Researchers are working in the laboratory on a promising chemical technology that can help solve the problem.

Fuel cells can be used to advantage to transform methane from biogas and natural gas into electricity. They are extremely effective and convert energy with a utilisation rate of up to 85 per cent or more if surplus heat is included in the equation.

This makes the technology interesting in cases where there is a desire to produce electricity from gas and fuel cells can thereby be used for such a purpose in areas with no access to the electricity grid.

The major challenge with gas and particularly with biogas is that they contain small amounts of sulphur which can destroy the fuel cell catalyst within a short space of time.

"Sulphur compounds in the gas react with the surface of the fuel cell catalyst where the methane is converted into hydrogen,

and this very quickly destroys the fuel cell. In fact, this is currently the greatest barrier to converting gas into electricity," says Associate Professor Anders Feilberg.

Together with his research colleagues, he has created the first promising results with a chemical pretreatment of gas which can remove more than 99 per cent of sulphur compounds in the laboratory. However, the technology is still immature, and there is a way to go before the researchers can carry out full-scale experiments.

Chemistry can make gas cleaner
The principle is that the gas is fed through a reactor with a fluid containing iron compounds, and these react with the sulphur molecules prior to being sent on to the fuel cell. It all takes place in a stable and fully controlled process and it appears at this stage – in the laborato-

ry – to act as a brilliant alternative to the microbial cleaning methods used today.

"Our aim is to increase and control the purity of the gas before it's sent through further desulphurisation and on to the fuel cell," says Associate Professor Feilberg.

The initial laboratory studies indicate that the chemical pretreatment method has the potential to increase the quality of the desulphurisation, making it a cleaner gas that is ultimately converted into electricity.

Simple measurements can predict sulphur accumulation
However, the problem with sulphur in fuel cells is not solved by a better cleaning technology alone. The desulphurisation products currently available on the market will still have a limited duration of ac-
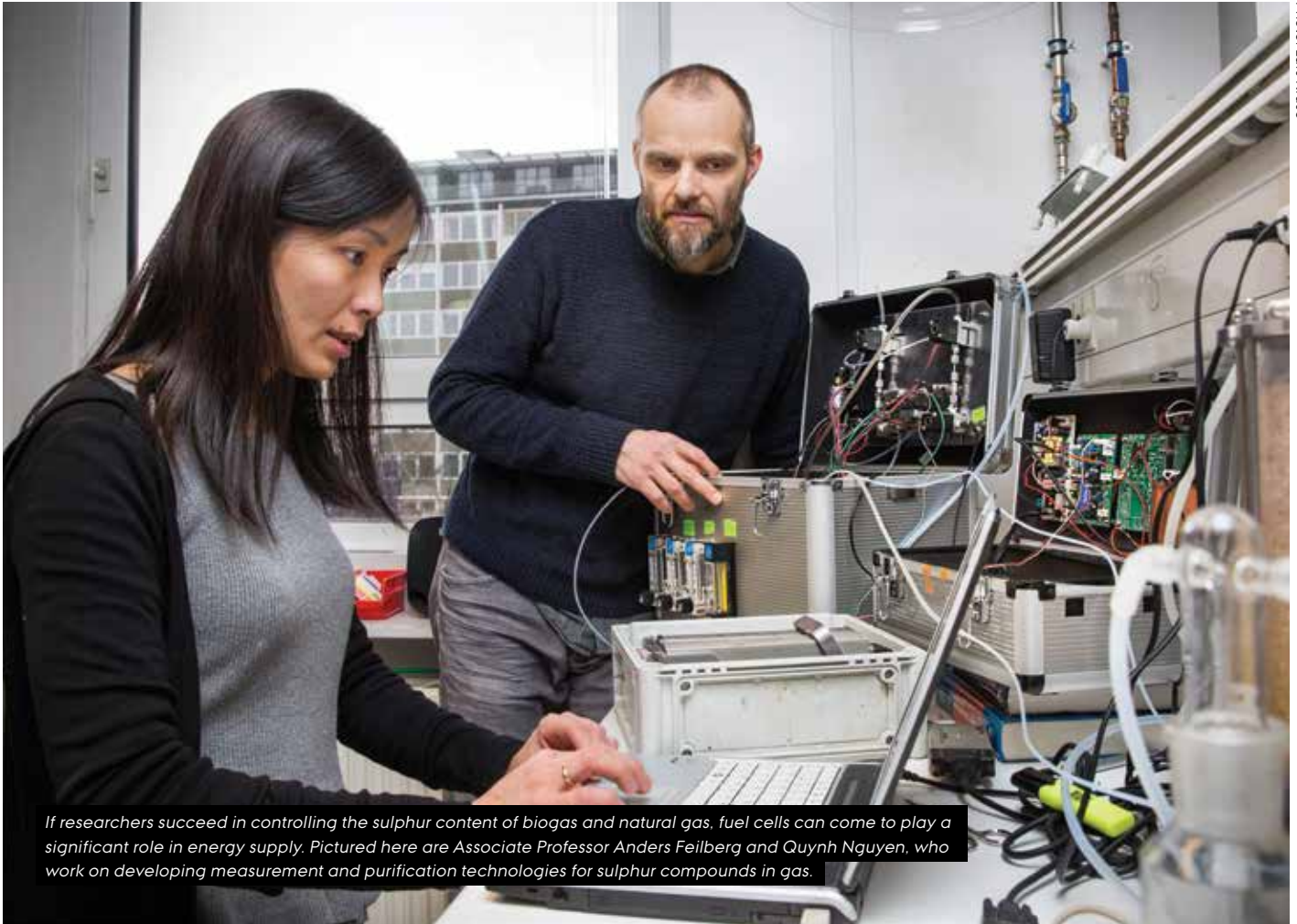
If researchers succeed in controlling the sulphur content of biogas and natural gas, fuel cells can come to play a significant role in energy supply. Pictured here are Associate Professor Anders Feilberg and Quynh Nguyen, who work on developing measurement and purification technologies for sulphur compounds in gas.

Photo: Lars Kruse

tion, and damaging sulphur compounds will sooner or later get into the fuel cell. "The problem today is that we can't say in advance when the desulphurisation product stops working. All we know is that it will eventually break down, and sulphur molecules will penetrate and destroy the fuel cell by deactivating its catalyst. If we could measure the sulphur compounds – even in very small amounts – and if we could do it in a continuous process, then we'd also be able to very precisely predict when it's time to change the purifier," says Associate Professor Feilberg.

The researchers are now working on the first prototype of a measuring instrument that can monitor in real time how the effect of the desulphurisation product wears off. The technology will be perfected and ultimately commercialised in the coming years.

project facts

TITLE
BoP-OP Balance of Plant Optimisation

SCHEDULE
2015–2017

FINANCIAL FRAMEWORK
Energy Technology Development and Demonstration Programme (EUDP)

PARTNERS
Dantherm Power, Danish Gas Technology Centre (DGC)

CONTACT
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TITLE
SIMBA – platform project about developing and demonstrating small fuel cell plants

SCHEDULE
2013–2017

FINANCIAL FRAMEWORK
Energy Technology Development and Demonstration Programme (EUDP)

PARTNERS
Dantherm Power, Danish Gas Technology Centre (DGC)

CONTACT
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AU Engineering, Campus Katrinebjerg, Aarhus

ENE
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Researchers are currently embarking on a new chapter in the history of energy, where we will be frontrunners for a sustainable transformation of the global climate. We will come to experience enormous changes in the way we produce, distribute, store and use energy. The world needs new technologies that can ensure a sustainable and intelligent energy supply, integrating sources such as solar, wind, hydrogen and biomass.

Is it possible to cultivate bacteria and get them to grow in tanks to become valuable biomass? Researchers will boost the microbial process and create a sustainable supplement to fossil fuels and traditional biomass. Pictured here in the laboratory is PhD student Laura Mia Agneessens.

Bacteria in the fuel of the future

Researchers made a breakthrough in 2015 when they showed that it is possible to get a certain kind of bacteria to produce methane by feeding them with water, electricity and carbon dioxide. They will now use the methane as a nutrient for another type of microorganism that can grow to become sustainable biomass in large tanks.

Great potential was shown last year when Danish researchers demonstrated that they could use certain types of microorganisms to design a microbial electrosynthesis that converts surplus power from wind turbines into methane gas as a stable energy carrier.

"One of the major challenges in converting to a sustainable energy society is finding new solutions to how we can store surplus power from fluctuating energy sources such as solar and wind. We believe that biotechnology can come to play a key role," says Associate Professor Lars Ditlev Mørck Ottosen.

The researchers expect that the new method for producing methane gas can be implemented within five years and become an important technology for storing electricity in the form of methane that can be integrated into the natural gas grid as required.

The electricity-eating bacteria can in principle produce other conceivable forms of biomass, but methane has the distinct advantage that it is a gas with a very low solubility and can therefore be purified by bubbling through a solution.

New bacteria grow with methane
The researchers have therefore also started to experiment with using methane from the electricity-eating bacteria to feed another type of bacteria that appear to be eager producers of biomass.

project facts

TITLE
Electrogas

SCHEDULE
2015–2019

FINANCIAL FRAMEWORK
DKK 20 million

PARTNERS
University of Southern Denmark, University of Queensland, Stanford University, University of Southern California, Landia A/S, Xergi A/S

CONTACT
Associate Professor
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ldmo@eng.au.dk

Hereafter, the biomass can be subsequently used for everything from fossil-free fuel to protein-rich animal fodder, which only requires minor genetic modifications of the microorganisms.

"Progress in biotechnology opens up for a completely new way of producing biomass and storing energy. If we can store surplus power from wind turbines in methane, and if we can use methane to produce sustainable biomass while maintaining carbon dioxide in the process, then the technology has very great prospects for the energy society of the future," says Associate Professor Ottosen.

Together with his research colleagues and industrial partners, he is experimenting with getting microorganisms to act as small energy factories, and they have already made an initial proof of concept.

In a large tank, the researchers will get methane and oxygen to bubble into a solution containing bacteria. Here the bacteria will breathe the oxygen and eat the methane after which they will grow rapidly. In the course of a short time, they will produce an energy-rich biomass that can be concentrated.

"It's basically a thick soup of bacteria that can be concentrated to an organic material, and this can subsequently be used for purposes such as animal fodder and food ingredients," says Associate Professor Ottosen.

Exactly how the bacteria produce the organic material and whether it is possible to get them to produce it in a profitable amount has not yet been clarified.

Sustainable biomass in tanks
Another interesting prospect in the microbial production of biomass is that it can possibly become an alternative or supplement to traditional biomass from agriculture.

In the coming years, the world will need to limit the use of fossil fuels, and the total land area available for cultivating biomass will get smaller. Finding new methods to produce biomass and store energy is therefore a matter of urgency.

"We need to develop the technologies for producing sustainable biomass and energy that we can use for electricity, heating, food, petrol, plastic and much more in the future," says Associate Professor Ottosen.

To start with, the researchers will closely study the ability of the microorganisms to produce biomass directly from electricity in the tanks at Aarhus University.

Energy savings and quality of life in the same equation

Energy renovation in residential areas has always aimed to reduce the total energy consumption of the buildings. It looks good in both the operating budget and the CO_2 balance, but it also has a number of social, cultural and health-related consequences. In the coming years, researchers will develop a model that can determine the impact of energy renovation on the well-being of the residents.

Aarhus University is spearheading a major Danish innovation project that will contribute in the years ahead with new knowledge about the overall value creation for society in connection with the energy renovation of residential areas.

The aim is to make a full-scale demonstration of two renovation projects in areas with different residential compositions, and to study their effects as regards the reduction in energy consumption and the impact on health and well-being.

"We'll renovate with a focus on energy savings, but we'll also find a method to determine the added value generated by renovation, such as a better indoor climate or new urban spaces in the built-up environment. Our aim is to develop an intelligent calculation model that can be used to assess renovation efforts more holistically and include attention to health, comfort and architecture," says Professor (Docent) Søren Wandahl.

Participants in the project include the Brabrand Housing Association – with

energy renovation in the Aarhus suburb of Gellerup – as well as DEAS, an administration company on the private rental housing market.

Better residential areas with low energy consumption

In this project, the researchers will reduce energy consumption in demonstration buildings by at least 50 per cent. This involves elements such as new facades, windows and roofs and, in this way, the renovation work will significantly change the indoor climate in the buildings and the architectural expression in the area.

"When we renovate, this normally always means an extensive transformation of the residential environment to some degree, and we'd like to be better at assessing the value of this or, more exactly, at turning it into a concept. Today, for example, we calculate how much heat loss we can avoid if we use a particular new facade coating and install new windows in the building, but we don't have any quantitative target for how this change affects the residents' indoor comfort experience or, for that matter, what significance it

has for the residential quality of the area," says Dr Wandahl.

With a comprehensive combination of features such as sensor-based energy monitoring, anthropological field studies, physiological tests and indoor climate assessments, the researchers will therefore develop a model to measure the total value of energy renovation, including technical, social and cultural aspects.

"We're used to assessing the value of building projects based on well-documented, objective standards such as insulation ability, heat loss, air humidity, temperature, air quality and inflow of light. We are now going one step further with a model that also include people's subjective experience of living with the renovations," says Dr Wandahl.

The project team will select specific measurement parameters during the first stage of the innovation project.

Complex data lead to good decisions
The researchers working on this pro-

What is good energy renovation? Is it significant savings on the heating bill, low costs in the building process, better indoor climate or an external architectural style that lowers crime in a residential area? In the coming years researchers will develop a decision support tool that can suggest the best combination of renovation initiatives.

Photo: Jesper Rais

ject will also identify options for energy savings and social value creation in the renovation process itself. This involves making transport to and from the residential area more efficient, managing logistics at the building site and minimising material waste. According to Dr Wandahl, however, it also means involving the residents in the building process in a socially sustainable way.

"There's a very big difference between the way residential areas are disturbed by renovation projects. We'd like to do it in a way that ensures the involvement and ownership of the people living in the residential areas. Previous studies have shown that this has great significance for the amount of vandalism and the number of break-ins on the site, and for subsequent employment," he says.

Within three years, the project partners will be ready with an intelligent modelling tool for renovation, which will work in principle as a value index.

"We're building a model with lots of data, and the idea is that we'll subsequently

find relations between the technical, social and cultural aspects of energy renovation. In practice, this means that each energy renovation project can be indexed so you can see its value on a scale from 1 to 100," says Dr Wandahl.

A developer will be able to use the model to test different priorities in a renovation design and thereby find the most suitable renovation solution for the individual residential area and provide the most value for money.

"The model will make it possible to find significant correlations, enabling the developer to assign high or low priorities" says Dr Wandahl.

project facts

TITLE
RE-VALUE (Value Creation by Energy Renovation, Refurbishment and Transformation of the Built Environment – Modelling and Validating of Utility and Architectural Value

SCHEDULE
2016–2019

FINANCIAL FRAMEWORK
DKK 21.2 million,
Danish Innovation Foundation

PARTNERS
Brabrand Boligforening (Brabrand Housing Association), DEAS, Enemærke and Petersen a/s, Wicotec Kirkebjerg a/s, Develco Products a/s, Racell, AART architects, Amplex a/s, IdealCombi a/s

CONTACT
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A new type of flow battery can store electricity cheaply, safely and efficiently. Visblue is a spin-out company that expects to have a commercial product available for consumers within a year. Pictured here is Anders Bentien, one of the researchers behind the new invention.

Flow battery ready for home use

Researchers have developed a redox flow battery that can store solar energy cheaply and safely – and this is good news for people with solar cells on the roof. The battery will be launched on the market in less than a year.

A scalable flow battery for home use will make solar cells a much better business for private individuals than they have been to date.

The recently developed flow battery is based on a known technology – vanadium electrolytes – where one of the advantages is that the effect and energy capacity of the flow battery can be scaled independently of each other, enabling batteries to be used in private homes.

The research group is now in full swing developing new generations of cleaner and even cheaper flow batteries based on in-depth knowledge of organic chemistry – as well as a completely new type of solar cell that can recharge the flow battery directly instead of producing electricity.

Patent on fireproof and rechargeable batteries

The organic flow batteries and photo-electrochemical solar cells are not ready

for market – they still require a certain amount of research and development, even though the ideas they are based on have already been patented.

The researchers behind the 'package' consist of Associate Professor Anders Bentien, who is an expert on flow batteries, and Professor Adelio Mendes, who is an expert on photoelectrochemical solar cells.

"While we're working on developing

the next generations, much has already been gained in vanadium redox flow batteries. They're not flammable like lithium-ion batteries, and they're considerably more economical. They can also be recharged far more times than lithium-ion batteries – about 10,000 times – without losing their capacity, and the investment price is falling. We're now on the way down towards EUR 200 per kilowatt hour – and that's just with vanadium. With organic electrolytes we can probably get down to less than EUR 75," says Associate Professor Bentien.

Storing solar energy pays off
It would generally be an advantage for solar cell owners to store surplus electricity at home instead of selling it to the grid. This is because solar cell owners in Denmark and many other European countries do not get nearly as much for electricity as they have to pay when they need to use it again.

The size of the advantage naturally depends on how much it costs to store

the electricity at home. And this is where the new redox flow batteries prove to be quite competitive.

According to Associate Professor Bentien, the battery's return on investment is less than 10 years for the individual owner.

"Ordinary consumers with a solar cell panel only use approximately 25 per cent of the solar energy, and they sell the rest. With our vanadium system, this would typically boost it to up to 50 per cent, making solar energy a much better business. And this would be with a moderately large battery. You could in principle get up to 100 per cent with a sufficiently large battery, but it wouldn't be worth it," says Associate Professor Bentien.

Development of the new redox flow battery – and particularly the coming innovations – is now located at Visblue, a spin-out company whose owners include the researchers and Borean Innovation, which has also invested in the company.

project facts

TITLE
Renewable FlowStorage

SCHEDULE
2015–2017

FINANCIAL FRAMEWORK
DKK 6.5 million (DKK 3.8 million grant)
Energy Technology Development and
Demonstration Programme (EUDP)

PARTNERS
VisBlue, EnergiMidt

TITLE
Photo-electrochemical charging of redox couples for conversion and storage of solar energy

SCHEDULE
2014–2018

FINANCIAL FRAMEWORK
DKK 6.4 million
Danish Council for Independent Research

PARTNERS
University of Porto, Portugal

CONTACT
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Forecasts for cheap and sustainable district heating

Pumping surplus heat into the district heating network can be an expensive exercise. A considerable sum of money and large amounts of greenhouse gases can be saved by getting better at predicting the weather forecast, heat consumption and electricity prices. What is more – all in the same equation.

With one of the largest single energy research grant ever awarded by the European Commission, researchers at Aarhus University are in full swing studying how to convert to sustainable energy in towns and cities as well and as cheaply as possible.

A total of seven PhD students are involved in the project, and Magnus Dahl is one of them. His job is to build an advanced prognosis model that can help district heating providers calculate probabilities. This will enable better decision-making that will ultimately make it possible to provide cheaper and more sustainable district heating.

"When you're working on creating cheap and environmentally responsible district heating, there are lots of things to take into account. To start with, we never know exactly how much heat we'll need. Will the temperature be minus five or minus six degrees? How much wind will there be? This makes a significant difference to the burden we put on heating producers to provide citizens with district heating," says PhD student Magnus Dahl.

The art of not over-producing
The researchers are using the district heating system in the City of Aarhus as a case. Most of the heating here comes from a central heat and power plant (Studstrupværket) as well as waste incineration, but this production has to be supplemented in peak load situations.

"We always try to have a heat load that corresponds as well as possible to the requirements of the citizens. It's expensive to produce more than is necessary, and we'd rather avoid using oil boilers because it's both costly and detrimental to the environment," says Magnus Dahl.

To produce a sufficiently large supply capacity without over-producing heat means having to take care and maintain a balance with large amounts of data. This involves a time-consuming analysis that also demands a certain amount of gut feeling, but Magnus Dahl is working on making it easier.

He is studying the likelihood of the temperature being one degree colder or hotter in the morning – or a wind speed of five metres per second instead of seven. He is also studying the risk of loss involved in buying electricity on the spot market. He combines all of this with forecasts of the total heating consumption in the City of Aarhus.

"My job is to make a formula for all risk assessments and visualise them in terms of percentages and graphs, so that you can quickly gain a clear forecast of the heating requirements and the supply situation, and to use this as a basis for decision-making. Bad decisions result in expensive district heating and have an impact on the environment, and the cost is ultimately passed on to the customers," says Magnus Dahl.

'READY' FOR SMART CITIES
Aarhus University and a number of companies and public sector partners have been awarded a historically large European Commission grant to find new solutions to how housing areas can reduce total energy consumption.

1,000 households as full-scale lab
The project involves 1,000 households in the City of Aarhus, which in the coming years will function as a full-scale laboratory for researchers. The name of the project is READY – an abbreviation for Resource Efficient cities implementing ADvanced smart citY solutions.

Its goal is to provide new knowledge about the most optimal energy renovation of residential areas to prepare them for the intelligent energy supply of the future.

READY is supported by a consortium of 23 different public and private partners. AffaldVarme Aarhus is one of these.
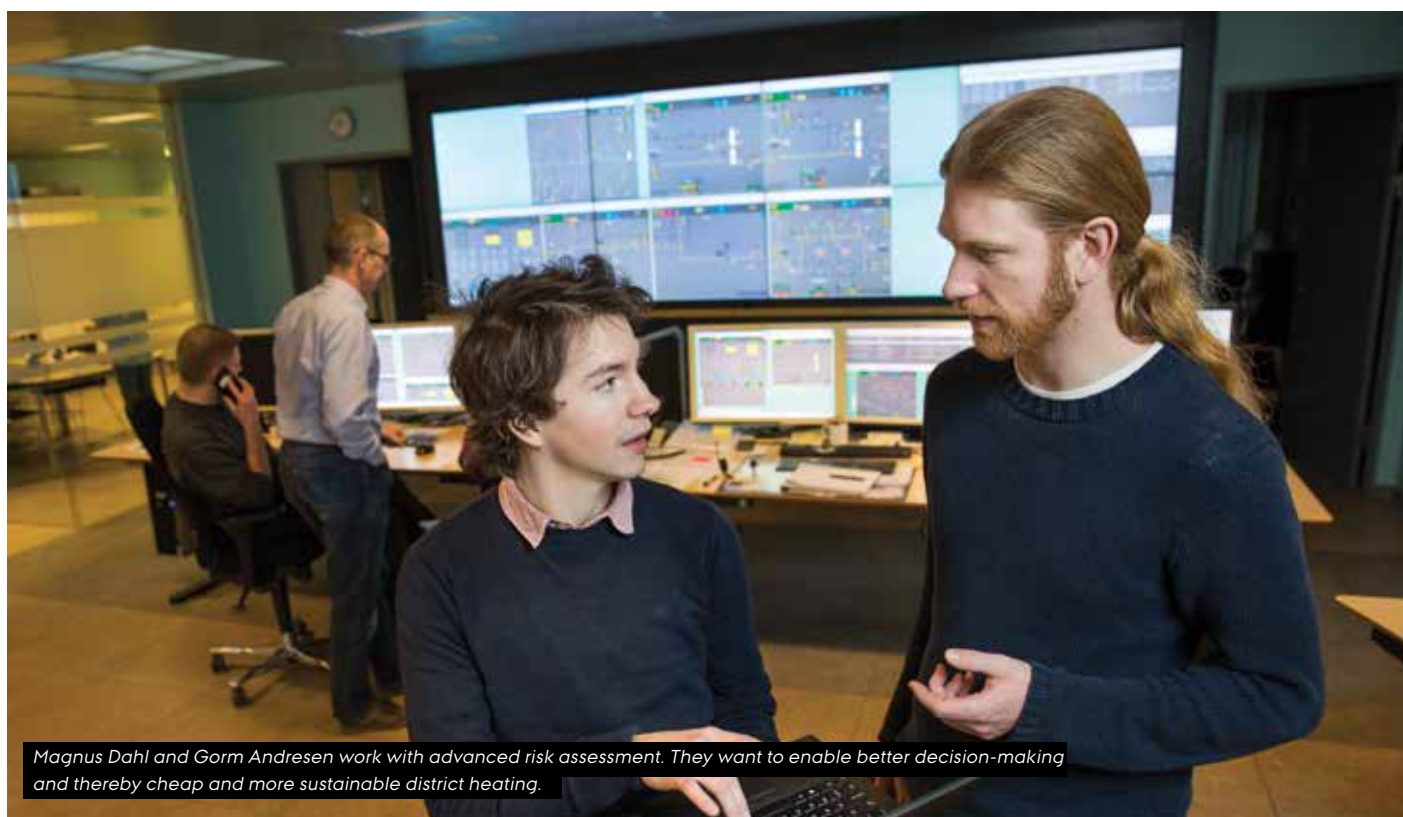
Magnus Dahl and Gorm Andresen work with advanced risk assessment. They want to enable better decision-making and thereby cheap and more sustainable district heating.

Photo: Lars Kruse

More electricity in the district heating of the future

As part of the READY project, the researchers will also study how they can integrate more electricity from sustainable energy sources into the district heating system. This includes testing whether it would pay to use solar cells to heat water and store it in large thermal tanks.

Another idea is to build an electric heating pump that can extract heat out of seawater. The heating supply in Aarhus is already linked to the electricity market and, according to the researchers, this link will become even stronger in the coming years.

"When we're preparing green towns and cities, the major challenge is to design a flexible district heating system that interacts with the electricity network. This enables us to exploit sun and wind energy when it's plentiful and use it for heating," says Magnus Dahl.

THE FLEXIBLE DISTRICT HEATING SYSTEM OF THE FUTURE IN AARHUS

The aim of the research is to assess the operational costs and risks involved in a large-scale district heating system. Here the technical limitations of the district heating system are taken into account through least cost dispatch modelling, and ensembles of weather forecasts and complex coupling to the electricity market are used to ensure cost-effective production planning. Hereafter the results from the analysis are evaluated on the day-to-day operation of the district heating system.

The researchers will use the modelling to explore potential economic and technical benefits of a number of new district heating technologies. These include low-temperature district heating, distributed or central heat storage, low heat consumption housing, solar thermal technology, power-to-heat systems and the integration of waste heat.

project facts

TITLE
Production planning of energy systems – Cost and risk assessment for district heating.
Part of Resource Efficient cities implementing ADvanced smart citY solutions (READY)

FINANCIAL FRAMEWORK
EUR 33 million,
European Commission

CONTACT
Smart Grid Programme Manager
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Industrial PhD Student Magnus Dahl,
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Very windy conditions provide more power, and this is good. However, this also contributes to wear and tear on the wind turbine components due to dynamic loads. Researchers now propose a large ring for the blades that is partly filled with liquid and can significantly prolong wind turbine lifetime.

Giant rings make wind turbines stronger

Giant rings partly filled with water can reduce vibrations in wind turbines by up to 40 per cent. This provides new opportunities to build enormous constructions in environments exposed to strong wind conditions.

Wind turbines are constantly affected by vibrations induced by the wind, waves and seismic activity in the Earth's surface. Although these vibrations vary, they contribute to the constant and continuous wear and tear of the structural components, thus reducing the fatigue life of the wind turbine.

"Constructions are constantly exposed to dynamic loads of different intensities. Some days there is no wind at all, while other days can be stormy, and we have no reliable method to predict the overall wear and tear this causes," says Postdoctoral Fellow Zili Zhang.

Large wind turbines are vulnerable
The larger the wind turbines, the more flexible they are – and this makes them particularly vulnerable to wear and tear due to stochastic dynamic loads.

Dr Zhang carries out research into structural dynamics, and has developed advanced mathematical models of how a specific wind turbine responds to different stochastic loads.

"We can simulate the way a wind turbine is affected by different strengths of vibrations. What happens if it is exposed to very strong waves, earthquakes or wind conditions? This is important to know if we're to become better at controlling the structural vibrations resulting from the environment.

At the same time, this provides key knowledge for the industry to help them realise their dream of even larger and more efficient turbines," says Dr Zhang.

Ring containing liquid can absorb vibrational energy
The researchers have used the mathematical models to design a device that absorbs – so to speak – the vibrations affecting the wind turbine. A ring partly filled with water has a diameter of about two metres. It absorbs energy of the structural vibration by the motion of the water and dissipates energy through small orifices fixed inside the ring, thus resulting in 30–40 per cent less wear and tear of the wind turbine blades.

This means that the wind turbine can withstand fatigue to a greater extent and thereby ensure safe operation and a longer service life.

"Using computer simulation, we've tested different devices that can dampen the vibrations in the rotating wind turbine blades, and we've found that the ring shape combined with a liquid that circulates when the blades rotate works considerably more efficiently than the dampers currently used by the wind turbine industry," says Dr Zhang.

For the time being, the researchers' design is purely theoretical. The next step

is to prepare a detailed mathematical description of how the wind turbines respond to various dynamic loads from the environment and thereby improve the design of the ring so that it not only prevents fatigue, but also smoothens power output.

The researchers expect that the ring can pave the way, in the long run, for erecting considerably larger offshore wind turbines than is possible for the industry today.

project facts

TITLE
Stocastic Dynamics in Wind Turbines

SCHEDULE
2016-2017

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It pays to increase energy consumption

A new study shows that it is possible to save money and reduce carbon dioxide emission by using more energy when it is generated by wind and the Sun.

What is the most optimal energy behaviour in everyday life with variable electricity prices? Researchers have carried out extensive theoretical mapping of the way private consumers can save money for heating in a modern supply system based on electricity.

Surprisingly enough, the mapping shows that by using approximately 10 per cent more energy for heating, it is possible to save about 10 per cent on the heating bill at the same time as protecting the environment with lower carbon dioxide emission.

Use energy and save money
By means of building simulations and advanced calculation models, the researchers came to the conclusion that using plenty of energy is both an economic and an environmental advantage, while it is also inexpensive and green.

Their methods for this purpose included specially developed prognosis systems to predict both energy prices and the energy's carbon dioxide intensity.

"We experimented with intelligent management of energy consumption with the aim of minimising the cost of space heating without compromising user comfort. The result is that you can use large amounts of energy at night to heat up the thermal mass of the building, after which you can turn off the heating altogether in the morning peak and during the daytime, when the total power consumption

and energy price are at their highest. You thus use more energy than you would without intelligent management, but you actually save money and take the pressure of the energy supply at the same time," says Associate Professor Steffen Petersen.

On the basis of their study, the researchers can also conclude that there are major 'green' profits to be made with intelligent management of the energy consumption of buildings.

"If you choose to focus on reducing carbon dioxide emission slightly in the management plan, you'll achieve a significant environmental gain for a very small price," says Associate Professor Petersen.

He emphasises that the precise economic and environmental advantage for an individual household depends on the building's specific thermal conditions, but that the result of the study will, under all circumstances, have an impact on the construction industry.

"We made a theoretical study of how buildings can and should act in a future with fluctuating energy production. Our current savings logic falls short in this regard so we have to start working in a completely new way on energy efficiency in buildings," he says.

Towards intelligent buildings
One example today is that heating

systems are often turned down at night to save energy and money when a building is not in use. In the energy system of the future, this would certainly save energy, but not necessarily money and carbon dioxide emission.

Instead of turning down the heating at night, the building's intelligent systems will actually increase the temperature because there are copious amounts of cheap power from sustainable energy sources.

In connection with mapping consumer habits, the researchers developed a system for the intelligent management of building operations, where it is possible to optimise a building's energy consumption regarding both price and environment.

During the course of 2016, they will try out the system in buildings in Aarhus, and subsequently ascertain the results of the theoretical mapping.

"We'll further develop the intelligent management so that a building automatically adjusts to consumer behaviour and comfort requirements in an energy-efficient way. I believe that in a few years it will be taken for granted that the building itself works out the heating requirement for the following day and when it is best and cheapest from an environmental point of view to use energy," says Associate Professor Petersen.

Use 10 per cent more energy and save 10 per cent on your electricity bill. It can actually pay to use loads of energy when there is plenty available. Researchers can document this in a comprehensive study of how private consumers can achieve the greatest savings on their heating bill in a modern supply system with flexible electricity prices.

Steffen Petersen has experimented with intelligent management of energy consumption with the aim of minimising the cost of space heating without compromising user comfort.

Simple technology makes elevators 'green'

Having a guilty conscience about the climate makes us choose to take the stairs instead of the energy-devouring elevator – at least to a certain extent. This is the conclusion of a research project involving almost 200 residents in a 12-storey building in Aarhus.

It stays remarkably still – the elevator at the Grundfos dormitory at the Port of Aarhus.

"It's because electricity is 'red'," explains Associate Professor Rune Hylsberg Jacobsen.

When the red lamp lights up in front of the elevator, it is because the available energy has a high carbon dioxide intensity with a deficit of energy from sustainable energy sources.

When the green lamp is showing, it is typically because the wind turbines are hard at work, which means the power has a low carbon dioxide intensity.

In a full scale laboratory the researchers have carried out one of the world's most radical energy monitoring experiments for a period of three years.

The elevator is used in windy weather

Together with his research colleagues, Associate Professor Jacobsen has been studying the extent to which the energy consumption of a group of residents can be influenced by providing them with information about considerate behaviour and appealing to their conscience.

Today, the vast majority of new buildings

Photo: Henrik Olsen

This tall concrete building in Aarhus contains advanced integrated smart grid technology for millions of kroner, and researchers have started a full-scale experiment on balancing the electricity production and consumption.

project facts

TITLE
Virtual Power Plant for Smart Grid Ready Buildings and Customers

SCHEDULE
2013-2016

FINANCIAL FRAMEWORK
DKK 9.4 million,
ForskEL-programme

PARTNERS
Municipality of Aarhus,
Alexandra Institute A/S
Grundfos Holding A/S
Develoco A/S
DONG Energy A/S

CONTACT
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are constructed according to standards that ensure a very high level of energy efficiency, so it therefore makes good sense to look for the potential for energy savings entirely elsewhere.

"If we want to reduce energy consumption in extremely energy-efficient buildings, there's no point in looking at whether we can squeeze in an extra layer of insulation. On the contrary, we should be taking an interest in the part of the energy consumption the residents themselves are responsible for. The major challenge is to highlight the consumption and thereby help them to adopt behaviour that's adapted to a lifestyle with power from sustainable sources," he explains.

The elevator experiment is the first of its kind to suggest opportunities for influencing power consumption at such a scale as to achieve a better balance with fluctuating energy supplies.

"We've studied whether we can motivate the building's residents to use power when it has a low carbon dioxide intensity, simply by informing them. And it looks promising. If we can get the residents to take the stairs to some extent simply by appealing to their conscience, it looks as though we can also get them to change a considerable number of other habits regarding power consumption," says Associate Professor Jacobsen.

Facts about energy composition, supply and demand were used by the researchers in the project. They also collaborated with anthropologists on mapping the factors that have an impact on sustainable energy behaviour in humans.

More activity on the stairs

After looking at the use of the stairs during periods when the power supply had a high carbon dioxide intensity causing the red lamps to light up, the overall results of the study imply that the coloured lamps can significantly reduce the use of the elevator in the building.

"The elevator/stairs ratio was clearly affected. Without the lamps, 6.8 peo-

ple took the elevator for every time one person took the stairs. With the lamps, this was reduced to 5.3 people," says Associate Professor Jacobsen.

To measure the ratio between the use of the stairs and the elevator by the residents in the high-rise building, the researchers used small sensors on the doors between the stairs on each floor. During the 'red' periods, they registered increased activity on the stairs, and this was even higher than they had expected. An elevator is typically responsible for about five per cent of a building's total energy consumption, and the small warning lamps can therefore have a relatively large impact on the aggregate level, according to Associate Professor Jakobsen.

"We've shown that we can reduce the carbon dioxide-intensive energy consumption in a single building with one elevator only. Looking at this in a larger perspective, it actually has the potential to significantly improve the carbon dioxide score on a world level," he says.

Photo:Anders Trærup

More stairs and not so much use of elevators. Researchers have been busy measuring and carrying out fieldwork among the residents of a 12-storey building to study the extent to which it is possible to change energy behaviour with the help of simple information. The photo shows Associate Professor Rune Hylsberg Jacobsen

AU Engineering, Campus Navitas, Aarhus
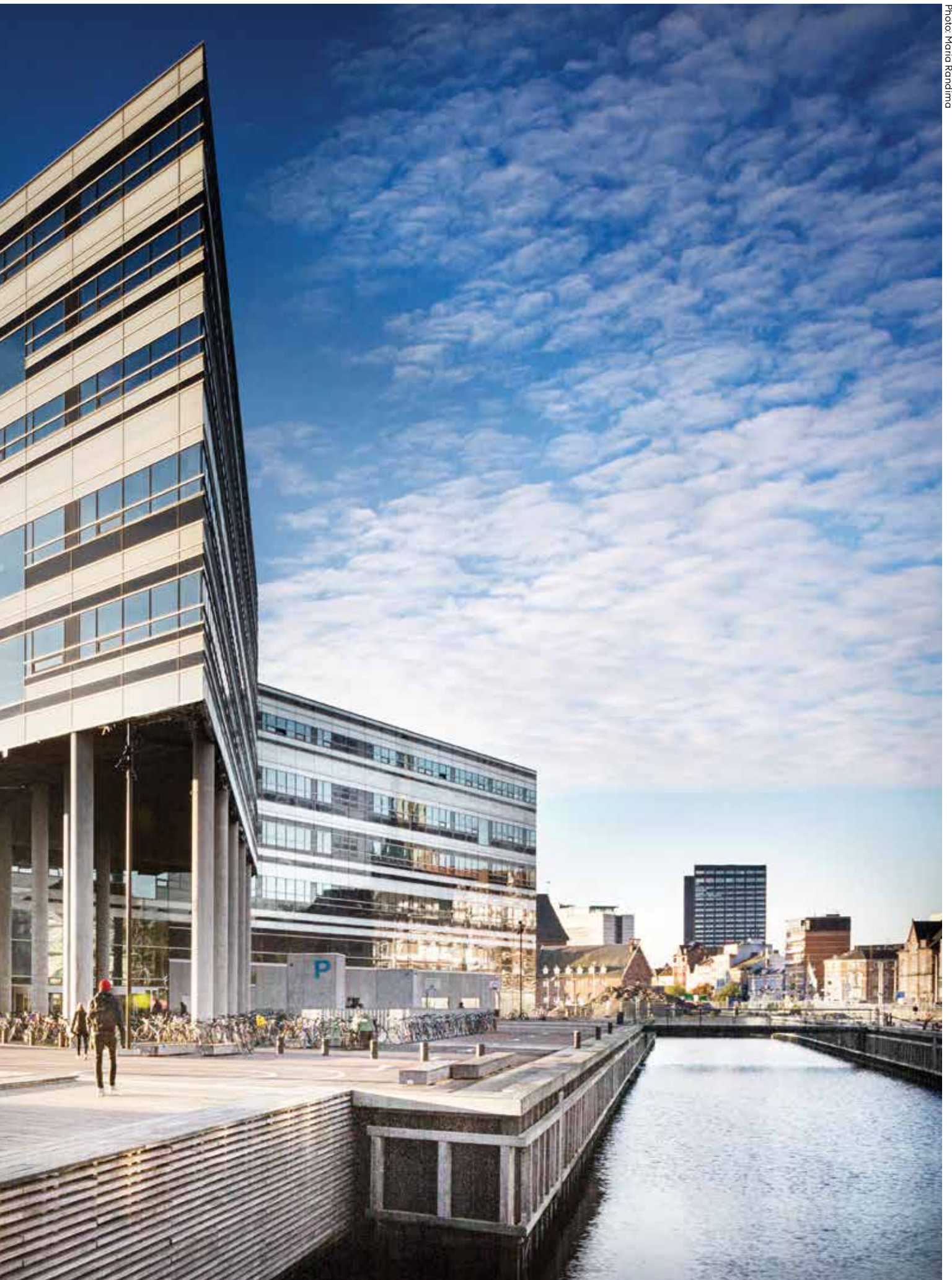
HEA LTH

Global demographic development puts considerable strain on health services in all communities. Technology is one of the most important drivers for a health sector that can ensure quality of life for even more of the world's population. In the years ahead, engineers will be involved in developing areas such as digital medicine, new forms of diagnosis and treatment, artificial organs and technology-based surgery.

New concepts in allergy treatment

A team of researchers has developed new methods to produce artificial copies of the antibodies in humans that cause anaphylaxis. The aim is to improve the medical treatment of people who are allergic to insect stings.

Approximately 30 per cent of the European population suffers from allergies and 3–5 per cent is allergic to insect venom. In Denmark alone, 50,000 people are at risk of severe allergic reactions if they are stung.

If aware of the allergy, they can currently be protected with an acute injection of adrenaline or treated with a standardised allergen vaccine. The problem is that the majority of people are not aware of their allergy. Furthermore, insect allergy sufferers do not react to the same allergens and, in some cases, the treatment therefore has a reduced effect or does not work at all. A limited protection at worst can be fatal.

"Vaccines for immunotherapy today are based on the natural sources such as venom from insects and can therefore contain very different amounts of allergens and even venom from different species of insects. All patients are treated the same way by using insect venom, and this sometimes is not ideal," says Associate Professor Edzard Spillner.

Artificial antibodies can provide better drugs
The researchers are therefore working on developing artificial allergens that mimic the allergens in insect venom. Moreover, they aim at establishing antibodies that are similar to those antibodies that are present in patients with severe allergy to insect venom.

Associate Professor Spillner is an expert in the development and design of proteins for clinical use. In his laboratory at Aarhus University, he has produced a variety of artificial allergens and also the first artificial human antibodies to insect venom. In collaboration with other researchers at Aarhus University, the most interesting ones have been crystallised recently.

Using a special biological technology, he and his research group have carried out a comprehensive mapping of the antibodies in patient serum that can cause anaphylaxis, and this is an important step in the direction of more knowledge of allergy, particularly to insect venom.

"Once we can identify and isolate specific allergens, we have routine access to studying the molecular processes going on in the blood of allergy sufferers. The component resolved approach is a major break-through in insect venom allergy

and can be a benchmark for individual immunotherapeutic treatment," says Associate Professor Spillner.

The technology has the potential for improved and more extensive diagnostic practice. The researchers estimate that the majority of people who are allergic to insect venom are currently unaware of their condition, and are unprepared for any severe allergic reactions that can occur when they are stung.

Additionally, patients with specific recognition patterns could be identified as those being at higher risk for unsuccessful immunotherapy using insect venom

The mystery of allergy
The researchers are now working in the laboratory with blood samples from patients with allergies and they are mimicking the body's immune system so to speak. At present, they are in the process of studying the interactions between artificial antibodies mimicking the human ones and their specific target structures from the insect venom.

They are also taking a close look at the release of mediators such as histamine, which drive the allergic reaction. Here

One single sting can have fatal consequences for the approximately 5 per cent of the population who are allergic to insect venom. Artificial antibodies can provide key information for development of improved or new drugs, and researchers at Aarhus University have crystallised some of the first in their laboratories. The photo shows Associate Professor Edzard Spillner in the lab

the known allergenic antibody IgE is particularly in the spotlight.

"We can isolate and rebuild IgE from the patient's blood and identify the target structure it reacts with. This way we can analyse how it behaves together with the insect venom or other allergens. The better we understand the molecular mechanisms of action, the greater our chances are of developing new concepts in allergy treatment" says Associate Professor Spillner.

The next step for the researchers is to describe precisely how the artificial antibodies bind to antigens, and this can be the key to finding out by which factors the allergic reaction is driven.

"We don't yet completely understand the impact of the IgE antibody binding to the allergens on the allergic response. We're studying the individual processes at the molecular level in the laboratory, and it will be some time before we have complete insight," says Associate Professor Spillner.

Break-through in the laboratory
The researchers hope to obtain first answers within near future. If they succeed

in identifying critical molecules, they will be able to provide better protection of individual patients. This is good news for all allergy sufferers because the method for designing artificial antibodies appears to apply to a wide range of other allergies.

"We carried out several of our experiments with allergens from insect venom, but could in principle have used all kinds of allergens. We expect to generalise our results and use the method to study the mechanisms behind many other allergic reactions," says Associate Professor Spillner.

project facts

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Balloons will burst defective artificial heart valves

Replacing an artificial heart valve that no longer works will be safer for patients in the future. Researchers will gain knowledge about how to burst worn out implants to make room for new ones.

A defective valve is one of the most common heart diseases in the Western world. Every year, cardiac surgeons implant more than 300,000 artificial heart valves to recreate a normal blood flow pattern and thereby improve the pumping function of the heart in their patients.

Doctors can currently choose between a mechanical and a bioprosthetic implant. A mechanical heart valve is much more durable, but also has an increased risk of complications such as blood clots, and patients therefore need to take anticoagulant drugs for the rest of their lives.

A bioprosthetic heart valve is made of animal tissue and therefore provides a more natural blood flow, where the risk of blood clots is minimal. The problem with these valves is that their durability is limited and they must therefore be replaced every fifteen to twenty-five years.

"Mechanical heart valves are typically offered to younger patients to avoid repeated surgical procedures. If it was possible to replace bioprosthetic heart valves without surgical intervention, how-

ever, it would provide doctors with more opportunities to use this type of implant," says Associate Professor Peter Johansen.

In a new project collaboration between Aarhus University and Aarhus University Hospital, he will help establish evidence-based knowledge about how to replace defective heart valves safely and accurately.

Balloon technique may render surgical procedures unnecessary

For a number of years, Associate Professor Johansen has worked closely with clinical researchers at the Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, where a gentle way to implant bioprosthetic heart valves via a catheter in the groin was originally invented and developed without the use of open heart surgery.

The same method is used in some cases as an alternative to repeating surgical procedures on patients with defective bioprosthetic heart valves, where the new valve is inserted in the old one. However, the space is sometimes so tight that it is

first necessary to burst the existing and worn implant to make room for the new one.

"The doctors can insert a high-pressure balloon into the defective heart valve and pump it up to make a fracture line in the outer ring of the valve. This can make room for implanting a new valve via a catheter, thereby avoiding a new operation," says Associate Professor Johansen.

The researchers will now use specially designed measuring equipment to very precisely determine how the doctors can burst the defective valve with a minimal risk of damaging the surrounding tissue.

Minimal risk of lesions of the aorta

This will take place in a considerable number of in vitro tests of different commercial heart valves that are systematically exposed to pressure in the laboratory. The combined measurements will contribute to clinical guidelines for how to burst different types of bioprosthetic heart valves in the most careful way.

"It's relatively simple to burst a heart

project facts

TITLE
Valve-in-valve therapy – fracture mechanics of bioprosthetic heart valves

SCHEDULE
2016–2019

FINANCIAL FRAMEWORK
DKK 2.8 million (Different funds)

PARTNERS
Aarhus University Hospital, various valve manufacturing companies

CONTACT
Associate Professor Peter Johansen, pj@eng.au.dk

Researchers use small high-pressure balloons to burst heart valves in the laboratory. The aim is to accurately calculate the minimum pressure required before a defective heart valve fractures.

valve, but it requires meticulous studies if it's to be done with precisely the pressure that's required and no more. We'll therefore – doctors and engineers together – gather new knowledge about carrying out this procedure so that patients are exposed to the least possible risk of lesions of the surrounding tissue," says Associate Professor Johansen.

The researchers have designed an experimental set-up for this purpose, which consists of a manometer (pressure gauge), a high-speed camera and a CT scanner.

The camera can film up to 120,000 images per second and thereby photograph the movements in the heart valve structures when they burst. The CT scanner can look into the valves so to speak, which provides an opportunity to analyse the fracture in the ring surrounding the bioprosthetic valve.

Specially designed measuring equipment very precisely determines how the doctors can burst a patient's defective valve with a minimal risk of damaging the surrounding tissue.

Ensuring the right dose of expensive medicine

With new technology, researchers will make it possible for doctors to prescribe medicine containing biologicals based on an assessment of the levels in the individual patient. This kind of pharmaceutical is often characterised by being expensive, and the effort will therefore benefit both individual patients and hospital finances.

In recent years, biological drugs for diseases such as arthritis and cancer have become popular in the health sector due to positive results in patient treatment. This type of medicine is based on particular proteins known as therapeutic antibodies, and these are extremely difficult and expensive to manufacture.

Sales of therapeutic antibodies are increasing rapidly and figures this year have reached more than DKK 370 billion globally. There is much to indicate that this trend will continue as researchers from all over the world get better at designing more antibodies with specific properties.

"Research in biological medicine is in full swing at a global level. We've only seen the beginning when it comes to using therapeutic antibodies in the health sector, and we're facing a future in which we'll see the introduction of many more," says Associate Professor Peter Kristensen,

who has years of experience in developing new antibodies.

When is enough enough?

For example, a one-year treatment of a patient's rheumatoid arthritis symptoms can cost as much as DKK 200,000, which means there is very good reason to see whether doctors can become better at prescribing the right dose, according to Associate Professor Kristensen.

"It's very difficult today to find out whether the treatment with therapeutic antibodies will have any effect at all on the individual patient, or how much medicine the patient regularly needs to achieve the optimal effect. If there is just ten per cent too much on average, this could provide an interesting overall financial savings potential for the hospitals, which can benefit other patients," he says.

The researchers at Aarhus University have entered into a collaboration with

the Danish Rheumatology Biobank (Dansk Reuma Biobank) and, in the coming years, they will develop new methods for dosing therapeutic antibodies more accurately on the basis of a simple blood test. The idea is to measure the amount of medicine remaining in the bloodstream before giving the next injection.

This might sound straightforward, but it is actually far from it.

"If you want to give the right dose, you have to take into account how much medicine is still in the body. This is complicated by the fact that therapeutic antibodies are designed to resemble the body's own antibodies," says Associate Professor Kristensen.

He will initially develop a method for measuring the therapeutic antibodies used to treat symptoms of rheumatoid arthritis. The method can easily be adapted to other types of biological medicine.

Using new technology, researchers will make it possible to measure when it is time for the patient's next injection with expensive biological medicine. They hope to be able to provide better individual treatment and cut down medical expenses. The photo shows Associate Professor Peter Kristensen who is developing a new method for dosing therapeutic antibodies in treatment of patients with rheumatoid arthritis.

One antibody out of billions

For this purpose, the researchers will use a library of billions of recombinant produced antibodies, and the researchers have developed technologies that make it possible to identify one single antibody from among the multitude, and subsequently optimise it in the laboratory.

They have previously used the technology for research into conditions such as cancer and ageing, and they will now use it to find exactly the recombinant antibody required to bind to rheumatoid arthritis medicine and not to the body's own antibodies.

"We know we can find recombinant antibodies in our library with such specific properties that they can bind to different types of biological medicine without also binding to the naturally occurring antibodies in the body. One of the possible points of attack is the sugars that attach themselves to the antibodies in the blood.

They're so small that we can't characterise them, but we know that the specific action mechanisms of the antibodies are affected," says Associate Professor Kristensen.

Once the researchers have selected the relevant recombinant antibodies, there is still quite a bit of engineering work required to integrate them in a measuring instrument that is both inexpensive and precise. This could be a test similar to the one used to measure blood sugar levels. Here the patient pricks a small hole in the skin and applies a drop of blood to a strip.

By carrying out cheap and frequent measurements, the patient will know with a great degree of accuracy when it is time for the next injection with the expensive biological medicine.

Cheap tests can reduce overdoses

The measuring method will also assist doctors in their assessment of the effect of the medical treatment. This is because therapeutic antibodies do not work on all patients and the effect may decrease with time.

This happens when the body begins to recognise the medicine as a foreign substance. In this process, new antibodies are developed against the biological medicine which therefore stops working.

"If we can measure when the new antibodies start to fight the biological medicine, we'll have a better chance of giving medicine that works for individual patients. This way, we'll be able to provide more reliable treatment, and we can cut down on the consumption of very expensive medicine in cases where it has no effect anyway," says Associate Professor Kristensen.
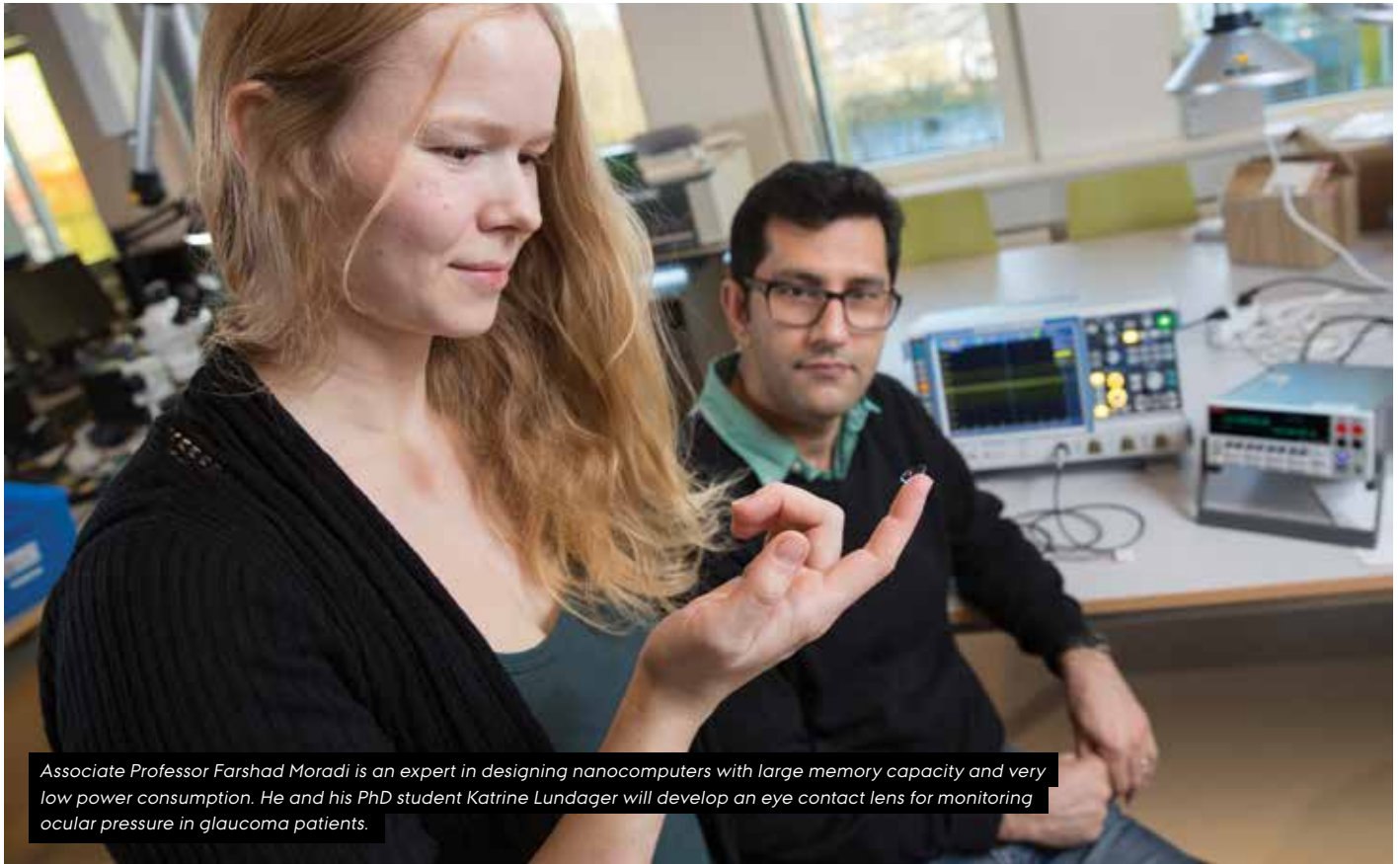
Associate Professor Farshad Moradi is an expert in designing nanocomputers with large memory capacity and very low power consumption. He and his PhD student Katrine Lundager will develop an eye contact lens for monitoring ocular pressure in glaucoma patients.

Intelligent contact lens will stop glaucoma

Researchers want to develop a contact lens with a small sensor that can monitor eye pressure around the clock and release precise doses of medicine to patients with glaucoma.

A contact lens with a built-in pressure sensor and microchip can be important in the treatment of glaucoma patients in the future. The idea is that the lens is placed on the eye the same way as an ordinary contact lens, and it constantly registers changes in the fluid pressure that plays an important role in the development of the disease.

Untreated glaucoma can cause changes in the optic nerve and ultimately lead to blindness, but appropriate medical treatment with eye drops can prevent an increase in fluid pressure and the progression of the disease.

Round-the-clock monitoring of eye pressure

Glaucoma patients currently have their eye pressure (Intraocular pressure-IOP) measured by an ophthalmologist or at a hospital by means of a special instrument. The problem with this method is that it can only be performed periodically, for instance only during clinical hours, which does not provide enough valuable data. Therefore, the researchers will design an intelligent lens that can monitor the eye pressure at intervals of just a few seconds twenty-four hours a day.

"We know that the ocular pressure in patients with glaucoma can vary from one moment to the next, and with considerable fluctuations in the course of a day. Using an intelligent lens, we can therefore make it much easier to monitor the disease and provide more accurate medical treatment," says Associate Professor Farshad Moradi.

The researchers will initially develop the electronics required for the lens so that it can store information about pressure and send a message to a computer or smartphone about when to take eye drops and in what dosage.

In the long run, they also expect to provide the lens with a polymer layer

project facts

TITLE
Self-powered System-On-contact-Lens
for Intraocular Pressure Measurement in
Patients with Glaucoma

SCHEDULE
2016-2019

FINANCIAL FRAMEWORK
DKK 1 million
GSST and MQRES

PARTNERS
Macquarie University, Australia

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containing nanomedicine, which can be
regularly and very precisely released in
the eye based on pressure monitoring.

Power from the Sun and eye movements

Dr Moradi is an expert in developing
microchips, and he collaborates with
both ophthalmologists and materials re-
searchers in the project. In its first state he
will develop the computer technology so
the contact lens is supplied with sufficient
data capacity and processing power.
The idea is to make the lens capable of

working entirely without battery power
and processing all information on chip.

For this purpose, the researchers are al-
ready working on different power-gener-
ating technologies. A flexible solar cell, for
example, can drive the electronics during
daylight hours, and a special piezoelec-
tric material will create elecwtrical energy
at night via mechanical forces from rapid
eye movements (REM) during sleep.

"We'll be experimenting with different
energy-harvesting methods to find the
right mix regarding what can be done
without compromising the comfort of the
lens user. Our aim is to create so much
processing power that the lens only
needs to be changed ocassionally," says
Dr Moradi.

The researchers expect to have proof of
concept and an early prototype of an
intelligent contact lens in the course of
three to four years.

Next step is cancer and diabetes

The lens will initially be developed to
measure eye pressure in patients with

glaucoma, but the pressure sensor can in
principle be replaced by a biosensor, and
this opens up for completely new appli-
cation areas. According to Dr Moradi, it
will be realistic within a few years to carry
out both cancer detection and blood
sugar measurements in diabetics via dif-
ferent biochemical markers in tear fluid.

"We're preparing the lens with a thin
channel that can guide tear fluid past
the sensor, and this opens up for inter-
esting new monitoring possibilities. We
know that you can measure the glucose
content of tear fluid, and we also know
that there's a correlation between certain
forms of cancer and the content of a par-
ticular protein in tear fluid called lacryglo-
bin. When the lens technology is ready,
it will be able to work without a battery
and provide data at short intervals, so
we can gain access to a considerable
amount of different health information
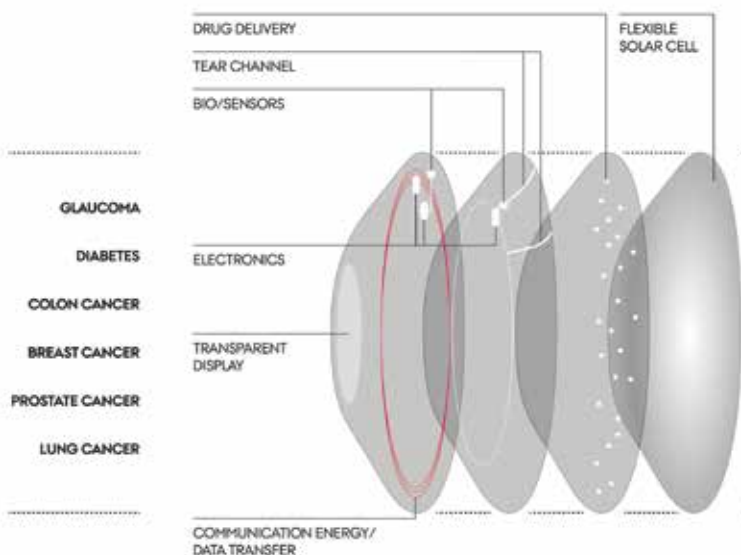via the eye," says Dr Moradi.

DRUG DELIVERY
TEAR CHANNEL
BIO/SENSORS
FLEXIBLE SOLAR CELL
GLAUCOMA
DIABETES
ELECTRONICS
COLON CANCER
BREAST CANCER
TRANSPARENT DISPLAY
PROSTATE CANCER
LUNG CANCER
COMMUNICATION ENERGY/ DATA TRANSFER

Photo: Lars Kruse

Less noise in large cities

A good sound environment promotes well-being and health. Researchers will now study the way noise behaves in urban space, and come up with new standards for acoustic quality.

The acoustic environment in which we live is possibly much more important than previously thought. In recent years, researchers have documented significant correlations between noise, mortality and lifestyle diseases.

Players in the construction industry are aware of reducing noise levels when they build new urban spaces or improve the existing ones, but they are fumbling towards a good solution.

At present, there are no standards for acoustic quality and only very limited knowledge about the way sound behaves and affects people.

"We know that sound has serious consequences for health and well-being. Today we can measure the sound level in decibels, but we have no prerequisites for working holistically with sound design in urban spaces. We don't know which buttons to push to get the best possible overall sound quality within the economic framework of a construction or renovation project," says Professor Poul Henning Kirkegaard.

Acoustic quality as design parameter

In the coming years, Aarhus University will participate with Lund University and Aalborg University in the Urban Tranquility project, the aim of which is to develop an index for acoustic quality.

The project will be the first step on the

way towards a paradigm shift in the construction industry, based on more in-depth knowledge of the impact of the design of buildings, pavings, town squares, planting and infrastructure on the sound environment.

"Sound is a complex research field. One thing is to point out obvious sources of noise and measure their strength. Another is to study the way sound is distributed in urban spaces and travels around the buildings' bearing constructions. And then there are noise sources that we only register indirectly. This could be vibrations transmitted through the ground without our noticing them, but which influence our well-being day in and day out," says Professor Kirkegaard.

New tools for architects and developers

The researchers will carry out a number of experiments and build a model that can predict the behaviour and influence of sound regarding a number of different health and well-being parameters. This means, in practice, that they will be able to assess the acoustic quality of a building or urban renewal project as early as the design stage.

"We'll integrate the knowledge we build up in a calculation model. This will make it possible to optimise the acoustic quality of a project while it's still on the drawing board. The design of the facades might need to be changed, the windows might need an extra layer of insulation, or per-

haps there are absorbent surfaces in the urban space, noise barriers, road paving or other things entirely that provide the best effect. The point is that we'll have a tool for prioritising," says Professor Kirkegaard.

It will take about three years to develop the calculation model so it can be taken into use by architects and developers. The researchers also expect to make a significant contribution with new knowledge about correlations between sound quality and health.

project facts

TITLE
Urban Tranquility

SCHEDULE
2016-2019

FINANCIAL FRAMEWORK
EUR 3.3 million – European Regional Development Fund

PARTNERS
Aalborg University, Lund University, SP Technical Research Institute of Sweden, COWI A/S

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Sounds affect us. And they have a greater impact than previously thought. But what is good acoustic quality?
In a new project, researchers will develop a model that makes it possible to predict how sound waves behave and
affect people in urban spaces. The photo shows Professor Kirkegaard who is an expert in architectural Engineering.

Smart sphygmomanometer provides warning of preeclampsia

Researchers at Aarhus University and Aarhus University Hospital have developed an intelligent measuring station that very precisely records the blood pressure of pregnant women as early as the 12th week of pregnancy. This can help determine the risk of preeclampsia.

Scientific studies show a statistically significant correlation between elevated blood pressure in the 12th week of pregnancy and the risk of developing preeclampsia later on. Recording blood pressure at an early stage of the pregnancy is one of several parameters that can contribute to identifying pregnant women at risk.

This is interesting because recent research actually indicates that preventive medical treatment can reduce the risk of developing severe preeclampsia with serious complications for both mother and baby, which can be life-threatening in some cases.

"Blood pressure can be a factor in identifying the risk before the symptoms appear. This means that by increasing efforts regarding routine investigations during pregnancy, including taking blood pressure measurements of a high quality, we can presumably reduce the number of cases of preeclampsia with serious complications," says Assistant Professor Stefan Wagner.

Together with his colleagues at Aarhus University Hospital, he has developed

an intelligent telemedical solution to measuring blood pressure – a self-measurement station that can carry out very precise and automatic blood pressure measurements of pregnant women without the help of hospital staff.

Precise self-measurements
The self-measurement station has been tested at Aarhus University Hospital in a pilot study involving the first 100 pregnant women in connection with nuchal translucency scans that had already been planned during the 12th week of pregnancy, and the results were good. The measurements were very precise, and the pregnant women gave a positive evaluation of the self-service solution.

The station is equipped with an automatic sphygmomanometer – a device for measuring blood pressure. Patients put their arm in the device, which has a screen with active guidelines, a scanner for their health insurance card, and different sensors that record sound and movement while the blood pressure is being taken.

It is all done without instructions or help from the staff, which is often a prerequi-

site for achieving high-quality measurements when standard sphygmomanometers are used.

"It's crucial for the quality of the measurement that the pregnant woman complies with a rest period before her blood pressure is taken, and that she sits quietly with her back straight and both feet flat on the floor without talking. We can now ensure all of this without involving staff resources," says Assistant Professor Wagner.

If the pregnant woman crosses her legs or sits hunched over the measurement station, she will be given a message to sit up straight. Once her blood pressure has been correctly taken, the station automatically transmits the data to the individual's chart along with a score for the quality of the measurement.

"We can look at the measurement later, and get a guarantee of its quality at the same time. What's special about this self-measurement station is that we can rely on the measurement being taken correctly," says Dr Puk Sandager, Department of Gynaecology and Obstetrics, Aarhus University Hospital.

Telemedicine can lead to fewer deliveries

The doctors expect to be able to use the measuring station for systematic precision measurements in the future to establish a screening programme for preeclampsia.

"With a screening programme, we expect to be able to prevent approximately half of the cases of preeclampsia in which the complications are so serious that the delivery has to be induced more than six weeks prematurely, and that the remaining half will get a much milder form of illness," says Dr Sandager.

In addition to recording blood pressure, the overall screening procedure for preeclampsia includes measuring two different hormone values and blood flow to the uterus, as well as information about any previous pregnancies. The project is continuing in 2016 with an even more extensive study with automatic blood pressure measurements that will include 600 pregnant women altogether.

The measuring station can eventually be used in a considerable number of other diagnostic contexts, and it will hopefully provide savings for the health sector by reducing unnecessary overtime payments at the same time as ensuring better quality for patients in connection with their blood pressure measurements.

Photo: Colourbox

By precisely recording the blood pressure of pregnant women as early as the 12th week, it is possible to indicate the risk of preeclampsia at a later stage of the pregnancy. Researchers have developed a telemedical solution that makes it possible to implement targeted screening programmes without leading to increased use of staff resources.

PRECI SION AGRI CULTURE

How do we ensure sufficient quantities of healthy food and clean water for a growing global population? This is one of the most acute challenges faced by the global community. At a research level, engineers are working on finding new technological solutions to ensure that we can produce more food and drinking water with fewer resources. The agriculture of the future will be based on new technology to an even greater degree than at present. In this area, Big Data, intelligent systems, robots and drones will help create automation, boost agricultural efficiency and reduce the sector's environmental impact.

Computer intelligence significantly reduces herbicide consumption

An algorithm that enables a camera to differentiate between weeds and crops can reduce a farmer's use of herbicides by virtually half.

To prevent their fields from becoming overgrown with weeds, farmers have to use herbicides in standard mixtures and amounts right across the field. Now researchers will try to improve this spray behaviour by means of a new camera technology and a patented algorithm that differentiates between weeds and crops.

The project was launched back in 2012 when researchers worked with Danish farmers to collect a database with several million images of weeds from the fields.

"The farmers took photos of their fields every 100 metres using their mobile phones or a consumer drone. They sent their photos to an expert who determined the type of weed and registered it in an online database," says Senior Researcher Rasmus Nyholm Jørgensen.

Computer identifies weeds
The database is now so comprehensive that the researchers can start work on

image recognition of the weeds. They have invested in a supercomputer with extremely large and fast graphics cards, and they are now 'training' it to identify a specific weed species within a fraction of a second.

The supercomputer can currently recognise a total of twenty-seven species with a very high level of accuracy and, according to the researchers, it will be capable within a year of identifying considerably more of the approximately 100 species of weeds in the Danish flora. If they succeed, computer-based identification will provide unprecedented opportunities for effective weed control in agriculture.

Smart sprayer prevents resistance
The researchers have already carried out experiments with the first early prototype of an intelligent sprayer that can dispense a herbicide dose when it sees weeds in the field.

"Based on the many images in the data-

base, we've 'trained' a computer to look down on the field and identify weeds. When it sees a weed, it can activate a spray nozzle, and when the weed is no longer visible, it can stop. It all takes place automatically, and we also hope that we can use the technology to select the right herbicide and spray it in optimal doses. This will save farmers the cost of purchasing herbicides, protect the environment and systematically vary the herbicides so that we prevent the weeds from developing resistance," says Senior Researcher Jørgensen.

The image analysis is made in less than a second and – with the twenty-seven identifiable weeds – it can already today reduce herbicide consumption in the fields by 40 per cent. However, the system is not yet commercially available. The researchers' ambition is now to optimise the algorithms for image recognition to make it financially possible to expand it to the agricultural sector.

Photo: Rasmus Nyholm Jørgensen

The team behind the RoboWeedSupport project has 'trained' a computer to differentiate between different weeds. The technology can be used to make agricultural weed control more efficient. The photo shows Senior Researcher Jørgensen photographing the field.

project facts

TITLE
RoboWeedSupport – Smart weed recognition will reduces pesticide consumption

SCHEDULE
2014-2017

FINANCIAL FRAMEWORK
DKK 6.3 million, from Green Development and Demonstration Programme (GUDP)

PARTNERS
University of Southern Denmark (Maersk Mc-Kinney Moller Institute), SpectroFly ApS, I•GIS, Knowledge Centre for Agriculture. Seven expert centres consisting of: Bornholm Agriculture (Bornholms Landbrug), Gefion (Zealand), Centrovice (Funen), LMO (East Jutland), Agri Nord (Himmerland), Agricultural Consultancy South (Landbrugsrådgivning Syd), and LandboNord (Vendsyssel).

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More biomass from meadows

Inspired by advances in military vehicles, researchers will improve the design of machines that can harvest grass from wet meadows.
If successful, this will provide access to considerably more biomass for energy throughout most of the world.

Biomass is by far the largest sustainable energy source available. Today it mainly comes from forest wood, organic waste and agricultural products such as straw. Large amounts of biomass from wet natural areas such as meadows can be better utilised than is the case at present. However, more knowledge is required about production conditions, plant growth, nutrient absorption and greenhouse gas emission, as well as new harvesting technology.

Researchers will take a closer look at new methods to harvest, store and pretreat wet biomasses, refine it to biogas, and optimise the whole process from meadow to processing plant – and they are already well on the way.

Wet areas are a challenge for tool carriers

Until now, meadow grass has been a difficult biomass fuel because the grassy areas have a high water level and are thereby relatively inaccessible to traditional tool carriers at most times of the year.

"Today you destroy the grass and soil conditions if you burden the ground with large machines, and this means we have poor access to harvesting crops in the meadows and using them for energy purposes," says Professor (Docent) Ole Balling.

His activities include participation in the NATO Advanced Vehicle Technology Panel and modelling the mobility of military vehicles inspired him to come up with the idea of designing harvesters for the vulnerable meadows with rough terrain and high water levels.

He is now taking part in the university's biomass research activities and applying his knowledge. Together with his team,

Photo: Colourbox

In the future, the water level will rise in many parts of the world, and more knowledge about options for cultivating and harvesting in wetlands is therefore a matter of urgency. Researchers will design harvesters that can carry grass from wet and delicate meadows without destroying the soil. This requires extremely detailed knowledge about the way particles in the soil behave under different types of load, and mathematical modelling therefore plays a key role in the design process.

project facts

TITLE
BioXtek

SCHEDULE
2014–2017

FINANCIAL FRAMEWORK
DKK 6 million

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he will develop new harvesting technology that is adapted to the specific soil conditions in meadows.

The aim is to be able to harvest at the same time as protecting and maintaining the natural quality of the meadows by preventing them from becoming overgrown with scrub.

Mathematical models of the earth voltage

The engineering challenge is to find the most optimal and gentle interaction between machine and soil, and this is where the Aarhus University researchers have a head start. In recent years, they have actually been working with a special form of modelling that makes it possible to measure the voltage in the soil and thereby the load rate in a considerable number of different harvesting scenarios.

"We use a modelling method that shows how the soil particles interact. This way, we can see what happens when the ground starts to give in. When you've got detailed insight into how the ground behaves under different load types, you can develop machines that take this into account," says Dr Balling.
The researchers can use the mathe-matical models to identify items such as optimal wheels or belts, steering mechanisms and tyres for the new type of harvester that is expected to be ready in the first model-based prototype during the course of the next couple of years.

In Denmark alone, there are about 200,000 hectares of meadows that can be used for biomass. The researchers' modelling technology is expected to be used to design harvesters and tool carriers for a considerable number of other lowland areas all over the world.

New algorithms provide a better harvest

Researchers have entered into a collaboration with one of the world's leading manufacturers of agricultural machinery. They are now well on the way with the first version of a fleet management system that can optimise a farmer's harvest.

Economies of scale and efficiency improvement are key words for the latest trends in the development of agriculture. Farmers who take care of the land get a better crop yield. An optimised execution of the harvest can provide both fuel and cost savings. And farmers can now get help in planning the whole process with computer intelligence.

In recent years, the university's leading experts in operations management and software engineering have been working intensively on developing computerised fleet management tools for agriculture. They have now completed the first early prototype of a system that can control all the machines involved in a harvest, giving them the best possible route in relation to each other.

"Computer intelligence can lift the logistical planning involved in agriculture to a completely new level. We've developed an algorithm that can select the mathematically optimal route for each of the machines involved in harvesting. This means that farmers can save time, fuel and money in their operations, and at the same time reduce soil loading," says Senior Scientist Claus Aage Grøn Sørensen.

No more harvesting using the same patterns

For the time being, the researchers have shown positive results in computer-simulated harvesting operations. With the new algorithms, they can control the harvest in a defined area with route planning that takes into account not only the field and vehicle dimensions, but also the soil compaction.

"In principle, we're doing away with traditional harvest methods in the fields, where there is no overall control of harvesting machines and transport vehicles. Instead of this, we're getting the computer to work out how the machines should move around in relation to each other, taking into account the status of the soil. It means the driving patterns become more complex," says Senior Scientist Sørensen.

For major agricultural regions such as the USA and Eastern Europe in particular, the technology can have a significant impact on the efficiency of the harvest. It is not uncommon here for farmers to keep track of five combine harvesters and a corresponding number of transport units in one operation.

Fewer kilometres mean healthier soil

When the 2016 harvest begins, the researchers will try out the intelligent fleet management in Danish fields. In connection with the 2015 harvest they used a GPS logger to record the driving behaviour of the farmers in the same fields, and this will make it possible for them to very precisely assess the efficiency improvement potential of the technology.

Under certain conditions, computer simulations of other field operations have shown driving savings of up to 15 per cent.

"We hope we can reduce driving on the fields by 10 per cent in connection with harvesting. This may not sound like very much, but at an aggregate level, it would provide considerable global savings of both fuel and time. We would also be reducing the problem of soil compaction and thereby the amount of subsequent care the fields require," says Senior Scientist Sørensen.

One of the really great side-benefits of using computerised fleet management is that the soil is exposed to less loading by the heavy machines, and the fertility is thereby increased.

Photo: Colourbox

Using the same patterns for harvesting the fields is a thing of the past. A new algorithm enables a simple computer to control the most optimal driving pattern for both combine harvesters and transport units in the same operation.

project facts

TITLE
Off-line and on-line logistics planning of harvesting processes

SCHEDULE
2014-2017

FINANCIAL FRAMEWORK
DKK 6,2 million

CONTACT
Senior Scientist Claus Aage Grøn Sørensen, claus.soerensen@eng.au.dk

Think Big (Data) in agriculture

Computer technology has changed the way businesses operate, and it has an increasingly profound impact on farming. In a project with a budget of DKK 100 million, researchers and companies innovate to improve competitiveness in future Danish agricultural crop production using big data.

Danish environmental regulations for the supply of nutrients to plants mean that the emission of nutrients from agriculture to the aquatic environment has fallen. However, this has come at a cost. The suboptimal fertilisation in relation to crop need has led to stagnating yields and quality in the past 20 years.

Future Cropping is a new innovative project that intends to remedy this problem by getting the best of both worlds – protecting the environment while maintaining high-yielding and efficient crop production.

This is to be achieved by integrating a range of data, decision support systems and technological solutions that enable farmers to tailor their management according to the local and actual conditions in the field.

"Until recently, the desired impact from state-of-the-art data analytics capabilities has not been achieved. However, current technological advances in areas like data management and communication technology in agriculture enable us to collect, combine and analyse different layers of information that can contribute to even more efficient production than we have today," says Professor Thomas S. Toftegaard, Head of the Department of Engineering, Aarhus University.

Differentiated treatment of fields

Not all fields are identical and we would do the environment, agriculture and the economy a favour if they were not treated equally. The comprehensive innovation project will provide research-based knowledge developed and tested in practice in cooperation with the industry and give agriculture the opportunity to treat the fields on the basis of their individual characteristics and conditions.

The project therefore aims to develop and commercialise more efficient and sustainable solutions for crop production, which will increase the yield per hectare by about two per cent per year.

"In the near future, big data will enable farmers to make improved and differentiated decisions in the production and operation chain," says Dr Toftegaard.

The increased efficiency coupled with the sustainability principle will benefit Denmark's environment, agriculture, employment and export market.

Computer intelligence in plant production

What is new and special about the project is that it will develop a data platform to enable the collection and integration of large amounts of information across all the main phases of the crop production annual cycle, ranging from soil preparation and growth monitoring to harvest activities.

The amount of data also forms the basis for developing intelligent, efficient and sustainable technologies, solutions and cultivation techniques for site-specific and high-yielding crop production with a low environmental impact.

"Today, almost any modern agricultural machine can be built or modified to be operated remotely and to generate and wirelessly transmit data. These technological advances will make it possible to utilise data to a degree we wouldn't have dreamed about only a few years ago," says Dr Toftegaard.

The researchers and the industry involved expect that big data can significantly increase the efficiency of all the major operations in crop production.

In addition to developing an advanced data platform, they are going to design, test and demonstrate technologies for intelligent tillage and crop establishment, intelligent and sustainable fertilisation, intelligent harvesting, and differentiated nitrogen regulation and drainage.

Researchers are going to establish a new open data platform that combines different layers of information, such as weather patterns, soil conditions and crop features. This will provide agriculture with the possibility of treating fields on the basis of their individual traits and conditions.

project facts

TITLE
Future Cropping

SCHEDULE
2015–2020

FINANCIAL FRAMEWORK
DKK 100 million,
Innovation Fund Denmark.

PARTNERS
University of Copenhagen
Kongskilde Industries A/S
SEGES, Orbicon A/S
Ejlskov A/S
Yara Danmark Gødning A/S
Novozymes A/S
Agro Business Park and AgroTech A/S
GEUS
FOSS
Rambøll Danmark A/S

CONTACT
Professor Thomas S. Toftegaard,
tst@eng.au.dk

Consider the example of farm equipment that takes out soil samples in real time, directly performs the relevant analysis and wirelessly transmits the results to a database in the cloud. Combined with weather predictions, these results can be used to make precise adjustments to nitrogen applications.

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Publications
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Østerlund, Jeppe Kiilerich ; **Christensen, Tommy** ; **Vestergaard, Lars Bang** ; **Bochtis, Dionysis**; **Sørensen, Claus Aage Grøn** / Biomass supply chain network design based on the cropping area and spatial distribution.
Proceedings of the 1st International Conference on Agrifood SCM & Green Logistics. 2015. Article in proceedings
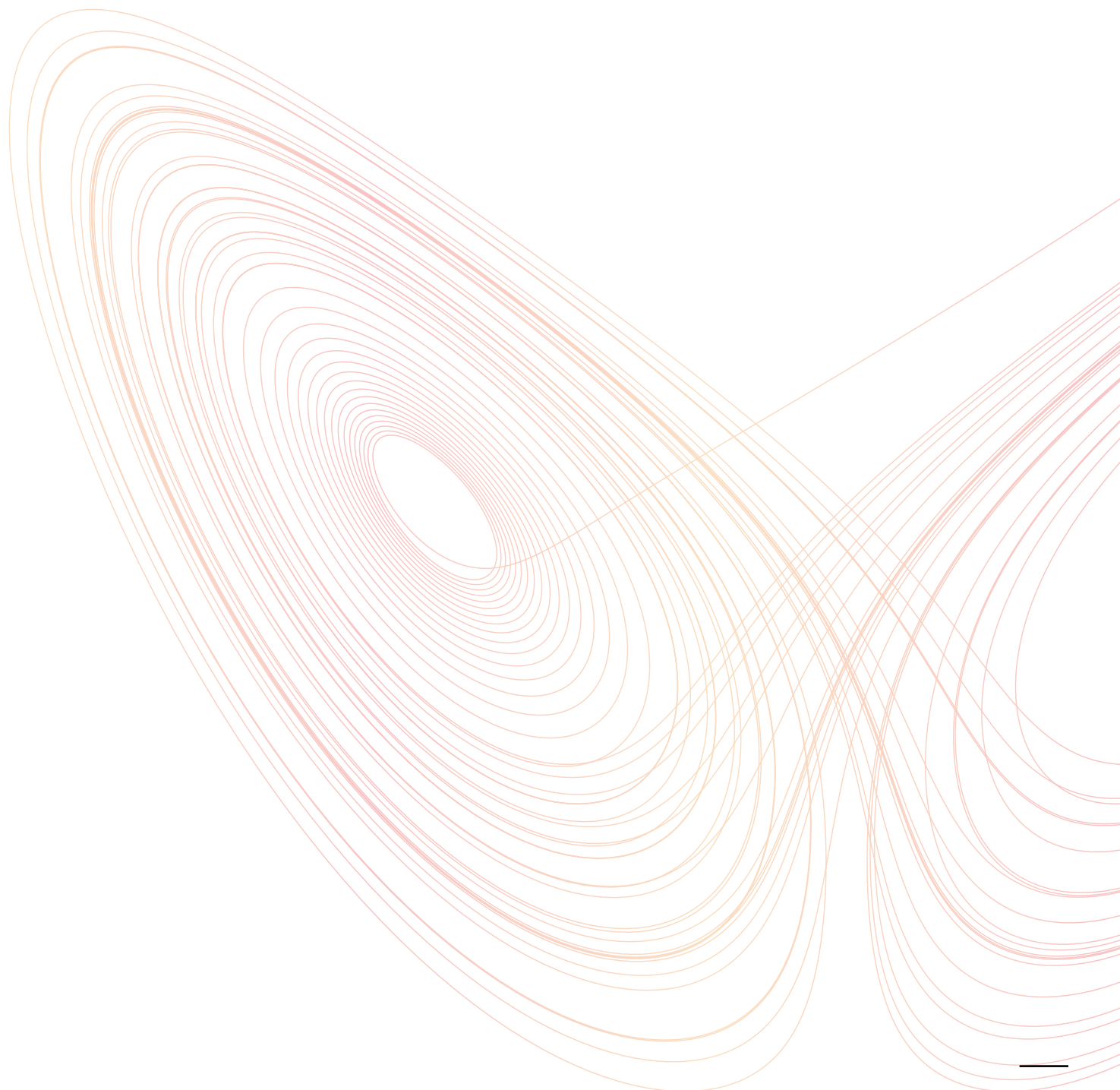
PATE
NTS

2015

Bäckström, Tom; **Pedersen, Christian Fischer;** Fischer, Johannes; Hüttenberger, Matthias; Alfonso, Pino **/ Concept for Encoding of Information.**

Nygaard, Jens Vinge; Perti, Christian / Injectable Hierarchical Scaffolds.
IPC no.: A61L. Patentnumber: PCT/DK2014/050422. dec. 10, 2014.

Nyholm Jørgensen, Rasmus; Steen, Kim Arild; Olesen, Carsten Riis **/ Method for removing animals from a field.**
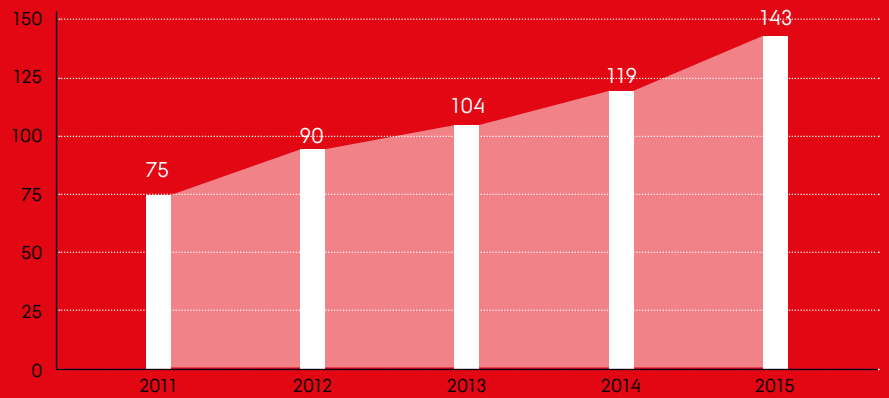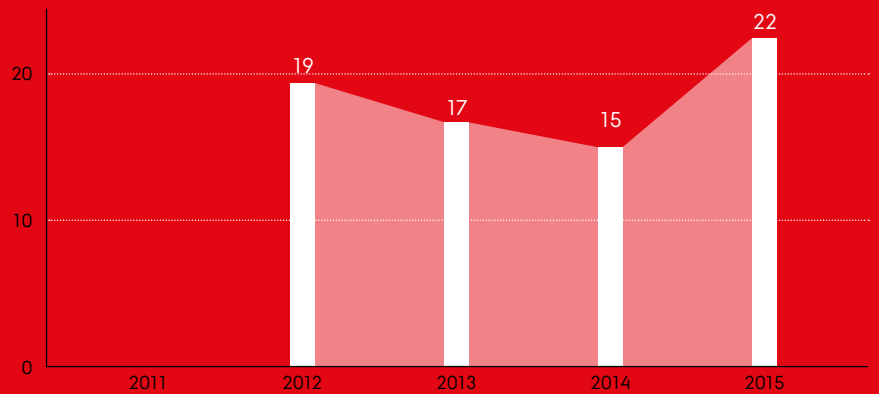Patentnumber: DK2015/050155.
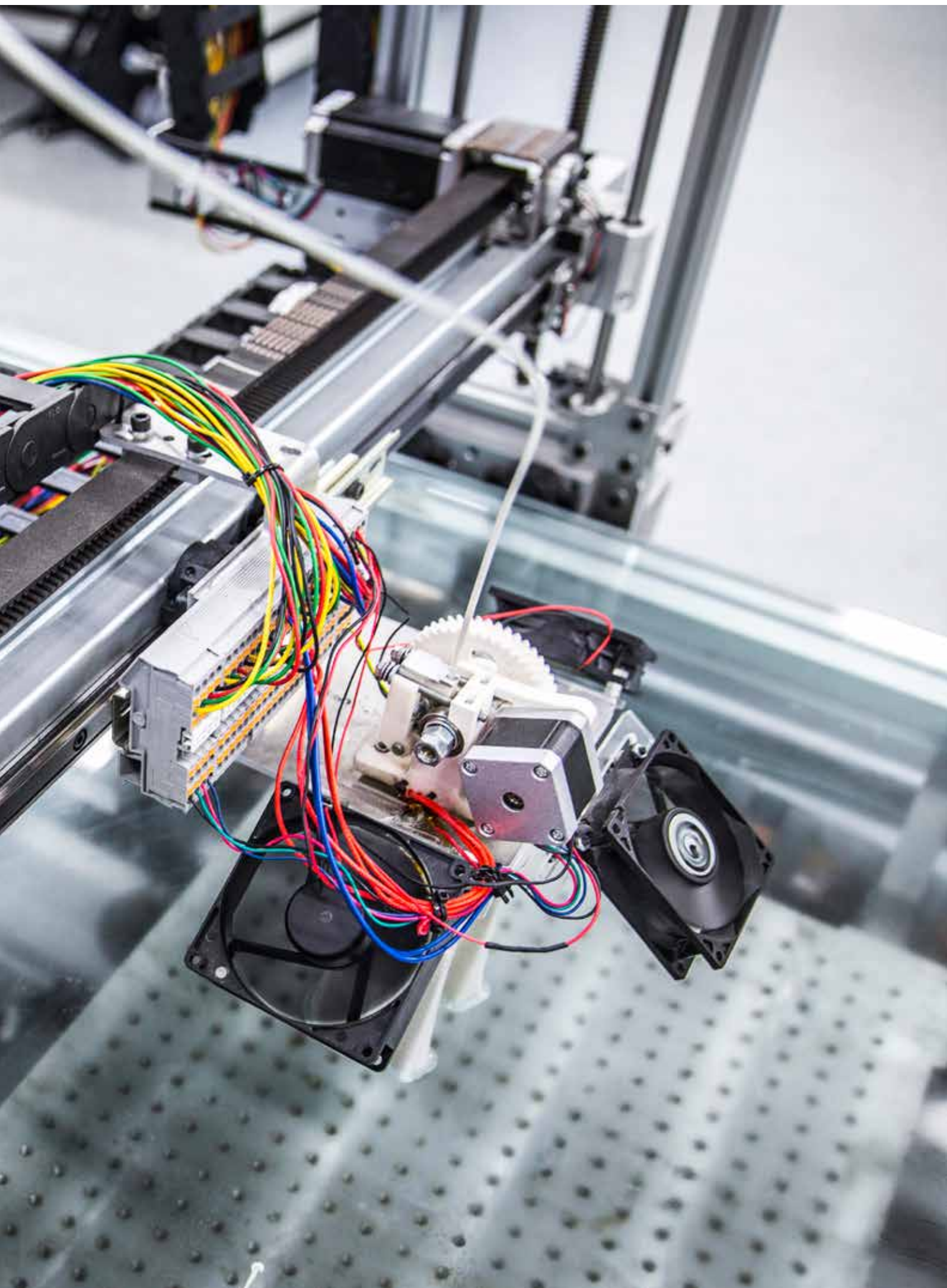
KEY FIGURES

TOTAL ENG TURNOVER (M DKK)
Based on annual FC3 budget

Year	Value
2011	75
2012	90
2013	104
2014	119
2015	143

TOTAL ENG TURNOVER (%)
Increase compared to previous year

Year	Value
2012	19
2013	17
2014	15
2015	22

EXTERNAL FUNDING TOTAL (M DKK)
Based on annual FC3 budget

Year	Value
2011	24,8
2012	29,7
2013	49,0
2014	61,4
2015	71,1

PEER REVIEWED PUBLICATIONS

250
200
150
100
50
0

152 — 2011
175 — 2012
209 — 2013
254 — 2014
256 — 2015
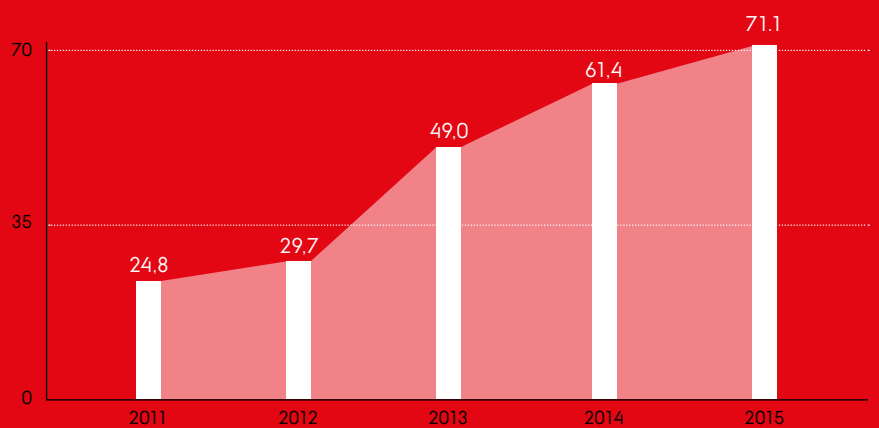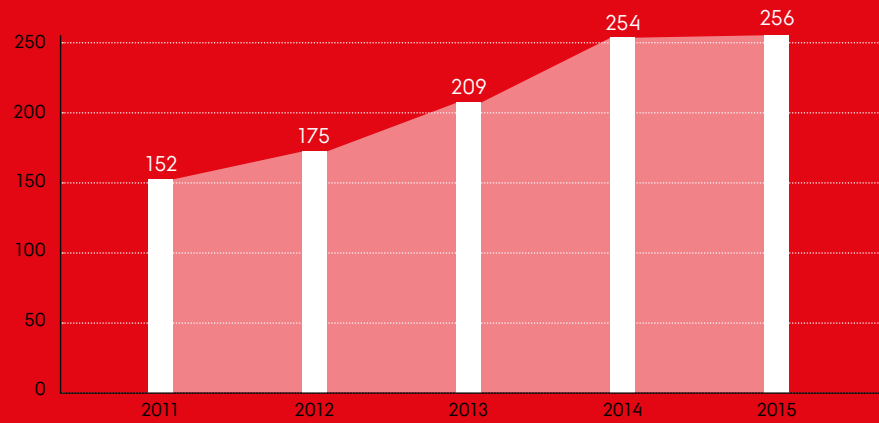
PEER REVIEWED PUBLICATIONS PER VIP

Senior VIP: Professors, Professors (Docent),
Senior Researchers and Associate Professors

6
5
4
3
2
1
0

4,1 — 2011
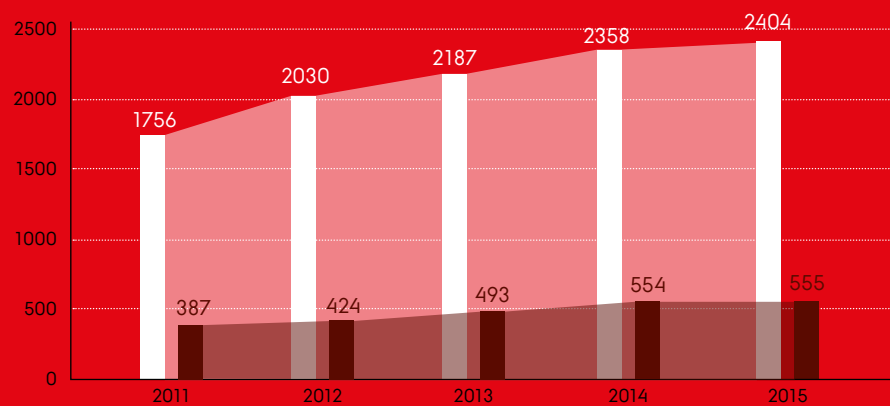4,4 — 2012
5,4 — 2013
5,9 — 2014
5,9 — 2015
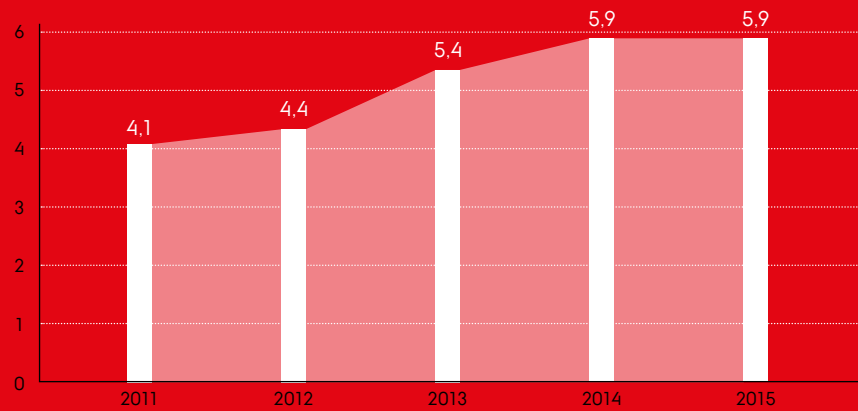
ENGINEERING PHD STUDENTS

60
50
40
30
20
10
0

45 — 2011
46 — 2012
52 — 2013
55 — 2014
60 — 2015
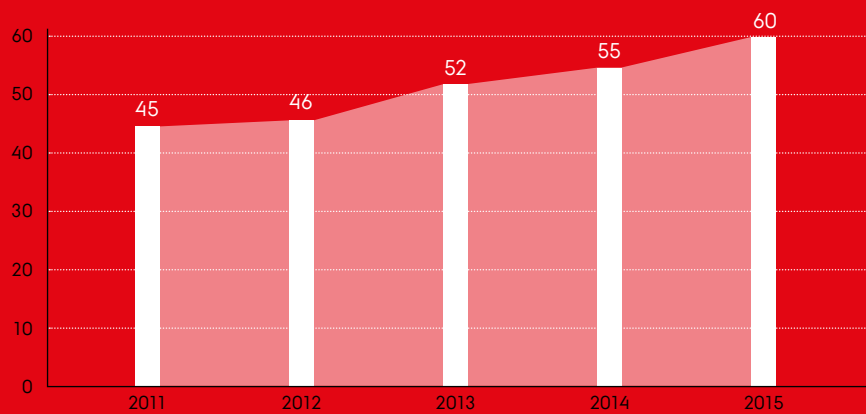
ENROLLED ENGINEERING STUDENTS

■ BACHELOR
■ MASTER

2500
2000
1500
1000
500
0

Bachelor:
1756 — 2011
2030 — 2012
2187 — 2013
2358 — 2014
2404 — 2015

Master:
387 — 2011
424 — 2012
493 — 2013
554 — 2014
555 — 2015

AU Engineering, Campus Navitas, Aarhus

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