DELFT OUTLOOK
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TU Delft

HUUB SAVENIJE
'It's time to call it a day'

NEW SOLUTIONS FOR SEA LEVEL RISE
The New Netherlands

Everything flows
A century of fluid dynamics

THEME
All electric

Coverphoto
'My plan was to photograph the new type of power poles in combination with the old type and a train passing by. But a freshly plowed field and a blue sky is sufficient as a backdrop. Simple is often more beautiful'.
(Photographer Sam Rentmeester)

EDITORIAL

Dorine van Gorp

All electric

Based on what researchers have to say in this issue of Delft Outlook, the Netherlands may well look very different in a couple of decades. We will need all this time to complete the energy transition to fully electrical. Things seem to be going well with the electric car. This month, the ANWB motoring organisation listed more than 40 models in the Netherlands. They are obviously driving around, as charging stations are always occupied. According to scientists, however, going on holiday in an electric aeroplane, being shot through a tunnel tube in the supersonic Hyperloop and electric commercial shipping are still far in the future. One important factor is the shift from fossil fuels to sustainable electricity. There is plenty of good news in this regard, particularly concerning the storage of wind and solar energy.
For example, an on-campus start-up is working on the construction of a water battery that does not involve the use of any acids or chemicals. Other researchers are working on converting electricity into hydrogen, making the power grid more suitable for generating green energy and switching from alternating energy to direct current produced through solar panels.
What can we do ourselves to absorb surplus green energy on sunny, windy days? "Use more energy", says energy expert Kornelis Blok. So if we have a stormy Christmas, feel free to hang another string of lights in the tree.

Dorine van Gorp,
managing editor

PHOTO: SAM RENTMEESTER

Page 07
All electric

04

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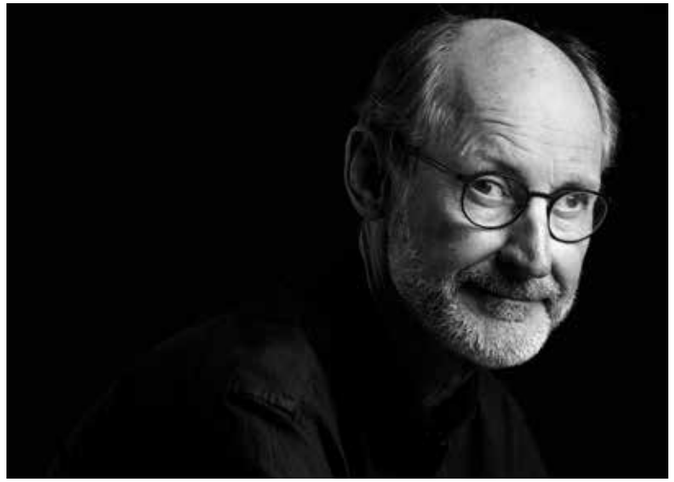
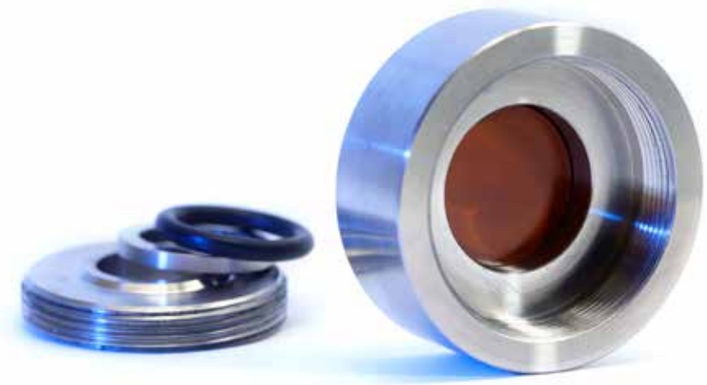


DELFT IN BRIEF

PHOTO: SAM RENTMEESTER

Millions for quantum internet

The European Commission is investing €10 million in a project aimed at outlining the contours of a quantum internet. This blueprint is being developed by the Quantum Internet Alliance, a consortium of European research groups and high-tech companies, led by QuTech of TU Delft. Quantum internet draws upon an intriguing quantum phenomenon to connect the various intersections within the network: entanglement. In this phenomenon, a change in the state of one intersection has a direct influence on the other, without any information being transferred between them. This allows communication that is inherently secure.



Promising membrane

Researchers from the Catalysis Engineering group (Applied Sciences) have developed a new type of membrane that selectively allows hydrogen to pass through. This could have important industrial applications. Hydrogen filters are used in all kinds of primary industrial processes, including hydrogen production and purification, CO_2 capture and more energy-efficient ammonia production – a raw material for artificial fertiliser. The round filter is no larger than a euro. It combines high selectivity for hydrogen with a high level of gas permeability, and it is resistant to industrial pressure and temperature. The membrane allows hydrogen to pass through, while largely blocking carbon dioxide.

Tailgating on the rails

The Dutch railways need a major overhaul, according to the inaugural address of the new Professor of Railways, Rob Goverde (CEG). The relay technology employed on the rails is 100 years old. Prof. Goverde calls for switching to the wireless European communication system ERTMS as quickly as possible. He is currently investigating the virtual coupling of trains. "The idea is to have trains run close behind each other. The vehicle in front leads and determines the speed. This approach is contrary to all principles within the railway sector. To date, trains have always been required to remain at a braking distance behind those in front of them." Given the complexity of the technology that this idea would require, he does not expect it to be achieved before 2050.

PHOTO: SAM RENTMEESTER

Flying weather stations

In order to fly safely, aeroplanes should have access to the most accurate data on wind and temperature. Researchers in Aerospace Engineering have devised a way to provide aircraft with data that are even more accurate: by using the aeroplanes themselves as sensors. The researchers installed an antenna on the roof of the faculty building and used it to intercept the flow of information between aeroplanes and air traffic controllers. Transmissions from aeroplanes include information on their barometric altitude. The researchers can use these data to derive data on ambient air temperature and wind.

Real-time imaging of the carotid artery

Researcher Dr Maysam Shabanimotlagh of the research group for acoustical wavefield imaging (Applied Sciences) has developed a method for visualising blood flow in the carotid artery. He created an 'ultrasound transducer' (transformer) with built-in electronics. What is special about this device is that it can make three-dimensional images in rapid succession (up to 1000 per second), for example to visualise the flow of blood in the carotid artery. This technique could become an important tool for the non-invasive screening of cardiovascular diseases.

Chaise longue becomes bed

A robotic 3D-printed chaise longue that can be transformed into a bed (and back again). This creation can now be seen in the Delft Science Centre. The creators (from the Robotic Building research group within the Faculty of Architecture and the Built Environment) expect that this kind of transformable material will be used in many more applications in construction and interior architecture in the future. Although things like 3D printing, variable rigidity and transformable structures are still relatively new, the researchers are already working on creating objects that can adapt and change depending on the needs of the user. This could be called '4D'.

Scanner goes for the gold

Industrial gold extraction is like searching for a needle in a haystack. On average, a tonne of ore contains one gram of gold. To find it, the ore is crushed into powder and then suspended in a cyanide solution which dissolves the gold. This process is not very efficient. For his doctoral research, Dr Marinus Dalm (CEG) developed a method for distinguishing valuable ore from worthless ore. He uses an infrared scanner to determine the type of ore. Rocks such as pyrite, alunite and rutile have characteristic infrared-absorption spectrums that are indicative of gold deposits. An ore without this kind of fingerprint probably does not contain any gold and can be set aside.

Bacteria in space

If we wish to go to Mars, we need a highly efficient way to convert urine into drinking water. Aboard the ISS, efficiency of 75% is being achieved with filters. According to Dr Ralph Lindeboom (CEG), the efficiency of re-use can be improved with bacteria that break down urea. He sent these organisms into space with a Russian rocket in order to investigate whether they can thrive in weightlessness. As Lindeboom reported in the journal Scientific Reports this autumn, they were still able to multiply just as well after revolving around the earth for a month and a half.

The Netherlands is sinking

A team of researchers headed by Prof. Ramon Hanssen (CEG) have processed three different types of measurement data – satellite radar, GPS and gravity measurements - to create an interactive map (bodemdalingskaart.nl) that shows subsidence in the Netherlands. The map has enabled researchers to distinguish for the first time between the deep causes of subsidence, such as gas extraction, and the effects in the uppermost few metres. It turns out that this 'shallow' subsidence is greater in some places in the Netherlands than the more familiar, deep causes. It is now possible to measure such subsidence, particularly in the peat and clay areas in the western part of the country.

PHOTO: SAM RENTMEESTER

PHOTO: IGEM

Gene doping

TU Delft students have developed a protein that can detect gene doping in the blood of athletes. They presented their idea this autumn during the International Genetically Engineered Machine (iGEM) competition. The protein is a fusion of two smaller proteins. One is part of the CRISPR-Cas family, a family of proteins that can cut and paste with DNA. They programmed this 'dxCas9 protein' to go in search of gene-doping DNA. The other protein adds a sort of bar code, which enables it to be read using 'nanopores', tiny holes through which DNA can be threaded. This produces an electric signal that is specific to doping DNA, and it can be read on a computer screen.

THEME
All Electric

Natural gas extraction in Groningen is being shut down and, in recent months, various climate talks have led to the conclusion that one solution for reducing CO_2 emissions can be found in electricity. The ambition is to add 75 million new solar panels, disconnect homes from natural gas and convert to electric transport. Is it really possible to go all electric?

PHOTO: SAM RENTMEESTER

PHOTO': SAM RENTMEESTER

'We could do perfectly well without nuclear power stations'

Nuclear energy is making a comeback. After TV presenter Arjen Lubach argued for nuclear power stations, the political party VVD jumped on the bandwagon. Prof. Kornelis Blok was incredulous.

People relaxing in the cooling waters of the Borssele nucleair power plant.

Nuclear energy has support in the Netherlands. The IPCC, the United Nations' climate panel, recently concluded in a report that the world should be using nuclear energy if we want to limit the temperature rise to less than 1.5 degrees Celsius in 2050 from 2010 levels. Lubach covered it and the next day VVD Party Chairman Klaas Dijkhoff said on TV that as far as his party is concerned, the Netherlands should build nuclear power stations fast. And a 1Vandaag (television show) opinion poll shows that 53% of the Dutch population are pro nuclear energy. TU Delft energy expert Kornelis Blok (TPM faculty) is watching the debate incredulously.

So why would the VVD now, about a month after the publishing of the IPCC report, start campaigning for nuclear energy?

"What surprises me is that an entertainer says something on TV and that the VVD jumps right in. I have always viewed nuclear energy as one of the many options to limit CO_2 emissions. It may have disadvantages, but it also has advantages. I am neither strongly in favour of it nor against it. However, when people say that we cannot do without it, they are wrong. We can do without it. A couple of months ago I co-authored an article with five colleagues from South Africa, Finland, Germany and Denmark that was published in the journal Renewable and Sustainable Energy Reviews on how this could be done. Our review was a response to a researcher's article in the same journal the year before that explained why he believed that nuclear energy was essential. I don't say that solutions are simple. We know that wind and solar energy are variable, but you can deal with this in all sorts of ways. You could always extend the energy networks so that you can cover energy shortfalls with surplus energy from elsewhere on the continent. People must be encouraged to use more energy, for example to charge vehicles, when it's windy or sunny. And you need storage facilities. You need a back-up that runs on fuel, such as hydrogen, which you can generate from wind and solar energy. The best would be a combination of technologies that varies between countries."

What would you say are the main advantages and disadvantages of nuclear energy?

"The first advantage is, of course, that there are no CO_2 emissions. The disadvantages are two-fold: one, the implications of the radioactive waste material, especially should an incident occur, small as the chance of an incident occurring may be; and two, the chance that the radioactive material or the nuclear technology are used for the manufacture of nuclear weapons. Nuclear power stations are becoming safer. Nuclear units can reuse the nuclear waste, thus reducing the problem of radioactive waste material. The thorium-based reactor which people are working on in Delft is an example of a completely different type of reactor that has far fewer problems. But it will be years before this technology is ready for use."

Nevertheless, people are now saying "bring on those nuclear power stations" – at least if 1Vandaag's opinion poll is to be believed.

"It could be that many people are positive about nuclear power stations, but ask those very same people if they would be happy if a nuclear power station was built a few kilometres from their homes and their enthusiasm suddenly wanes. The climate agreement categorically states that by 2030, 70% of our electricity must be generated from sustainable sources such as sun and wind. Now what you're hearing in certain quarters is "Don't be difficult and just build nuclear power stations instead of wind turbines". But you will see that at least six or seven large nuclear power stations will need to be built. I can tell you now that that'll be very difficult in a densely populated country like the Netherlands. Not to mention that it is hardly even technically possible in the short term."

And is it feasible to build enough wind turbines and solar energy farms?

"If we want to achieve the goal of 70% of the power being generated by renewables by 2030, if we take just wind turbines alone, from 2022 onwards we will have to generate 1 gigawatt of wind energy per year extra. That equates to 100 large turbines built each year. This isn't that difficult to achieve at sea."

Goodbye AC, hello DC

Alternating current is on the way out, so say the TU Delft researchers behind the DC Distribution Smart Grids project.

Funded by the EU's Horizon 2020 programme, Dr Pavol Bauer and Dr Laura Ramirez Elizondo of the DC Systems, Energy Conversion & Storage department (EEMCS) are studying what is required to make sustainable low voltage DC (direct current) grids possible.
"AC voltage is a legacy of the past," Ramirez Elizondo earlier explained to Delta ('From AC to DC: no more adapters'). "All our devices, from laptops to toasters and TVs, use DC voltage. Transformers convert the AC (alternating current) voltage from a power outlet into DC voltage for these devices, while solar panels produce DC voltage too."
Ramirez Elizondo says it is inefficient to convert electricity from DC to AC and back to DC again.
However, there are quite some problems to overcome before we can switch to sustainable low voltage DC grids. For example, the DC grids will need to be more resistant to faults such as short circuits. This is one of the subjects that the TU Delft researchers are working on as part of this EU project. They are also creating algorithms to balance the supply and demand of DC grids, because the introduction of a new electricity supply system will change the way we use energy. Electricity production by solar panels and wind turbines varies strongly and will require clever measures to be used efficiently. The solution could be smart grids, networks in which grid operators, electricity producers and consumers coordinate how they use the grid. TvD

Electric flight still a pipe dream

"Amsterdam to New York by electric plane? Won't happen," says professor Leo Veldhuis. He and researcher Joris Melkert discuss the future of electric flight.

Electric flight is still in its infancy, though it is already possible. "You can already buy a two-seater with which you can fly for an hour," says Joris Melkert. The aircraft is manufactured by the Slovenian firm Pipistrel. TU Delft is partnering with this company in a research project to design a slightly larger model.
But Veldhuis and Melkert say that electric flight will remain impossible for long-haul flights. The energy density of batteries is a factor of 50 or 60 lower than that of kerosene. "This means you need to carry too much weight in batteries; weight that is not used up in flight like kerosene," explains Veldhuis. According to Melkert, this is not set to change any time in the near future: battery efficiency is improving by only 1 to 3% per year.
An intermediate solution is a hybrid-electric version that uses kerosene. "We burn the fuel in a turbine engine and use this to power a generator," says Veldhuis. "The generator powers a number of electric motors distributed throughout the aircraft."
An example is the Airbus E-fan X, which Melkert thinks will fly in 2020. "One of the four engines in this aeroplane is replaced with an electric motor and a number of batteries," he explains.

Airbus approached TU Delft to develop a radically new aircraft concept based on hybrid-electric propulsion. "They want to test it in a fairly large aeroplane, comparable with the A320, which can fly 800 miles carrying 100 passengers," says Veldhuis. This is one of the European projects being carried out as part of the Clean Sky research framework.

Airbus approached TU Delft to develop a radically new aircraft concept based on hybrid-electric propulsion

The aviation industry is responsible for some 2 to 3% of global emissions. Measures such as electric taxi systems and electric on-board systems powered by fuel cells can only reduce emissions by a tiny percentage. "If we really do our best, I estimate that hybrid-electric solutions will lead to about 10 to 15% CO_2 reductions by 2050," says Veldhuis.
The real problem, think both researchers, is the growth of the global aviation sector by some 5% annually. The current rate of innovation can not keep up with that pace. Add to this the fact that a standard aircraft like the Airbus A320 costs about €100 million and has a service life of more than 20 years, and it will be clear why it will take a few generations of aircraft yet before commercial hybrid-electric flight becomes reality.
Veldhuis believes the way forward is to combine various measures. "One: electrify short and medium haul aircraft as much as possible by applying new concepts, new engine integration systems and by using batteries and fuel cells. Two: reduce the number of flights (it's unavoidable!). Three: fly slower; that uses significantly less energy." CvD

Are fully electric ships a utopia?

A motor yacht glides silently and emission-free through the water. The future of electric-powered engines in pleasure craft looks rosy indeed, but the commercial shipping industry is a different matter.

Rinze Geertsma, marine officer and PhD candidate in Maritime & Transport Technology, once participated in a project to build an all-electric ship in Great Britain. The frigate generated all the electrical energy needed to power the vessel and run all the systems on board. "But the electrical systems for this took up so much space in the ship that they have since reverted to hybrid solutions," he explains.

Quicker and quieter

So Geertsma spent the last four years studying alternative ways of reducing emissions. In an age when the commercial availability of batteries and other electrical alternatives is increasing exponentially, he included two new goals alongside emission reductions: with the help of electrical solutions, ships should be able to accelerate more quickly and sail more quietly. Geertsma puts it in layman's terms: "You want the concept of a Toyota Prius combined with the performance of a Tesla."
He began his thesis with literature research and discovered that electrical shipping was already quite common. "Mainly ferries that shuttle between A and B." He thinks the TESO that sails between Den Helder and Texel could be made fully electric. "They have one in Norway, the Ampère, which uses batteries and electric motors. They plug the vessel in as soon as it docks and the batteries are fully charged even before the new passengers are all on board."

A 100% sustainable boat does exist, and it is on the TU Delft campus

However, even this solution is not completely climate neutral. 'Batteries have a limited service life, and you also have to wonder where the energy to charge the batteries comes from.' He compares it with electric driving in the Netherlands. "Most of our energy is not produced from renewable sources, so how green is your electric car actually?" In that respect Norway, that generates 80% of its energy needs with renewable hydropower, is doing better than the Netherlands, where only 14% of electricity is obtained from renewable sources.

An innovative dream team

And yet, a 100% sustainable boat does exist, and it is on the TU Delft campus. It is powered by solar energy and owned by the Solar Boat Dreamteam, a group of enthusiastic students who build a new sustainable version every year. In previous years they sailed through quiet canals and harbours, but this summer they are going to sea, which means the boat will have to undergo a complete metamorphosis. It will need to be able to face waves, strong currents and stormy weather if the three crewmembers are to sail from Monaco to Cannes and back. "We also want to set a world record by crossing the channel from Calais to Dover using only solar energy," says Exposure Manager Redmer Aarnink.
He also hopes that the techniques and innovations conceived by his team will help to make the maritime sector more sustainable. "Although we don't think that a boat covered in solar panels is the solution." He is personally more inclined towards hybrid solutions. "Or an alternative system of shipping," he concludes. "In 2020, the Norwegians will start testing small autonomous boats that carry a single container." This would make many truck journeys superfluous; instead, a boat with container would shuttle between various harbours. "It would be amazing if you could do that on a large scale!" MvdV

PHOTO: SOLAR BOAT TEAM

Supersonic with electricity

High-speed travel will soon no longer only be the domain of kerosene-slurping aeroplanes. The Hyperloop is powered by electricity and promises to transport people and goods at the speed of sound, although it may yet be some time before its becomes a reality.

This spring, TU Delft's Hyperloop team wants to demonstrate that they can exceed 300 kph and hopes to conduct tests in one of the unused railway tunnels nearby Delft central station (two of the four tunnels will not be used by trains in the next few years).

Asja Föllmi of TU Delft's student team explains that "both ProRail and Delft Hyperloop are enthusiastic about this idea, which is currently the subject of a feasibility study". The tunnel section under consideration is about one kilometre long.

The Hyperloop is a conceptual high-speed transport system that uses depressurised tubes to transport magnetically levitating capsules containing passengers or freight. The low air resistance is what makes the system suitable for efficient high-speed travel. At least, that is the plan.

To encourage the development of a working prototype, Elon Musk's SpaceX company organised the Hyperloop Pod Competition. During the last edition of the competition, which was held last July at SpaceX's headquarters in Hawthorne, California, TU Delft's Hyperloop team came in second. The team's Atlas 01 capsule reached a speed of 142 kph. The winner was the WARR Hyperloop built by TU München, which reached an incredible 467 kph. "We want to break that record next year," says Föllmi, "and yes, it would definitely be great if we could use one of the railway tunnels for our tests." TU Delft's capsule 'only' reached a speed of 142 kph during the last competition because the motor overheated. "It gets extremely hot in the Hyperloop in California and our capsule wasn't designed to withstand the high temperatures. This year we will be prepared."

ProRail press officer Coen van Kranenburg informs us that the people at ProRail will do everything they can to make this test site possible. "The Hyperloop is the future of railway transport. It would be excellent publicity if the capsule could be tested in the railway tunnel." TVD

'The Hyperloop is the future of railway transport'

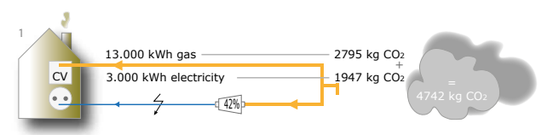
PHOTO: SAM RENTMEESTER

How sustainable is electric heating?

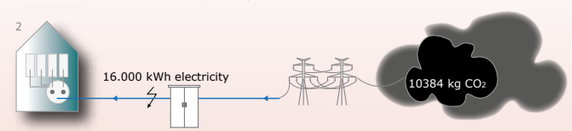
The gas industry is being phased out and the trusty gas boiler will need to be replaced by electric forms of heating. Energy epidemiologist Prof. Laure Itard (Architecture and the Built Environment) calculated the CO_2 emissions. Is electric always sustainable?

"There is still a long way to go to achieve 100% renewable electricity production and much research is required into the best options for replacing gas," says Itard. There are many different options available, she says, such as a district heating network fed with deep geothermal energy, thermal energy storage or residual heat. A user can increase the temperature as required using a heat pump, or maintain a basic temperature in the home and boost it locally with infrared panels. The best option for each case in terms of investment, operating costs and CO_2 emissions is a tricky puzzle, made more complicated by the lack of seasonal storage for heat or electricity. JW

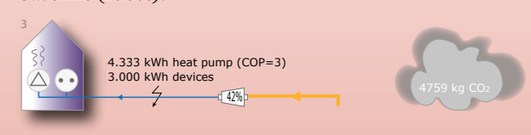
1 The baseline is a modern, fairly well-insulated home of 120 m² with balanced ventilation (ventilation with heat recovery) and a roof of 60 m². If the heat demand is 8000 kWh for heating and 5000 kWh for hot water, and electricity consumption is 3000 kWh, the total emissions amount to 4742 kg of CO_2 per year (see baseline figures).



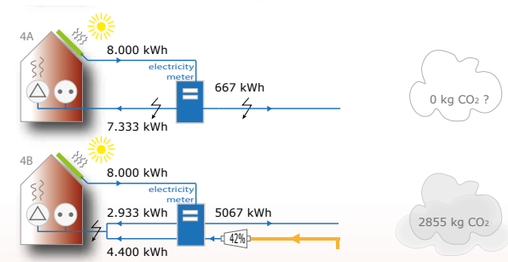
2 We install a gasless system with electric heaters and boilers. Electricity consumption increases to 16,000 kWh, equivalent to 16,000 x 0.649 (average emissions of the Dutch energy mix) = 10,384 kg of CO_2 per year, more than double the baseline (219%).



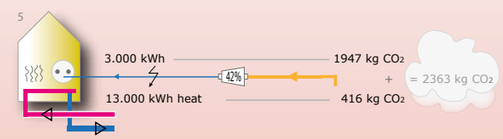
3 We purchase an (expensive) heat pump with a coefficient of performance (COP) of 3, decreasing the electricity demand for heating and hot water by a factor of 3 (4333 kWh). Total electricity consumption is then 7333 kWh, equivalent to 4759 kg of CO_2 per year and approximately equal to the baseline (100%).



4 We install solar panels too. The total production is 8000 kWh per year, of which 7333 is used by the household and 667 kWh is fed back to the grid. Is the home now CO_2 free? Unfortunately not. The mismatch between summer production and winter consumption means that about 40% of the electricity is obtained from the sun and 60% from the grid. In this case this is 0.6 x 7333 = 4400 kWh, equivalent to 2855 kg of CO_2 per year (62%).



5 We are hooked up to a district heating network. Because this is waste heat, the CO_2 emissions are low: 0.032 kg/kWh. The electricity consumption is 3000 kWh, equivalent to 1947 kg of CO_2, so a total of 2363 kg of CO_2 emissions (50%).



Baseline figures: 1 kWh gas = 0.113 m3; 1 kWh gas = 0.215 kg of CO_2; 1 kWh of electricity = 0.649 kg of CO_2; electricity generation efficiency = 0.42. The proportion of renewable energy is 6.6% in the Dutch energy mix. Waste heat produces 0.023 kg of CO_2 per kWh.

Battery Lab improves batteries

Increasing use of electric cars, e-bikes and green power means the demand for better batteries is growing. Some 20 people are working on the batteries of tomorrow in the TU Delft Battery Lab.

The new Battery Lab opened its doors in TU Delft's Reactor Institute last spring. Applied Sciences researchers Dr Erik Kelder and Dr Marnix Wagemaker and their teams are working on the next generations of batteries: from cheap static storage of renewable energy to compact and lightweight batteries for electric vehicles and electronics.
The laboratories are equipped to facilitate all phases of battery making and testing. In addition to Li-ion batteries, the Battery Lab is also testing Na-ion batteries (for cheap mass storage) and solid Li-ion batteries (leak-free and safe).

Fume cupboards are used to build batteries in oxygen and moisture-free conditions using electro-spray techniques. The testing room has sufficient capacity to test 150 batteries simultaneously. Frans Ooms is pleased to have all the facilities under one roof now, because he says it facilitates standardisation and hence also the quality of the research.
The researchers closely follow the paths of ions through the electrodes and the electrolytic medium using neutron diffraction, NMR (nuclear magnetic resonance) electron microscopy and many other techniques. They can also follow the ageing process of electrodes.

The Battery Lab also conducts computer simulations to test battery components at the atomic scale. Other techniques are applied to scale the results up to the electrode level. Wagemaker is happy with the new lab: "The lab has been enlarged and offers even more possibilities for research. All of the lab facilities are now located together in one central place.

The Battery Lab is also testing Na-ion batteries, for cheap mass storage

It can also be combined with the RID's unique infrastructure, including neutron depth profiling, neutron diffraction and solid state NMR. This will enable us to better understand the complex battery processes, so that we can develop better batteries." JW


PHOTO: SAM RENTMEESTER

Dr Erik Kelder and Dr Marnix Wagemaker are working on the next generations of batteries.

Environmentally friendly battery


PHOTO: RAYMOND RUTTING

In a corner of the campus Green Village is a green hut containing 20 drums of water: this is the AquaBattery pilot project. The water battery stores electricity in saline and fresh water and is connected to the five adjoining student apartments.

The campus water battery by AquaBattery, a start-up, is the most environmentally friendly battery conceivable. The BlueBattery, as the company calls it, uses no acid, chemicals or metal, but only saline and fresh water and an active membrane that only allows salt ions to pass through, and not water.
The idea for the water battery was inspired by a demo model for the production of electricity from a combination of sea water and fresh water set up on the Afsluitdijk causeway. The water battery applies the reverse process (electrodialysis). Salt ions are removed from the brackish (half salty, half fresh) water by passing electrical load through the membrane. The result is an extremely saline solution on one side of the membrane and fresh water on the other. If you place another suitable membrane between these two liquids, electricity will start to flow again.
The water battery does have disadvantages, such as its size. Two cubic metres is required for the storage of 1 kWh, which is more than 100 times the volume of a lead battery, but the water battery does have a similar efficiency (70%). The membranes take up quite some space too: one cubic metre of membrane is required for 1 kW of power. With the support of membrane manufacturer Fujifilm and grid operator Enexis, development is now focusing on reducing the volume by a factor of ten. The water battery has advantages too: the concept is easy to scale up or down for the required storage capacity and power.
Moreover, the size of the device is less of a hindrance in built environments; AquaBattery sees opportunities for the storage of solar energy by consumers if the feed-in tariff is lowered, or even better, a water battery as a neighbourhood buffer. JW

How the Blue Battery works

Soon everything will be electric and power will increasingly be obtained from variable sources such as sun and wind. That's why we need gigantic batteries to stabilise the power grid.

This is the idea that inspired the Maastricht entrepreneur Dr Jan Huynen (86) to get a PhD. More than 30 years ago, Huynen was involved in Limburg in plans for an underground pump accumulation plant (O-PAC). The design of this 'blue battery' (not to be confused with the BlueBattery of AquaBattery) involved a combination of a lake on the surface and an underground basin, connected by downpipes and with pumps that would also serve as generators. When there was a power surplus, water would be pumped up, and during shortages it would pour down 1400 metres to power the generators. Many years later, he decided to continue the development of this concept of an underground water reservoir.

The design of this 'blue battery' involved a combination of a lake on the surface and an underground basin

The share of green electricity in the Netherlands is expected to grow from 8% today to 63% in 2030. This means we will require huge electricity buffers that can quickly switch between storage and supply. Huynens' design is based on an electrical capacity of 1400 MW (comparable to a large power plant) and storage capacity for six hours. He estimates the construction costs at €1.8 billion. Huynens' promotors, professor emeritus at TU Delft Han Vrijling and professor Gert Jan Kramer (Utrecht University) agree that such a buffer is necessary. "The Netherlands has insufficient storage capacity if it doesn't want to rely on fossil fuel plants," says Kramer. "The necessity and technical and economic feasibility of this idea have been proven. Now it is time to take the next step and implement it in a joint partnership between the industry, the government and the business community," Vrijling adds. JW

Blue Battery for Green Energy, Delft Academic Press, €25.

How to make liquid electricity

It is a cruel irony that renewable energy is abundant in the summer and scarce in cold and dark winters. TU Delft researchers think they can solve the problem by converting electric energy into fuel.

TU Delft is a partner in the Power to Ammonia research programme, whereby surplus green electricity is converted to ammonia whose uses include fuel for the Nuon plant in Eemshaven.
Nuon is interested in CO_2-free fuel and in seasonal electricity storage, because this could enable their gas-fired power plants in Eemshaven to play a role in a future where electricity is 100% renewable and CO_2 free.
The principle involves using green electricity to split water through hydrolysis, which results in hydrogen and oxygen. Hydrogen can be mixed with nitrogen extracted from the air (the atmosphere contains 78% nitrogen) and converted into ammonia (NH3) under high pressure and temperature. Unlike hydrogen gas, ammonia can be stored in liquid form in large tanks. It has a high energy density (half that of diesel) and is clean burning; if a suitable catalyst and a small amount of oxygen are used, only water vapour and nitrogen will be released.

Electrochemical production

Professor of Energy Materials Fokko Mulder (Faculty of Applied Sciences) is searching for an alternative way to produce ammonia. Ammonia is traditionally formed using the Haber-Bosch process, which functions fine if applied at a large scale in a continuous process. "But in a sustainable future," explains Mulder, "the electricity supply will be variable and sourced from 10 MW solar farms or wind turbines. This will require more flexible and possibly also smaller-scale ammonia production, which is why we are working on electrochemical ammonia production. One possible route involves combining hydrogen and nitrogen electrochemically into ammonia in a reactor. An alternative is to convert water and nitrogen into oxygen and ammonia. The latter would actually be more elegant, because no hydrogen is formed as an intermediate product. The Netherlands Organisation for Scientific Research NWO/TTW is currently funding the development of an electrochemical cell and the corresponding electrodes, membranes and electrolytes. Many research groups are working on this around the world, producing ammonia electrochemically remains a challenge. The response time and selectivity are proving difficult, and the pilot plants are still very small-scale."

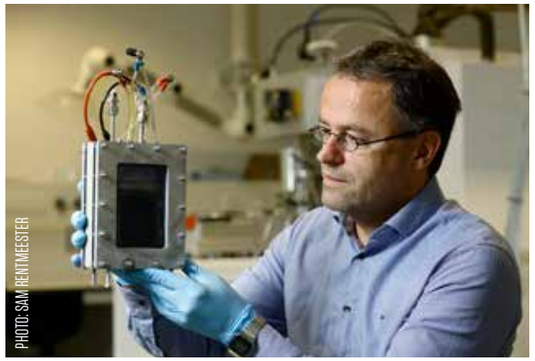


PHOTO: SAM RENTMEESTER

Professor Fokko Mulder shows the first version of the Battolyser, a a combined nickel-iron battery and electrolyser that first charges and then produces hydrogen.

The Battolyser is suitable for both short-term and seasonal storage of electricity

Battolyser

Another invention conceived by Mulder's research group, the Battolyser, could be the solution to increase hydrogen production and reduce costs. The Battolyser is a combined nickel-iron battery and electrolyser that first charges and then produces hydrogen. This means that, in principle, the device is suitable for both short-term and seasonal storage of electricity. The battery function improves the business model by helping to cover the total cost of electricity storage and so reduce the cost price of green hydrogen. Volatile and flammable hydrogen gas is the enemy of battery makers, but in electrolysis it is actually the intention to produce as much as possible. Mulder's research group studied the efficiency of water splitting in a nickel-iron battery and found it to be more than 80%. To date however, hydrogen production has always been seen as a disadvantage rather than an opportunity.
A number of PhD students working on various projects hope to present their results in 2021. JW

View

Professor Peter Palensky (intelligent electrical power grids) fathoms the consequences of increasing demand and simultaneous out phasing of conventional power generation for the power grid. "That's a big ... challenge."

"The grid itself is experiencing a lot of changes on all edges and of course it has to catch up, it has to respond and change, because as it was the last hundred years, that is over. There are many new aspects, mainly due to our decarbonisation efforts and all the renewables such as wind and solar. The common aspect is that they are varying.
The dynamics that we had in the grid in the past was dominated by big rotating machines, and these are phased out now. These machines were the reason that everything was fine, thanks to their mass and inertia they were swallowing every problem, they were keeping everything stable. Everybody relies on that inertia, even the renewables. They feed in, but they can only feed in because there is still enough inertia out there. The moment you have more and more renewables and less and less inertia, we have to change things.
So researchers are now very busy in designing new controls, new protection and new principles that work with less and less and less inertia. Up to the extreme case of only power electronics in the grid.
The scenario of 100% varying renewables is calculated by different countries to see how much storage they would need if all our conventional generation units would be replaced by green ones, and if we assume that there will be two weeks cold winter days, cloudy, and no wind. This is the worst-case scenario that people usually take, and it's several up to dozens of terawatthours of storage that you need, depending on the size of your country. The point is, this is a lot of energy. And no matter how you store it, it's massive. If this energy jumps out of its storage ... it's extremely dangerous. You cannot fool physics. It's energy and if you don't have it properly contained, and it gets loose, it will wreck.
But there are some storage types that we are good in, that we are experienced with. Currently, also in the Netherlands, hydrogen is a big topic. There are new, big hydrolysers in megawatt scale where you take wind power from somewhere and produce hydrogen, store it, in some form of gas in a cavern underground. The storage of caverns can reach terawatthour scale. This kind of storage is of national magnitude, they can buffer for an entire country over seasons. You produce in summer and you use in the winter.
That's one direction; the other direction is storage on substation level and on household level. That also makes sense, mainly in preventing capacity problems. I mean transport electrification and heat pumps alone would need a factor three in our distribution grids in upgrades. Not only is that very expensive, it would also mean extensive cable works in our crowded cities - forget it! So that's a big ... challenge.
You'll need more intelligence in the grid and distributed storage. It will be a puzzle of different principles and technologies to modernise the grid." JW


PHOTO: SAM RENTMEESTER

‘It’s time to call it a day’

Why does the Netherlands excel at water management? It is not because of the polders, but because of centuries of work by Dutch engineers all over the globe. Time for a retrospective with departing hydrologist Huub Savenije.

TEXT JOS WASSINK PHOTOS SAM RENTMEESTER

The Professor of Hydrology (Faculty of Civil Engineering and Geosciences) took his leave from TU Delft on 28 September. The day before was spent with 20 of the 35 PhD candidates he supervised over the years. They have flown over especially from Africa, Asia and South America. It is a fitting farewell for a man who's field of research has always been outside the Netherlands. 'The hydrology of the Netherlands is actually not very interesting,' he thinks. 'As Louis XIV remarked: the Netherlands is made of deposits from the French rivers. And it's true! But the French rivers them-selves are much more interesting, as are the higher stretches of the Rhine.'

Your farewell speech, 'Did everything fall somewhere else?' sounds like a reference to your inaugural address in 2005: 'Most falls somewhere else'. What is your message?
"I used the falling somewhere else as a metaphor for the problem with hydrology. We conduct microscale measurements and are supposed to explain them at the macro scale. But it's also a metaphor for research that often goes wrong. I mean to say: not every shot hits its target. In fact, I am convinced that you need to miss your target many times before you can hit it."

How does missing your target help you to hit it?
"I believe you only get breakthroughs if you go off the beaten track. Of course you can stay on that track – together with all the competition – because everybody does that. Breakthroughs are only found on unbeaten paths, but sometimes the paths are dead ends."

Doesn't that contradict NWO's research policy, that most calls to mind 'research on de-mand'?
"That's exactly my point. NWO (Netherlands Organisation for Scientific Research) and European grant programmes expect you to submit a high-risk proposal, but the assessors subsequently question the feasibility of the idea and whether it harmonises with existing research. That forces you to stick to the beaten paths. Such research is also easier to publish. Colleagues are interested in the tiniest improvement on what we already know, especially if they are cited in the references! But if you do something new, they think: 'What is he up to?' Or: 'What does he know about my field?'"

From his start in 1978, Savenije studied the penetration of salty seawater in open river mouths. These estuaries are rich ecosystems, fertile fishing grounds and key agricultural areas (as long as the salt does not infiltrate too far). Inspired by the colourful stories he heard about Africa and Asia from his former tutor, professor Adriaan Volker, the young engineer Savenije headed to Mozambique in the 1970s to study salt penetration in estuaries.

How did you go about doing your research in the estuaries of Mozambique?
"Without any literature or means of communication, I set down to puzzling it out myself. I started conducting measurements. I initially thought it was all very complicated – that's what I had learned in the lecture theatre – but in my measurements I discovered a remarkable simplicity. It was really quite easy to describe the salt penetration mathematically. It took me years, of course, but I discovered analytical equations I could use to describe salt penetration in simple terms. I went on to apply my findings in four estuaries in Mozambique. After that I worked with a consultant and travelled all over the world, and the theory worked everywhere."

'Holists like me examine the behaviour of the whole system'

Savenije became known as an internationally active researcher with an eye for overarching patterns and international cooperation. He was awarded a PhD for his formulas for salt penetration in estuaries in 1992. But he continued to wonder how it was possible that the outcome of such complex three-dimensional flows, involving salt and water in a multi-branched pattern of cur-rents, was apparently so easy to describe with a few simple formulas. He found the key to this puzzle only a few years ago, when he started to notice a parallel between river basins, the circulatory system and the veins in a leaf: nature always finds the most efficient path.

Can you explain more about the veined structure of river basins?
'You see, there are two different approaches. Reductionists divide the world into little pieces and apply their balance equations to them.
Holists like me examine the behaviour of the whole system. We assume that a system is more than the sum of its parts. I discovered that a river ba-sin forms patterns, like the veins in a leaf. When water flows through a leaf you can see a pat-tern in the veins, and the same applies to water that flows through a human body. My veins and your veins are not the same, but they display the same pattern. The pattern determines how the blood flows such that every cell in your body gets enough oxygen with every beat of your heart. Suddenly it becomes simple."

Do you see the same pattern in hydrology?
"My observations suggest simplicity, but the basic equations show that it's complex. So how do you reconcile the two? I have thought much about this, and I think that it is related to the second law of thermodynamics (increasing entropy in an isolated system, ed.). This is a very important law that describes how everything has a direction; that we grow older, and not younger. The law also limits the efficiency of processes, because even if the energy remains constant, the en-tropy will increase, which means some of that energy is released as heat. When I speak of pat-terns, I am essentially referring to efficiency. The pattern of your veins is a very efficient way of getting oxygen to your cells. A river basin with a leaf-like vein pattern is a very efficient way of draining off water."

Did idealism drive you to seek out far-off countries, or was it a lust for adventure?
"It was more than that. Why does the Netherlands excel at water management? It is not because of our polders, but because Dutch engineers have always worked all over the globe. Our colonial past has brought us experience of complex and untamed systems, with cyclones, extreme downpours and raging rivers. I was taught by people like professor Adriaan Volker, who worked in the Dutch East Indies. Our fame is based on our knowledge of the world, not just the Netherlands."

'The Netherlands excels at water management because Dutch engineers have always worked all over the globe'

You helped to establish the TU Delft Global Initiative. Was that because of your conviction that Dutch engineers understand the world?
"Cooperating with developing countries not only serves a humanitarian goal, it's also good for the Netherlands. Such relationships are important for us. Everybody is talking about climate change, so we need to learn from countries that already have our future climate. Our storms will become more intense. If you want to understand this, you need to go to the countries where cyclones occur regularly. The science of hydrology involves finding solutions for the problems of tomorrow by studying how systems work. The Netherlands is too small for that."

Savenije talks quickly and passionately. He pauses to take a call from Vietnam; 'Excuse me, I have to take this call.'

It is difficult to imagine that you will be retiring.
"Everybody says that, but it's a fact. I have spent the last five years bringing everything togeth-er, and the last two years completing unfinished business; I'm satisfied I can leave it now. I am still supervising a few PhD students, but I'm old and no longer need to be in the vanguard. It's time to call it a day."

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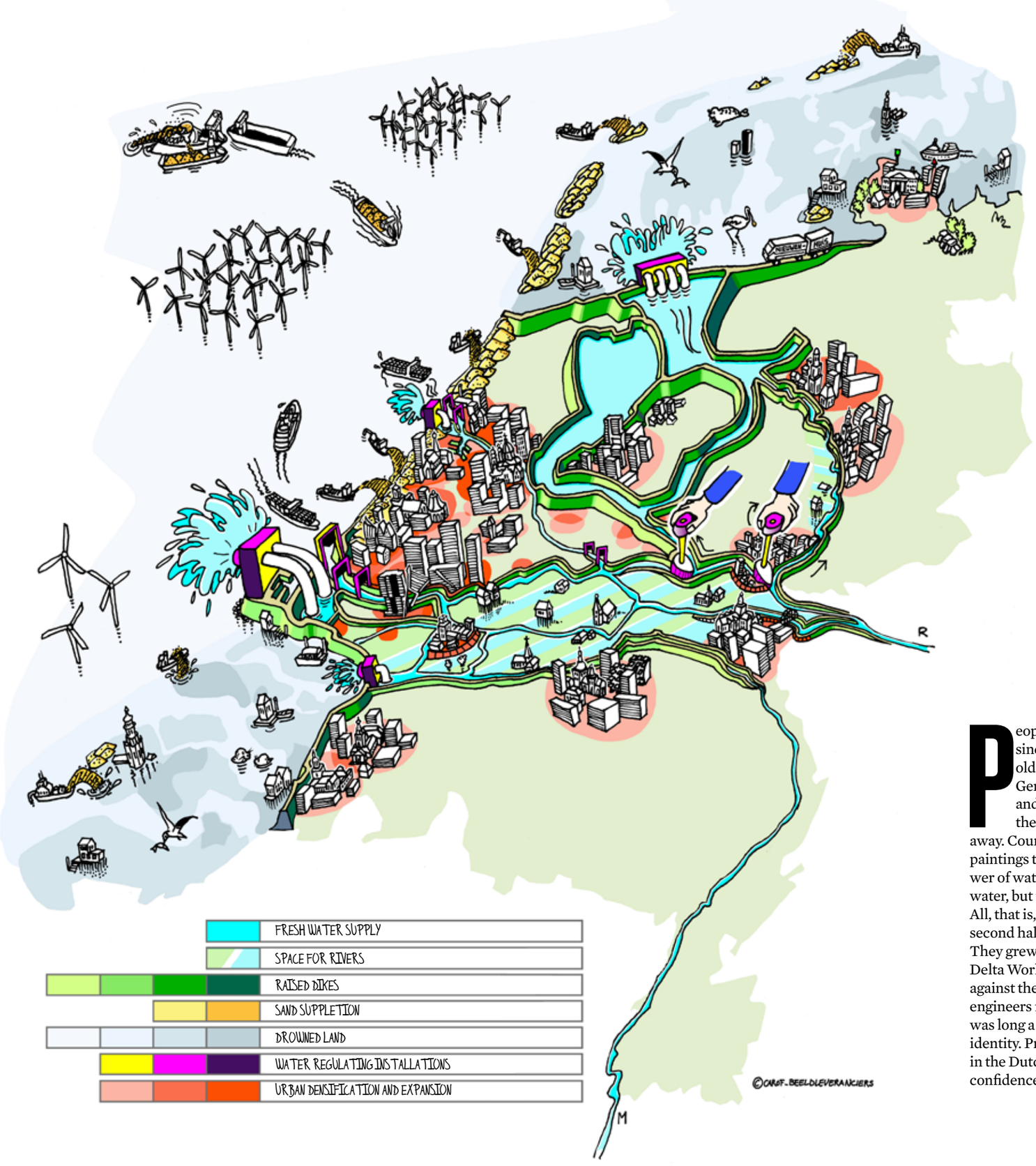
CV
Professor of hydrology Huub Savenije joined the Faculty of Civil Engineering and Geosciences in 1998 where he led the Water Resource Management research group. He graduated from TU Delft in 1977, and went on to work in Africa and Asia, returning to Delft in 1990 to complete his doctoral thesis (1992). Two years later he was appointed professor at Unesco-IHE in Delft, and in 1998 he was made a professor at TU Delft. He served as editor-in-chief of the journal Hydrology and Earth System Sciences (HESS) that became an open access resource in 2005. Last year, the American Geophysical Union (AGU) gave him the International Award for his contribution to the field and his scientific work for developing countries. Savenije has been succeeded by Dr Hessel Winsemius, formerly of Deltares.



The New Netherlands

The sea level may well be rising much faster than scenarios suggest. If this is so, the current measures will be inadequate to keep our feet dry. Is it time for radical new plans?

TEXT: JOS WASSINK ILLUSTRATION: CAROF BEELDLEVERANCIERS

People have been afraid of floods since time immemorial. The oldest stories are to be found in Genesis and relate how Noah and his ark were saved while the rest of creation was swept away. Countless writings, etchings and paintings testify to the destructive power of water. People learnt to live with water, but they remained wary of it. All, that is, except the Dutch in the second half of the twentieth century. They grew up in safety behind their Delta Works, a monumental barrier against the sea that drew hydrological engineers from all over the world and was long a source of Dutch pride and identity. Problems with floods? Call in the Dutch. They'll fix it! Today this confidence is starting to crumble, and the age-old fear of flooding is trickling back.

Sea level rise accelerating

"When I started researching the effects of climate change in 1990, we thought I was studying a scenario that lay far in the future. Today we have realised that the sea level may be rising much faster than we thought and that drastic measures may need to be taken as early as 2050. My children will be just as old as I am now then." The speaker is Dr Marjolijn Haasnoot, climate and water researcher at Deltares and Utrecht University. She is the lead author of a report entitled 'Potential effects of accelerated sea level rise on the Delta programme' (Deltares, September 2018). The first sentence says it all: "The sea level could rise much faster than was assumed up to now in the Delta programme." The reason for this is the recent discovery that the land ice on the South Pole is also melting; up to now, it was assumed that climate change

'We may have to take drastic measures as early as 2050'

barely manifested on Antarctica. Now it turns out that the glaciers there are being undermined by warm sea water, causing them to retreat. On top of this, it seems unlikely that the temperature increase will be limited to 2 degrees by the end of the current century. In

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the best-case scenario, if all countries comply with the international agreements, the temperature will rise by 3 degrees, and otherwise even more. The current Delta scenarios all assume a maximum sea level rise of 1 metre by the end of the century (compared to 1995). According to Haasnoot and her colleagues, however, this could be 2 to 3 metres by 2100 (increase of 4 degrees); and even 5 to 8 metres by 2200, warns Deltares. What does this mean for the Delta programme?

System failure

"We studied the effects of a rise of 2 metres on the Delta programme," explains Professor of Hydraulic Engineering Bas Jonkman. "That seemed reasonably manageable without major changes to the system. More sand on the coast, stronger dikes, close the storm surge barriers more often; we estimated it would cost €1 billion per year, which is doable."
But if the water rises even higher, the system will fail. For a rise of 1.2 metres, it will be more effective to replace the Maeslant Barrier with a lock, and above 2.1 metres the Oosterschelde Dam will have to be closed permanently, Deltares has calculated. Technical solutions are available, but it will be extremely expensive and the risks of failure high. Salt water will penetrate the groundwater system and all river water will need to be actively pumped away.

Radical approach

A radically different approach will be required above a 2-metre rise, and that is exactly what Geert van der Meulen presented in his thesis entitled 'New Netherlands'. He sketched a fascinating picture of a new 'Little Netherlands'. In his design, the northern town of Den Helder has become an island and Assen is a seaport. The new Afsluitdijk causeway runs from Medemblik to Lemmer. All the land above is part of the New Wadden Sea. To the southwest, the islands of Zeeland have been replaced by a huge nature reserve. The 'Green Heart of Holland' has been completely built over to provide homes for 1.7 million Dutch climate refugees. Half of the Netherlands is surrounded by high dikes and densely populated, the other half is wetland.

Half of the Netherlands is surrounded by high dikes and densely populated, the other half is wetland

Van der Meulen explains that he emulated landscape architect Prof. Dirk Sijmons in that he tried to find where the essential backbone of the country is, and where there is leeway. Which areas with natural, urban, industrial or other heritage do you need to protect and which can you abandon in order to better protect the rest?

His New Netherlands is a starting point from which to reconsider the current Delta programme, says Van der Meulen. "Normally, drastic measures are only taken after a disaster. But sea level rise is a disaster that we know is waiting to happen. There is no need for us to be taken by surprise."
Haasnoot recommends monitoring the land ice on Greenland and the South Pole and developing calculation models to predict sea level rise more accurately. Bas Jonkman is keen to establish a design studio together with the faculties of Technology, Policy and Management (TPM) and Architecture and the Built Environment to conceive designs for a New Netherlands. He believes that solutions can be found for a sea level rise of up to 10 metres. After that it will be time to evacuate. As Johan van Veen, the father of the Delta plan predicted: "One day with a sigh of relief we will give up this country to the waves." <<

THE FIRM

In 2009, Rinke van Remortel won a design competition with his Dopper sustainable water bottle. Seven years later, his efforts have enabled to him to leave his full-time job and focus all his energy on his design company.

"When I entered my design, I thought my chances of winning were quite high," reminisces Rinke van Remortel. The challenge was to design a reusable bottle for tap water. When the competition was announced he was still working as a product designer for VDL Hapro, a company that makes car roof boxes and tanning beds. Van Remortel designed the now-familiar bottle with the cap that doubles as a cup.
But he never expected the bottle to be such a huge success. "To start with we just hoped we'd be able to recoup our costs," he laughs. "That meant selling 200,000 bottles; we've now reached 7 million." When sales continued to rise, Dopper decided to buy out all the rights to the product. "I didn't get any royalties, but I was well rewarded."
Even as a student he dreamed of starting his own business. "The thought kept niggling at me even after I got a full-time job. Thanks to the Dopper rights, I now had enough seed capital to make the dream come true; 'If I don't do it now, I never will,' I thought to myself." And so he did. In 2016, he handed in his resignation and started working full time for his own business, with Dopper as his calling card.
Being his own boss has made Van Remortel's work a lot more interesting. "I can now manage every step of the production process myself, if the customer so wishes, from market research, design sketches and prototype development to optimising production. The broad schooling I received at TU Delft means I can take care of all these aspects." His favourite part of the process is concept development. "What I enjoy most is conceiving new ideas – like the Dopper."

Photo: Sam Rentmeester

Company:	Remortel
Established:	2016
Degree programme:	Industrial Design Engineering
Number of employees:	Himself and one trainee
Mission:	To design products that make it easy for people to contribute to a more sustainable society
Turnover:	"It's a one-person business, so turnover fluctuates"
Target group:	Mainly SMEs that produce consumer products
In five years' time:	A team of people working for the company and an own label

'What I enjoy most is conceiving new ideas'

One of his most recent projects was for Zsilt, a Dutch start-up that produces beach toys from sustainable materials. Van Remortel designed the first range of seven products that will hit the market next year. "This start-up wants to produce sustainable toys. Thanks to Dopper they found their way to me."
He has always been interested in sustainability. "I think it happens automatically if you're a designer. You see so many superfluous or environmentally unfriendly products being dumped on the market for low prices." That has to stop, thinks Remortel. "It can only lead to pollution in the long term. That's why I want my company to focus on sustainable and high-quality products."
MvdP

It would be no exaggeration to call the imposing orange and blue tower of Electrical Engineering, Mathematics and Computer Science a landmark. The 90-metre high building is a symbol of the university in the city. But for how much longer? The Executive Board would like to demolish the municipal listed building.

Opened in 1969, the building originally housed only the department of Electrical Engineering. Almost 50 years after the opening the tower is at the end of its useful lifespan. According to the university, the building no longer meets the demands and desires of education and research, even after an extensive and costly renovation.

The university is currently investigating demolition and developing new construction plans for teaching rooms and the Department of Electrical Engineering, in the car park behind the building. This will be followed by new construction for Mathematics and Computer Science, as well as the Else Kooi Laboratory. Buildings for teaching, research and food and drink outlets are planned for behind the current building.

Stichting Docomomo Netherlands, a working group for the preservation of modern heritage, is opposed to demolition, and it started a petition last year, which has now been signed by 854 people.

Architects:
- Van Bruggen
- Drexhage
- Sterkenburg
- Bodon

First pile:
1962

Floors:
23

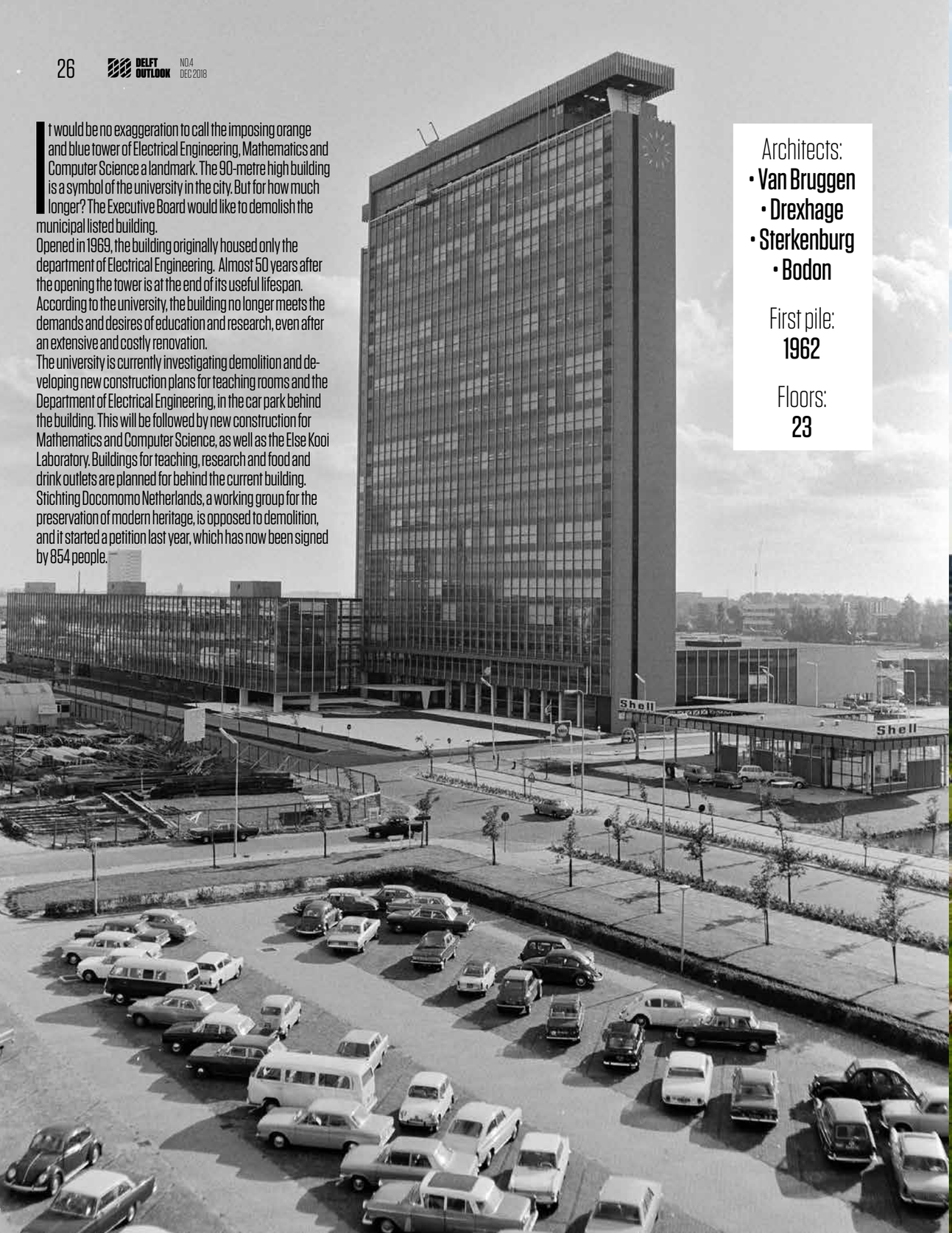

Photo: Sam Rentmeester

Waves on flowing water focus striking laser light in illuminated tracks. PhD student Mike van Meerkerk investigates the occurrence of instability on a water surface, using a standing wave of water that flows from right to left over an obstacle.

TU Delft celebrates a century of fluid dynamics

One hundred years ago, Jan Burgers was appointed professor of fluid dynamics at Delft. Professor Jerry Westerweel looks back on this field and three young researchers look ahead.

TEXT: JOS WASSINK, GIULIO DACOME PHOTO'S: SAM RENTMEESTER

The nice thing about fluid dynamics is that it all takes place at a human scale; water flows under a bridge, clouds glide through the air, and when it rains you get wet.

People like Jerry Westerweel, who is a professor of fluid mechanics, see fluid dynamics everywhere around them: in turbulence, blood circulation, pollution or wind turbines. Everything flows. If you want to see the world through the eyes of an expert in fluid dynamics, the FYFD website has an endless supply of mesmerising footage of falling drops of water, quadruple rainbows, spontaneous avalanches or bats in flight.

A century ago, professors C.B. Biezeno and C.P. Holst decided that the mechanical and maritime engineering department needed a new lecturer who could lay a theoretical foundation for a better understanding of fluid dynamics. Leiden University professor Paul Ehrenfest, alerted his former doctoral candidate Dr J.M. (Jan) Burgers to the vacancy. Back then, Burgers was working on atomic theory for the legendary professor Henrik Lorentz, but he started to wonder if this field was really his destiny.

> Fluid dynamics are everywhere; in turblucence, blood circulation, or wind turbines. Everything flows

Burgers started work at TU Delft in October 1918, and two years later a wind tunnel and towing tank were ready for use . Burgers talks about this in his memoirs, which he wrote down in 1975 in Maryland (USA). Under his leadership, theory and experimentation came to be seen as a whole, an approach that still characterises fluid dynamics at TU Delft today. This was also mentioned during the 'Flows are everywhere' symposium on 18 October celebrating a century of fluid dynamics at TU Delft, where three young researchers also presented a glimpse of the future.

CHANGING MEASUREMENT TECHNIQUES

But first a look back at this fascinating past. Would Jan Burgers still recognise his laboratory today? Westerweel (born 1964) thinks not: "We have a cabinet filled with old instruments, but everything else about measurement technology has changed completely. A wind tunnel is always a wind tunnel – it was one of the earliest ideas – but the technology for measuring in it has changed tremendously. Burgers measured wind speeds and turbulence with a filament. The rate it cooled down was a measure of the speed at that point, and the turbulence could

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be estimated based on the variation in this speed. Back then turbulence was the most important area of research, as it still is today. Back in the 1960s, the brilliant physicist Richard Feynman said that turbulence was one of unresolved problems of physics; even he wasn't prepared to take it on."

SWIMMING WITH THE SHARKS

Most progress over the past century has been made in measurement technology and processing power, says Westerweel. "Burgers measured a single point with his filament. Today we can measure a hundred thousand points at once. The measurement volume is about the size of your wallet, but we are now expanding into larger volumes. We recently studied the shark aquarium at Blijdorp zoo. We wanted to see if we could track a shoal of a thousand false herring while it was being attacked by a shark, whereby we scaled up the measurement technique from 10 x 10 centimetres to 10 x 6 metres and 25 metres deep. Two divers swam in the tank with a calibration plate while a third diver was on hand with a pole to keep the sharks away. We set up four synchronised cameras and shot three-dimensional images to reveal how a shoal of herring separates and reforms when a shark penetrates it."

Professor Jerry Westerweel

Flow calculations gained sway in the 1980s when computers finally had enough processing power. The more turbulent the flow, the more complex the calculation. The Reynolds number is used as a measure of turbulence. It roughly describes the ratio between flow velocity and viscosity. A rule of thumb is that a flow will switch from laminar to turbulent at a Reynolds number of 2000. "Successful simulations are now conducted with increasingly higher Reynolds numbers," says Westerweel. "When I got my PhD in 1993, the flow in a tube could be accurately simulated up to a Reynolds number of 5000. Today the simulation threshold is 50,000 to 100,000, which makes it interesting for industry. Industrial issues can now be analysed using Large Eddy Simulation, a mathematical model for calculating flows."

> 'We wanted to see if we could track a shoal of a thousand herring while it was being attacked by a shark'

He picks up an iPad and taps the screen. A current flows round obstacles which leave eddies in their wake. "You can see how the eddies are shaken off," explains the professor of fluid mechanics. "In the late 1980s and early 1990s you would have needed a supercomputer for this; now you can run it on your smartphone."

THE NEXT CENTURY

The current generation of fluid dynamics researchers have access to 3D measurement technology and powerful computers to calculate their Navier-Stokes equations. Around them, the world is changing, and with it the applications of their field. Within the next hundred years, the focus may well shift from refineries and diesel engines to wind turbines, geothermal energy, heat pumps and exchangers.

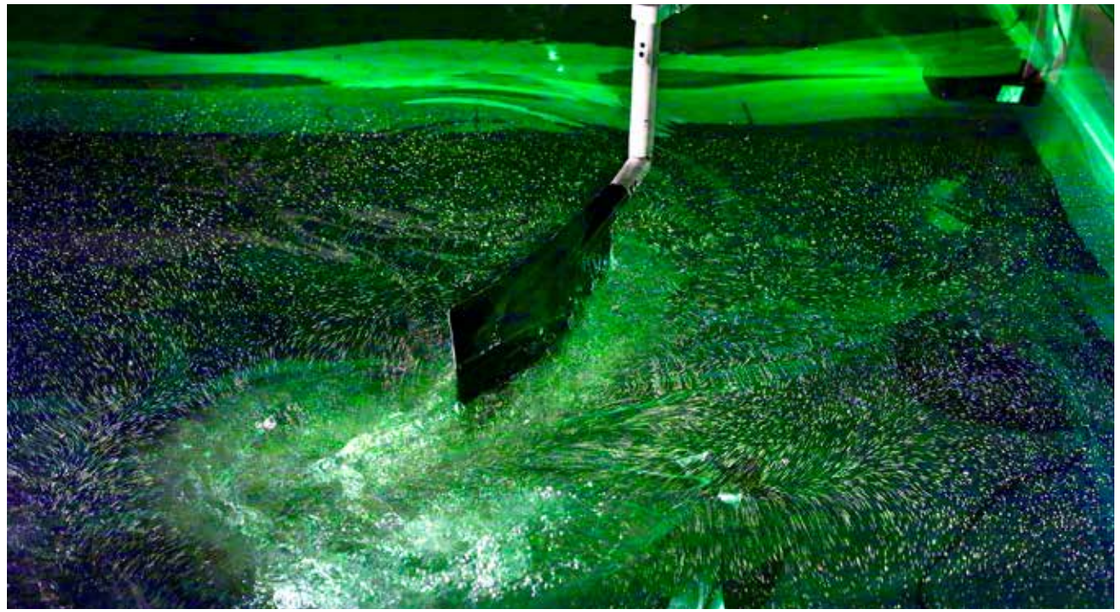
Westerweel does not venture predictions; he leaves that to three 30-year-olds who have a fresh perspective of the century-old field. At the Fluid Mechanics Centennial symposium, organised together with the J.M. Burgers Centre, Dr Daniel Tam of TU Delft, Dr Alvaro Marin of the University of Twente and Dr Hanneke Gelderblom of TU Eindhoven presented their visions of the next century of fluid dynamics.

"Why do all those painstaking calculations?" Gelderblom wondered aloud to a room full of fluid dynamics experts. Neural networks and self-learning systems are used everywhere, so why not in fluid dynamics? Could you enter flow data into a trained neural network and then just sit back and watch what the system produced? Who would still need Navier-Stokes equations? Gelderblom quickly quashes her own thought experiment with the conviction that any problem analysis will always need to fall back on the theory; aimless calculations will never replace careful problem analysis.

MINDLESS PROCESSING POWER

But Gelderblom is not the only one who is attracted to the idea of cheap processing power. Daniel Tam, who was voted teacher of the year by the 3mE faculty last year, notes that it is difficult to explain to students what the physical principles behind the observations are and why they are important . "Students would rather run the entire experiment through MATLAB and let the computer do the maths," says Tam.

The relationship between experimentation and simulation is shifting towards cyberspace. Increased processing power and improved numerical methods have made simulations cheap and reasonably reliable. Researchers can use computers to run simulations that cannot be reproduced in real-life experiments.



A rowing blade (scale 1:2) moves through a horizontal plane with laser light while a camera captures the flow under the setup through 10 cm thick glass. PhD student Ernst-Jan Grift investigates accelerating and slowing currents around the blade to see how rowers can go faster.

> Neural networks and self-learning systems are used everywhere, so why not in fluid dynamics?

But Tam still has some reservations. "We don't really know how to use computers yet," he thinks. Computer models generate mountains of data, often more than researchers can use. "For fluid dynamics, you can suffice with the speeds in the x, y and z directions and the pressure. But a computer model includes the temperature too and then it really goes crazy." The most common way to analyse fluid dynamics with a computer is using Computational Fluid Dynamics (CFD), but it produces such a huge amount of data that an extensive post-processing step is required to render it useable.

Speaker Alvaro Marin has also seen how experiments are being replaced by computer simulations, particularly when it concerns large Reynolds numbers. But Marin still thinks the results of simulations must always be validated with experimental data, because models may be incomplete, researchers may miss something, or there may be a programming error in the simulation. Finally, it is also safer if you know that your predictions correspond to the actual situation.

EXOTIC FLUIDS

In addition to simulations and experiments, the younger generation also points to the further development of the theory of complex and nanoscale fluids. For example, Tam is studying fluids at the scale of living cells, where it appears that fluids can move under their own power without an external driving force. These fluids are also no longer homogeneous, which makes the Navier-Stokes equations much more complex. The same applies to fluids to which polymers or microparticles have been added. The industry is developing more and more exotic fluids such as fast-drying or adhesive ink that work well in practice, but about which little is understood. The theoretical foundation of fluid dynamics will need to be developed further if it is to continue to play a meaningful role in the development of strange fluids, giving a strong theoretical foundation for us to understand more about fluid dynamics. Funnily enough, that's the same assignment that was given to Jan Burgers when he was appointed at Delft a century ago.

Fuck Yeah Fluid Dynamics: fyfluiddynamics.com

HORA EST

Suggesting that our technology will eventually take over from us is a huge over- and underestimation of mankind.

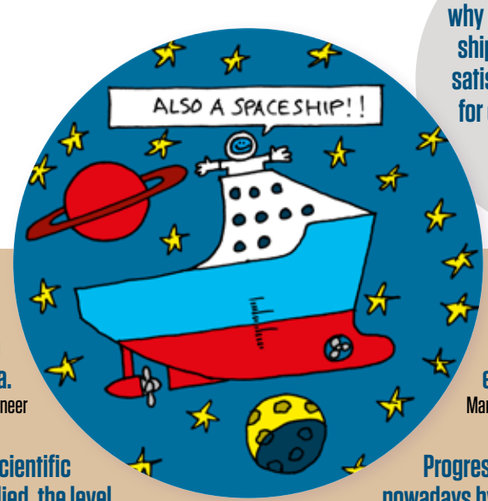
Niko Vegt, industrial design engineer

"I am annoyed by TV programs in which is claimed that technology will take over. By saying that, we overestimate ourselves; many of the reasons given for it are not realistic. Technology developers want us to believe that because they want to sell us their projects. But we must not underestimate ourselves either. As people, we are very capable of determining what works and what does not work in the area of technology.

We must mainly focus on issues that are relevant now. For example, I am working on a project about low-skilled and digital literacy. In doing so, we first have to examine how people can deal with apps and websites. Robots that take over from us are not yet at issue. We should therefore not want to go too far ahead of things."

It is hard to understand why in this 21st century most ships are still developed to satisfy design requirements for conditions that she will hardly ever meet

Geert Kapsenberg, maritime engineer



Action should be taken to relieve the stress levels and increase certainty for people working in academia.

Ruben van Drongelen, physics engineer

In a circular economy, true innovation means considering what happens to a product at every stage of its lifecycle.

Marcel den Hollander, industrial design engineer

Similar to many other fields, for scientific work to become popular and applied, the level of simplicity and a loud voice are often more important than the quality.

Willem Geert Versteijlen, offshore engineer

Progress in civil engineering is measured nowadays by the degree of multidisciplinary relevance.

María Ibáñez, hydraulics engineer

Calling a coffee break on a conference or symposium a "networking break" puts unnecessary pressure on young PhD students and is counterproductive.

Erik Gillebaart, aerospace engineer

A good researcher should learn how to work independently while needing to cooperate with others and being open to their suggestions.

Runhai Feng, geology engineer

No scientist can transfer his/her analytical thinking to all the aspects of life.

Ignacio Olavarria, physics engineer

Life can be regarded as an optimization process between leisure time, energy and money, whereby each phase in life can be characterized by its own constellation.

Peter Anker, electrical engineer

After Delft

Sandra Bruil always had a fascination for jewellery design, so she decided to combine her Master's of Industrial Design with a practical course in jewellery making. She recently started running her own jewellery design company.

Bruil discovered she enjoyed the combination of technology and creativity at secondary school. "In Year 4 we had to think about our further education choices. The first option that caught my eye was jewellery design, a vocational training course. Right away my teacher said I should consider a university degree." This led her to TU Delft, where she chose Industrial Design. 'It was a good choice. I particularly enjoyed the projects that involved producing tangible things."

After her Bachelor's programme, she continued to dream about jewellery design. She decided to take a year off university and take the first year of the part-time course in jewellery design in Schoonhoven. Her mark for her first practical assignment was a 5.5. "That was a shock. I subconsciously assumed that it would be a breeze for me after TU Delft. But it takes more than only intelligence." It only made Bruil more determined. She enjoyed the first year so much that she completed the entire course next to her Master's in Industrial Design. Equipped with both qualifications, she started searching for an industrial design job and registered as a jewellery designer with the chamber of commerce. She also started work as a user experience (UX) designer. But in early 2018, she started to wonder: "What do I really want? So I decided to leave my other job and focus entirely on my business."

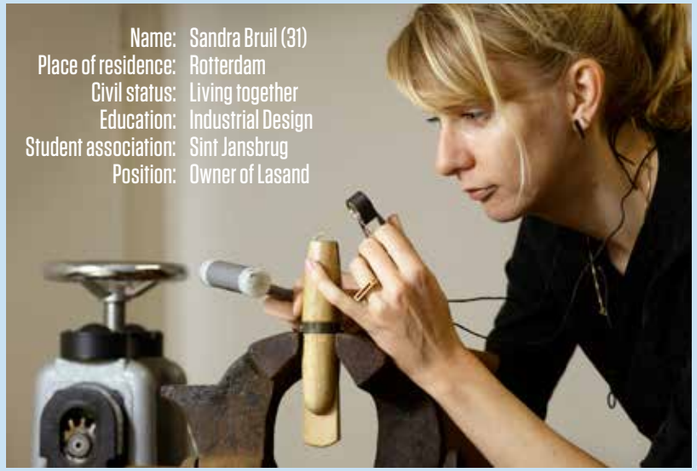


Photo: Sam Rentmeester

'You can use a 3D printer to create detailed designs that can't be made by hand'

She profits from the things she learned during the industrial design programme every day. "I work with the user-centred design method, using the customer's background story as the input for the design." So Bruil feels it's important to devote plenty of time to the first meeting with the customer. "The meaning of the item of jewellery to the customer is central to my design."

She also learned how to use a 3D printer during her study at TU Delft. She thinks this makes her one of the few jewellery designers who knows how to make good use of this tool. "Colleagues in the trade tend to look down on casting work, as if they think it's an easy way out, but I think it is the perfect way to design things that are too detailed to create by hand." Looking back on her time at TU Delft, she says she enjoyed the prevailing mentality there. "If you had an idea, they told you to go ahead and make it and see what happens. I like that approach." Working from home can inhibit customers from dropping in to her workshop, says Bruil. "So my plan for the future is to rent my own studio." MvdP

In person

Rhythima Shinde (Faculty of TPM) has been named Best Graduate of 2018. She completed two Master's degree programmes within two years: Engineering and Policy Analysis, and Computer Science. The first degree also included field work in India, and the second involved a thesis project at ETH Zurich. 'I love research', remarked Shinde in an earlier interview with the journalistic platform Delta. The Best Graduate of 2018 won a monetary prize of €2500 and a new laptop. The prize is awarded each year by the Delft University Fund.

Prof. Sybrand van der Zwaag has been awarded the prestigious gold Grande Médaille from SF2M (the French materials science society) for the totality of research throughout his career. He is the first Dutch scientist to receive the medal in the 70-year history of the prize. Previous winners include such renowned materials scientists as Bain, Mott, Haasen, Pineau, Rappaz and Purdy.

Former Rector Magnificus Prof. ir. Karel Luyben has been appointed president of the Executive Board of EOSC (European Open Science Cloud). Luyben has been a champion of Open Science for years. As president he will represent CESAER, the European partnership of universities.

The hydraulic engineer Prof. ir. Neelke Doorn holds the new chair in the Ethics of Water Engineering within the Faculty of TPM. Doorn studied civil engineering and, even as a first-year student, wanted to use engineering to improve the world. As she argued in her inaugural address: "sometimes, it's important not to build anything".

TU Delft has gained a new top-class sportswoman. In October, the first-year mechanical engineering student and racing cyclist Rozemarijn Ammerlaan (18) won the world championship in the Women's Junior World Time Trials in Innsbruck. Regarding the combination of elite sports and science, she told Delta, "It's a question of good planning".

COLUMN

Everything electric

More than one hundred organisations have spent almost an entire year meeting, squabbling and quarrelling about the Climate Agreement, the route to halving Dutch greenhouse gas emissions by 2030. One of the key instruments in this huge operation is electrification; converting processes that use coal, oil and gas – 93% of the energy mix – to green electric power. This includes powering cars, heating homes and producing goods in factories.

Electrification is a good idea. Just as we fondly remember the coal scuttle, generations after us will laugh about how we used to pour flammable substances into a tank and then burn them to keep warm or to get from A to B. "What about those exhaust gases, grandma?" "Well sweetie, we just breathed them in."

Electricity has an excellent reputation. Invisible, inaudible, odourless and, in the rich West, available everywhere and all the time. And while groups of westerners will campaign against almost anything, the first group of anti-electricity protesters is yet to be established. However, it's not all moonlight and roses. There have already been protests against electricity transportation; concerned citizens don't want the 380kV high-voltage cables, required for the large-scale energy transition, in their backyards. However, it's the production of that electricity that meets with resistance.

The feel-good citizen who charges his Tesla Model S up with electrons is actually using 86% fossil fuel and only 14% green. This ratio is set to change dramatically during the coming years. The plan is for 70% of this energy to be green by 2030. The big question is where all this electricity will come from. All the sources have disadvantages, as Minister of Economic Affairs Wiebes elaborately explained in parliament this October. So there is not only a movement against fossil fuels; the renewable alternatives also face increasing opposition. They are said to occupy too much space, damage nature and be ugly. And so 'we' are against covering 20% of the North Sea with wind turbines, against huge solar farms with panels glinting in the sun covering an area the size of hundreds of football fields, against biomass, because some say it's worse than coal, and, of course, against nuclear power.

Although the five sector groups met regularly this year to talk, haggle and quarrel about the national climate agreement, there is still no master plan for how we are going to get our energy for the next century. And that is to be expected. The Netherlands is not a country of far-seeing plans and grand gestures; we prefer to optimistically improvise our way forwards. That's the way we do it, with all the hassle, tumult and endless fuss that implies; two steps forward, one step back. That won't improve with the electrification of the Netherlands; it may even get worse.

Remco de Boer is a technology & science communication specialist.

Calvin Rans has been chosen as TU Delft's Best Lecturer. How does he keep his students motivated?

What does this election mean for you?
"It is a little bit different than being voted the best lecturer of our faculty. My efforts in teaching now have a wider visibility than in my own little Aerospace Engineering bubble. It was quite a nice little thing to receive."

In your first-year course, you teach students using blended learning. Students watch movies and then work together on exercises (flipped classroom). Did this lead to better results?
"It led to better results in the sense that the students who passed did better. About 35 to 40 percent of students fail. Instead of having to go back and look at entire recorded lectures, they had short videos on specific topics. This left more classroom time for issues they were struggling with."

You came to class in ice hockey clothing. Why?
"I realised that the way the material in a lot of my lectures is presented can be very boring. Blended learning gave me more space in class, so I decided to demonstrate a real engineering application rather than do the calculations. I am Canadian and I like ice hockey, so I brought in a hockey stick. We watched a video of someone taking a slap shot and looked at the deflections."

Is there a lot of engineering in a hockey stick?
"People think it is just a simple stick but its properties change along it. Essentially it is a calibrated catapult. If you hit the ice with the stick when you take a really hard shot, you will bend the stick. If you hit the puck, it acts like a big spring that throws the puck like a catapult. It is the design of the stick that is very important in how you throw the puck."

Photo: Sam Rentmeester

Did you get feedback from the students?
"Yes, they get excited. The the secret of teaching is to plant the seed of motivation in students. If they can't see what something is potentially useful for, then it just becomes an endless exercise."

You are developing an open online textbook for aerospace engineers?
"That is what my educational fellowship is for. All the textbooks for my second-year Structural Analysis & Design course date back to my generation and before. They very much focus on the maths and the analytical stuff. I want to make an open textbook in a digital format and embed blended learning videos in it. The students can watch some interactive components and do some virtual experiments."

What will you do with your prize?
"With the EUR 5,000 for educational use, I will buy a HoloLens, an augmented reality headset. I like to play with new learning technologies and see how useful they are."

Best Lecturer election
Students from all eight faculties choose their best lecturer. Out of these eight, a jury chooses, consisting of education director Rob Mudde, members of the student council, the Student Council and the winner of last year. Calvin Rans competes for the national title, to be announced. on April 13, 2019

TEXT: AGAATH DIEMEL
PHOTO: GUUS SCHOONEWILLE

SCIENTIST BY DAY, MUSICIAN BY NIGHT

In 2011, India-born Vasudevan Lakshminarayanan received a TU Delft Excellence Scholarship which enabled him to study Chemical Engineering in Delft. This turned out to be a defining moment in his life. He strongly believes in the power of giving back.

Vasudevan Lakshminarayanan: "For me, TU Delft is the right place to make great castles."

Vasudevan Lakshminarayanan is an expert on hydrogels, a class of materials mostly known to the general public from baby diapers, hair products etc. "Diapers contain a polymer that can soak up its own weight in water hundreds of times", Lakshminarayanan explains. "I worked on supramolecular hydrogels in particular. These are composed of smaller molecules, that spontaneously self-assemble when they are activated by a trigger, such as pH, light, temperature or even an enzyme". There are many possible applications for such materials, e.g. as vehicles for drug delivery, but also as a flow additive for coatings or paints.

MICROPATCHES

As a PhD researcher at the Advanced Soft Matter group, he studied the relationship between the mechanical properties and the microstructures of such supramolecular hydrogels. "Together with a researcher from the University of Amsterdam, I made a model to predict hydrogels' properties like gelation time," he says. "In another project, I also devised a method to create hydrogel micropatches by applying an electrical current. Subsequent steps will be to develop that method into an easily scalable approach for the largescale production."

His interests are by no means limited to his own subject. He also worked on visualising research samples with the help of cryogenic transmission electron microscopy (cryo-TEM). "I am very happy that our collaborations have resulted in a number of publications. Recently, we published a paper on directed nanoscale self-assembly, which can potentially be used for capturing viruses during water treatment."

PRINGLES

He first visited Delft during a bachelor research internship at the University of Muenster. "I read up on TU Delft and discovered there was an interesting Master's programme in chemical engineering, with a focus on product and molecular engineering. Both were topics that had interested him from a young age: "I remember running up to my chemistry teacher with the ingredient list on a box of Pringles and asking her: 'Sundari ma'am, what do these substances do? It fascinated me that products we use in daily life are essentially formulas made up of a number of chemical ingredients."

Studying at the Advanced Soft Matter group (ASM), he chose drug encapsulation as his Master thesis topic. "I divided my time between DSM and the university. DSM is a leader in the production of food actives. I looked at whether a certain anti-fungal active could be used in food applications loading it in a polymer nanocapsule." Lakshminarayanan graduated cum laude, with his research outcomes being presented at the 2013 conference of the American Institute of Chemical Engineers (AIChE).

> 'I realised that you don't need to be a know-it-all, just be a learn-it-all'

ACHIEVEMENTS

It was just one in a long list of achievements. "I graduated cum laude twice and received two important scholarships", Lakshminarayanan says. "But over the years, I have come to realise that there are achievements on many fronts: achievements related to excellence academic or otherwise, but also milestones related to your own personal journey. You should sometimes think back about where you came from, realise where you are now and be humble about it. Because no matter how many summits you climb, there will always be a bigger one to climb afterwards", he adds.

GIVING BACK

He also believes in the power of giving back. "I have taught a number of Bachelor's and Master's courses, and I have mentored two Master's students. When they graduated, I felt very satisfied. To be able to touch the lives of others is something remarkable." If there is one message he likes to pass on to generations of students coming after him, it is this: "During my entire span of learning, I realised that you don't need to be a know-it-all, just be a learn-it-all. That is the best attitude to make the most of every scenario."

Lakshminarayanan's natural inquisitiveness has led him to undertake a whole host of extra-academic activities: "During my Master's I was president of the Indian Students Association, ISA Delft, and during my PhD I co-organised group trips for colleagues. I was also a board member of Young Delft, and I am now associated with the TU Delft alumni relations and the Scholarship Club, which is a platform for all scholarship students. I was also the vice-president for the Indian Classical Music club of my university."

MUSIC LOVER

The latter is because his second love, next to science, is music: "I am a singer and performer. You could say I am a scientist by day and a musician by night. I am a member of Zangam, the first Indian classical music choir of the Netherlands. I am also part of a live band called Madras Chorus." Mixing music and research is all about creating balance, Lakshminarayanan believes. "They say the right side of the brain is the creative side and the left the intellectual side, but I sometimes feel that in my brain there is a dynamic switch between the two: I get energy from the right side and send it to the left, or the other way around."

SANDBOX

Looking back, he fondly compares TU Delft to a large sandbox. "You usually see two types of kids in the playground: those who make just ditches and those who make beautiful sandcastles. For me, TU Delft is the right place to make great castles. If you have the diligence and the perseverance to translate your vision into reality, you will always find support for your ideas."

Are you inspired by this story? Would you like to explore your options for lasting involvement at TU Dleft? Please send us an email at alumnirelations@tudelft.nl

ALUMNI NEWS

Alumni Activities

22 december
Alumni Sinterklaas drinks reception in Istanbul

21-26 January
Alumni Tour China, Hong Kong, Beijing, Shanghai (check the website for the definitive date)

Register via the alumni community tudelftforlife.nl or the website alumni.tudelft.nl.

Contact:
Questions, comments or ideas?
Email: alumnirelations@tudelft.nl
Website: alumni.tudelft.nl
Community: tudelftforlife.nl

'TU Delft for Life' is the online community for all Delft alumni. Expand your network, rediscover old student friends and keep abreast of all the latest news and events. You can register at tudelftforlife.nl, where you can also change your address or contact details.

TU Delft FOR LIFE | SINCE 1842

Online alumni community TUDelftforLife.nl reaches 5000 members

You are not simply a TU Delft engineer for a moment: it marks your whole life. A mark you can carry with pride! TUDelftforLife.nl is the worldwide meeting place for all TU Delft alumni. It is a place where 5000 alumni have now been able to contact each other and keep up with the latest news and events.
In addition, the online community is continually adding more opportunities. For example, you can join a variety of groups within the community (e.g. according to topic, geographic location or specific study associations).

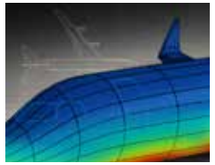
Want to become part of this growing, flourishing community? Creating an account is quick and easy:
1. Go to 'www.tudelftforlife.nl'
2. Select 'Sign Up' at the top of the page
3. Preferably, select 'Register with LinkedIn'
4. Follow the steps and answer a few questions
5. The system will verify that you are an alumnus
6. Welcome. You are now a part of TUDelftforLife.nl.

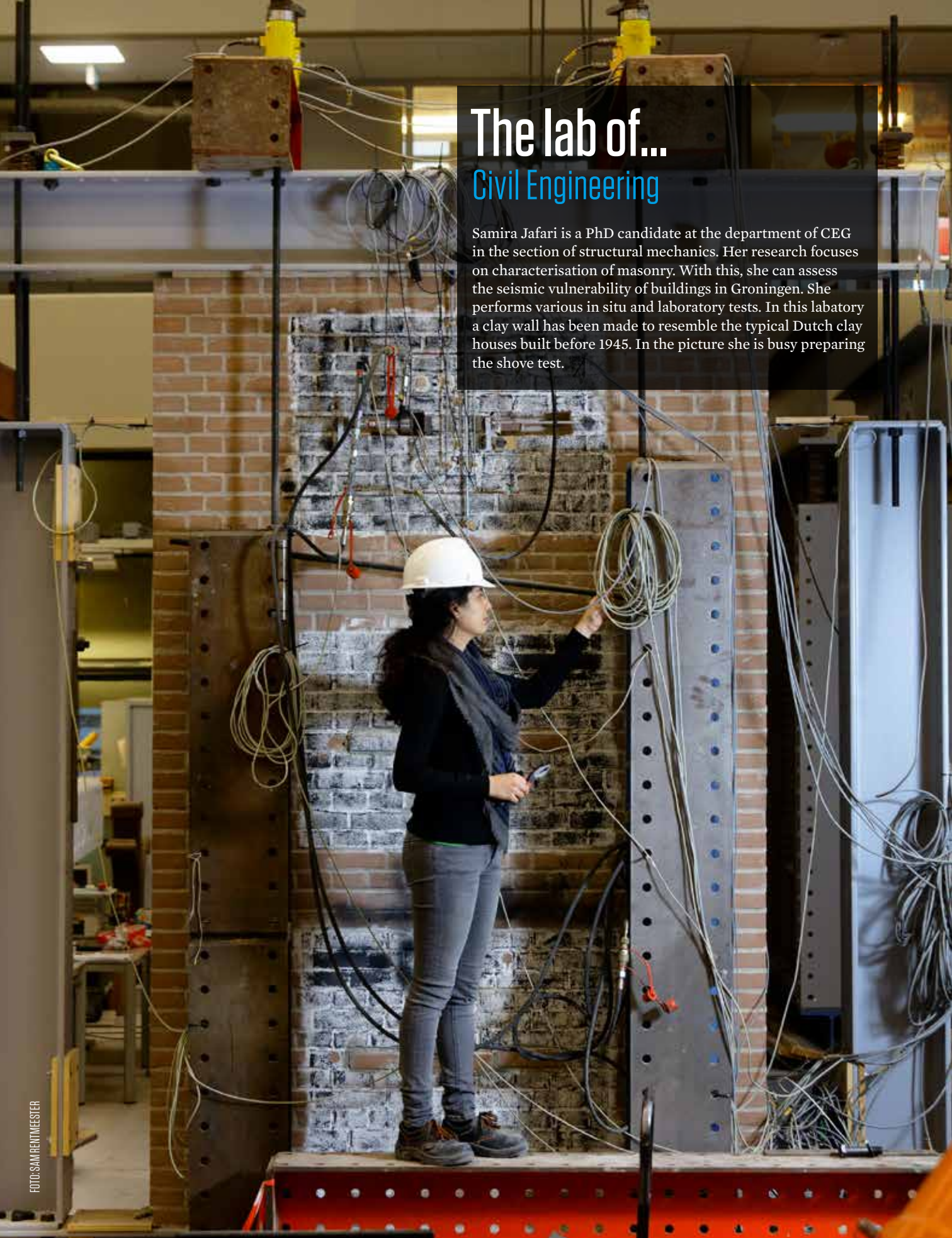
Lifelong learning – 25% discount for alumni

TU Delft alumni are entitled to a 25% discount on the following selected courses, which will start in the first half of 2019:
Design Your Next Career Move (continuous start: 'self-paced')
- Aeroacoustics: Noise Reduction Strategies for Mechanical Systems (starting date: 15 January)
- Rotor and Wake Aerodynamics (starting date: 11 Feb.)
- Non-linear Modelling (starting date: 11 Feb.)
- Aeroelasticity (starting date: 11 Feb.)
- Modeling, Simulation and Application of Power and Propulsion Systems (starting date: 11 Feb.)
- High-rate Anaerobic Wastewater Treatment (starting date: 15 May)
- Energy Friendly Renovation Processes (check website for starting date)
- Nanofiltration and Reverse Osmosis in Water Treatment (check website for starting date)
- Fiber Reinforced Polymer (FRP) Composites in Structural Engineering (check website for starting date)

If you would like to know more about the courses and the alumni discount, visit: https://online-learning.tudelft.nl/special-alumni-selection.







The lab of...

Civil Engineering

Samira Jafari is a PhD candidate at the department of CEG in the section of structural mechanics. Her research focuses on characterisation of masonry. With this, she can assess the seismic vulnerability of buildings in Groningen. She performs various in situ and laboratory tests. In this labatory a clay wall has been made to resemble the typical Dutch clay houses built before 1945. In the picture she is busy preparing the shove test.

FOTO: SAM RENTMEESTER