

TO₂MORROW

Magazine on results in the Open Innovation Network

2019

TO₂federatie
De samenwerkende organisaties
in toegepast onderzoek



Impact for society

TO2 2019 Impact Report



The polder as a battery

By using smart control, pumping stations and locks in the Netherlands can save energy and money. **p.4**

Getting drugs onto the shelf faster

A new innovation can shorten the development process of drugs by years. **p.20**

Heading for more robust plants

Using smart tools for sustainable agriculture leads to more robust species requiring less crop protection. **p.26**



Impact for society

We face major social challenges in the Netherlands and all over the world. The ageing of the population is putting pressure on the affordability of care. Climate change threatens biodiversity and the growing world population needs renewable energy sources. These challenges are not always resolved easily. They call for a wider approach by the government, knowledge and educational institutes and the business community. Within the Netherlands, as the Dutch State Secretary for Economic Affairs and Climate, the TO2 institutes are my responsibility. They play a major role in bringing together all these parties in respect of our common needs. TO2 institutes are applied research organisa-

tions: Deltares, MARIN, TNO, Wageningen University & Research (WUR) and NLR. These organisations are united in the TO2 federation.

This is the first edition of the TO2 impact report. This annual report enables TO2 institutes to showcase examples of some of the problems they are working on together, and how their solutions contribute to a sustainable, clean, healthy and safe future for the Netherlands. Solutions that not only help society further, but also increase the earning capacity of the Dutch business community, with special attention for innovation in SMEs.

The economic opportunities of social challenges are pivotal to the mission-driven innovation policy to which the

TO2 institutes provide an important contribution. The examples in this report are arranged in the themes on which this policy focuses. These include 'energy transition and sustainability', 'agriculture, water and food', 'health and care', 'safety' and 'key technologies'.

One of these examples is software developed by Deltares, with which surplus renewable energy that may otherwise go to waste, can be used to run pumping stations. This also results in major savings for market parties (page 4-5). In addition, TNO shows how it contributes to more efficient care by using ground-breaking AMS technology (Accelerator Mass Spectrometer) to drastically accelerate the development time of new drugs (page 20). Another example is the development of autonomous sailing on which MARIN, NLR and TNO are working together (page 22-23). This technology has to help people in future to perform hazardous tasks (e.g. disabling sea mines) and also ensures an increase in safety at sea. WUR shows how key technologies (such as robotics and sensor technology) can contribute to improving sustainability ambitions in agriculture, partly by further reducing dependency on chemical pesticides (page 26-27). Read this report, especially if you want to know more about all the other worthwhile contributions from TO2 institutes to a better future for the Netherlands.

I hope you enjoy reading this edition.

Mona Keijzer

State Secretary for Economic Affairs and Climate

CREDITS

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In the overview below, each of the institutions, who are part of the TO₂ federation, summarize their key areas of activity and the key technologies they develop and apply.

The TO₂ federation consists of:



WUR

Wageningen University & Research is the joint venture between Wageningen University and Stichting Wageningen Research (foundation). We have more than 5,500 employees and 12,000 students from over 100 countries working in the fields of healthy nutrition and the living environment across the globe, both for governments and for the business community. The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". The Wageningen University & Research's strength lies in combining specialised research institutes and the university for collaboration in various natural, technological and social science disciplines. As a result, scientific breakthroughs can quickly be translated into practice and into education. Wageningen Research is part of the TO₂ federation and consists of several research institutes who are active in the themes Food & Biobased Research, Bioveterinary Research, Livestock Research, Marine Research, Economic Research, Environmental Research, Plant Research and Food Safety Research.



MARIN

The Maritime Research Institute Netherlands (MARIN) conducts research into hydrodynamics, maritime (zero-emission) technology and operations with simulations, model testing, true-size measurements and training. MARIN focuses on shipbuilding, shipping, offshore industry and public authorities. To this end, MARIN pays attention to the following social themes in the mission-driven innovation policy: energy transition and sustainability; agriculture, water and food; and safety. Key technologies that receive special attention are artificial intelligence and autonomy & decision support.



Deltares

Deltares conducts research into water and subsoil. Research is mainly focused on deltas, coastal regions and river areas. Deltares has five areas of expertise: 1. Water safety; 2. Adaptive delta planning; 3. Building in the Delta; 4. Water and raw materials; and 5. Ecosystems and environmental quality. Deltares' research contributes to all social themes in the mission-driven innovation policy: energy transition and sustainability; agriculture, water and food; health and care; and safety. Key technologies that receive special attention include data science, software innovation, as well as measuring and monitoring.



TNO

The Netherlands Organisation for Applied Scientific Research (TNO) has a mission to connect people and knowledge, to create innovations that permanently enhance the well-being of society and the competitiveness of companies. TNO believes in jointly creating value in economic as well as social terms and, together with partners, focuses on innovations in nine domains: Construction, Infra and Maritime; Circular Economy and Environment; Defence and Safety; Energy Transition; Healthy Living; Industry; Information and Communication Technology; Strategic Analyses and Policy; Mobility and Logistics.

Developing and making key technologies functional for application, is one of TNO's core activities within these domains. These include photonics, nano- and quantum technology, but also new forms of production, material and chemical technology. Key technologies are characterised by a wide field of application or scope in innovations and sectors. They will radically change the way we live, learn, innovate, work and produce. Key technologies are essential in resolving social challenges, such as safety, energy and care. Key technologies also enable groundbreaking innovations of processes, products and services, and provide a major contribution to the economy, to the emergence of new businesses and new markets, to an increased competitiveness and to bolstering job creation.



NLR

The Royal Netherlands Aerospace Centre (NLR) connects the sciences, business community and government in the Netherlands and internationally. This knowledge organisation conducts applied science research in the market segments: industry, civil aviation, aerospace and

defence. NLR's work covers the full spectrum of 'Research, Development, Test & Evaluation' (RDT&E). Within the mission-driven innovation policy, NLR's research focuses on the social themes: energy transition, sustainability and safety. Examples of key technologies that receive special attention are artificial intelligence, augmented/virtual reality, digital twin and state-of-the-art materials (e.g. composites and 3D metal printing).



Problem: Operational pumping stations use a great deal of energy. At the same time, energy companies and grid operators are looking for a good use for their 'surplus energy' generated by increased solar and wind energy.



TO₂ Solution: Deltares and the University of Technology Eindhoven developed a toolbox that calculates when it is 'smart' to pump with renewable energy that may otherwise go to waste.



(Expected) impact: By using surplus energy in this way, it will not go to waste and market parties would eventually need to invest less in expensive storage systems such as batteries. If all water authorities start using the toolbox, they can save up to 70% or 45 GWh of energy with a direct CO₂ saving of 22 kilotons. That is almost 50% of current carbon emissions for pump energy in water management.

The polder as a battery saves up to 70% energy

Deltares

By using smart control, pumping stations in the Netherlands can save energy and money. By using renewable energy that may otherwise go to waste, Deltares has developed software for 'smart pumping'.

Energy for 15,000 households. That is what water managers can save when they allow locks, barrages and pumping stations to work at times when windmills and solar cells have a 'surplus' of energy. The energy price is an indication for this. This is also advantageous for the energy suppliers and grid operators, who do not need to store this energy. This was apparent from the ***Slim Malen*** (smart pumping) research project by Deltares and the University of Technology Eindhoven, in conjunction with STOWA, eight water boards, eight (energy) companies and Rijkswaterstaat, at four locations at various water boards.

Polders are flexible energy buffers

The principle is clear: you mainly pump in periods when a great deal of renewable energy is available. This means that the polder itself acts a battery, says Ivo Pothof, an expert on renewable energy from water at Deltares. "It recharges itself

by an excess of rainwater and 'discharges' while pumping away surplus water. If water managers do so at times when there is a great deal of renewable energy available, there will be more balance in the supply and demand of electricity. That is a key contribution in the energy transition." According to Pothof, water boards can save 30% to 70% of energy annually by using smart control systems. This will also reduce their carbon emissions considerably. Current carbon emissions for pump energy in water management amount to 46 kilotons, according to ***Klimaatmonitor*** (climate monitor). This is equal to the emission of 251 million kilometres travelled by car.

Smart control strategy

But how does it work? And surely there must be other arguments about pumping or not? Answers to these questions and more are in a toolbox for smart control strategies. This software links weather forecasts, tidal movements, storage

capacity and pumping properties to the renewable energy targets of water boards, thus making a balanced timing possible. Deltares has further developed this open-source toolbox called RTC Tools. If all water authorities start using it, they can save up to 70% or 45 GWh of energy with a direct CO₂ saving of 22 kilotons. The toolbox readily applies the intelligence in practical terms.

If grid operators would need to store that energy, it would cost at least €150 million

Looking for a good use

Energy companies and grid operators are important partners in Smart Pumping. They are looking for a good use of for their 'surplus energy' generated by increased solar and wind energy. In the





long run, it will save companies from using thicker cables and expensive storage systems such as batteries. The consultancy firm E-Risk and Deltares calculated the 'storage capacity' of the Dutch water system being drained. If grid operators would need to store that energy in batteries, it would cost at least €150 million.

Transitioning in forthcoming years

The principle of smart pumping has been tested in four desk studies, in which water systems have been assessed using the RTC Tools. Conclusion: water boards can achieve results even with simple control systems. This often requires very little investment and there is an immediate gain. More complicated systems cost more, depending on the extent to which water boards already make use of centralised control. The studies themselves showed energy savings of 5% to 70%. Posthof explains the major differences as being due to the variation

in circumstances. "A water system with few tide movements has far less room to manoeuvre."

Pothof expects water boards to switch to advanced control systems in the coming years. Then they could be carbon neutral by 2025.

Hydroelectric power plants

The knowledge gained in the pilots is also useful for hydroelectric power plants abroad. The reconciliation between expected rainfall, buffering in reservoirs, and an optimum use of the hydroelectric power plant, is comparable. But in the Netherlands too, the knowledge gained is used for other applications, like controlling sustainable heat networks. Here heat is stored in buffers and buildings, so that the renewable sources can supply as much as possible and the use of (fossil fuel) peak provisions remain minimal. ■

More info at: www.slimmalen.nl

Who: Deltares and the University of Technology Eindhoven, in conjunction with STOWA, water boards, (energy) companies and Rijkswaterstaat.

Duration: March 2016 – March 2019.

Budget: €1,050,000



Problem: Achieving the climate targets requires a substantial reduction in carbon emissions in the Netherlands. Forests along highways are still not being utilised adequately.



TO₂ Solution: Based on a study on how roadside forests can contribute to climate targets, WUR developed an online tool box filled with smart climate control measures for land managers.



(Expected) impact: Reducing carbon emissions through smart forest management and contributing to the circular economy by using timber to generate green power and applying it as building material.

Roadside forests: suitable as biomass and building material?

WUR

By planting forests along highways and near petrol stations, Rijkswaterstaat wants to contribute to the climate targets. Some of the timber can be used to generate green power. A pilot study by Wageningen University & Research (WUR) researched how this can best be addressed.

As from 2030, the government wants to capture 1.5 million tons of CO₂ through forests and timber. Rijkswaterstaat sees opportunities to plant 100,000 hectares of forest along highways or near petrol stations over the next twenty years. The Netherlands now has about 365,000 hectares of forest and this could increase by more than a quarter. According to Rijkswaterstaat, the forests can be planted in a strip of at least 300 metres deep along Dutch highways, so a total of three thousand kilometres will be planted. In addition to reducing carbon emissions, roadside forests can also contribute to the circular economy. This could be timber and cuttings used for the generation of green power. Another application would be as building material, provided the timber is of good quality. WUR coordinates several Rijkswaterstaat pilots with forest managers and land managers to research how this can best be addressed. In various parcels of woodlands along highways, WUR researched the location factors and the characteristics of plants and shrubs (species, density, wood volume). Supplemental growth ring measurements have been done to determine productivity, drought sensitivity and the

overall vitality of plants and shrubs. Based on this, the researchers made recommendations where Rijkswaterstaat can best expand in the future. Here the starting point is that production of this high quality wood does not affect the image of the landscape and its biodiversity.

For land managers, the pilots provide a full online 'toolbox' with smart control management for mitigation (countering climate change) and climate adaptation (adjusting to a new situation). Both in the development of this tool and in the expansion of the

project, we need the help of various partners, including various government bodies, **Staatsbosbeheer** (National Forest Service of the Netherlands), **Natuurmonumenten** (Society for the Preservation of Nature in the Netherlands) and the Water Boards. ■

Who: WUR in conjunction with Rijkswaterstaat, H+N+S Landschapsarchitecten, Stichting Hout Research and **Staatsbosbeheer**.

Duration: end February 2020.

Budget: €80,000.





Problem: The market for floating solar power plants is now mainly concentrated in small inland lakes, but, with larger areas such as the North Sea, a higher energy generation can be achieved. The present generation of floating solar power plants, however, is too vulnerable to wind, waves and currents.



Solution: MARIN, ECN part of TNO and Utrecht University developed a floating solar power plant that, despite its light weight and large surface area, does not break up in high waves.



(Expected) impact: By (partially) using the space between offshore wind turbines for floating solar power plants, renewable energy generation in respect of wind alone, could be doubled.



MARIN's offshore basin model scale experiments take place in Wageningen.

How do floating offshore solar power plants become storm resistant?

MARIN, ECN part of TNO

In the Netherlands, floating solar power plants are mainly found on small inland lakes. But the North Sea also offers plenty of opportunities, on condition that the systems are wave-resistant. Energy generation at existing offshore wind farms can double, if only one-fifth to one-quarter of the space between the turbines is used for floating solar power plants, which are developed by MARIN in collaboration with ECN part of TNO and Utrecht University.

The market for solar power plants in inland waterways is maturing increasingly. In 2019, around 1 GW of solar power plants were afloat worldwide, which is about the same capacity as all wind turbines in the Netherlands' part of the North Sea. At present, the existing market is mainly concentrated in smaller lakes. But with larger surfaces like the North Sea, a greater impact can be achieved.

Over the past two years, MARIN carried out measurements in the Slufter (Maasvlakte), the IJsselmeer and the North Sea. The aim is to develop solar power plants with a service life of 25 years, which are resistant to storms and high waves, Senior Project Manager William Otto explains.

Lightweight with a large surface area
The distinguishing factors that floating

solar power plants have over existing floating structures is the low weight of the structure and the huge surface area. William Otto confirms that this lightweight structure has been chosen to limit the use of raw materials as much as possible. The solar panel, cabling and (micro)inverters jointly weigh less than 100 kg/m², which ensures that they float only 1 cm deep in the water. On the other hand, there is a need for many hectares of surface area. This combination of low weight and huge surface areas calls for flexible structures. In addition to computer simulations, model scale experiments are an important and essential element in the MARIN research. These are conducted in our own basins in Wageningen. Researchers use new optical measuring methods to identify deformations in large surface areas. These affect the amount of sunlight that the floating solar power plants can eventually capture and determine whether they survive the storm without failing. ■

Who: ECN part of TNO, MARIN, Utrecht University, energy company TAQA and the company Oceans of Energy in Leiden.

Duration: 2018-2020.



Problem: The construction and demolition sector in the Netherlands produces 25 megatons of waste each year. To reduce our ecological footprint, we need to reuse more material instead of discarding it.



TO2 Solution: TNO developed a calculation method that calculates the future residual value of a building element. This enables owners to decide whether such an element still deserves a second or third lease of life.



(Expected) impact: A circular construction sector. By reusing products, costs are reduced and the focus shifts to restoring and refurbishing products instead of producing and demolishing. Products will be designed to last several service lives and to make new earning models possible.

Calculation method gives building products a second lease of life

TNO

The construction and demolition sector in the Netherlands produces 25 megatons of waste each year. What if we reuse all that material, instead of discarding it? TNO developed a calculation method that gives building products a second lease of life.

Half of all the materials used by the Netherlands every year, is contained in buildings. If we want to reduce our carbon footprint, we need to be more efficient and smarter in dealing with raw materials. That means using fewer new raw materials and also using products for longer. Or, as summarised by the English: refuse, reduce, reuse, recycle and repurpose.

Higher sustainability using waste

Reusage begins by looking at waste differently. For this purpose, TNO is developing the Residual Value Calculator together with the C2C ExpoLAB. It calculates the future residual value of building elements; this is not based on amortization or the current market value of the material, but takes into account various factors such as the product's quality, how easy it is to dismantle a product, transportation as well as maintenance and repair costs. The prototype is

based on two elements that are familiar in the Dutch offices landscape: internal walls in offices and façades of buildings.

Residual value is never zero

We think it is quite normal to amortize housing and offices over a service life down to zero euro. Components often still have a (residual) value at the end of this service life. At present, this value is determined by the current market value of the materials such as glass, wood or concrete. However, the value could be higher. For example, a product is not only made up of wood, but also of good workmanship, technology and the use of machines.

Second lease of life

Take an internal wall, for instance. That lasts a long time; until it has been written off or has become superfluous due to expansion of personnel and a differently designed open-plan office. The standard solution

would be to demolish and to shred it into wood chips for the chipboard industry. Now let's assume that you dismantle an internal wall, check its technical quality, give it a coat of paint and reassemble it into a single internal wall at another location. Then the product can be reused for another decade and retains its added value. Interior and façade walls are only the beginning: the aim is for this 'calculator' to learn the value of many different building products, which will provide an insight into the actual residual value of various movable and semi-tangible goods and perhaps even the immovable assets in a building.

Consequences for the building industry

With this calculation method, the owner not only contributes to circular material

The calculation method enables new business models





Demolition is a standard solution for interior walls. But what if you can dismantle these and reuse them?

use, but can also better assess whether it is economically viable to use a product for a second or even a third time. The impact of this is enormous. This will reduce costs for the user of the product. Additionally, TNO predicts that the focus will shift from producing and demolishing to repairing and restoring products.

Products will even be designed to be able to last several service lives. Designers will also reconsider how to divide the design into easily detachable parts. Just like lego blocks.

Subscription

TNO works with various parties in the wall-cladding sector such as Alkondor, Blitta, Kawneer, Pilkington, and Schüco, to assess the impact of residual value on their business models.

By using this new calculation method, a used building element still has a 'proven' value. It can be taken back, refurbished

and used again. This enables new earning models, such as lease or buyback.

The calculation method can also help to obtain circular financing for new business models: by presenting an accepted residual value to the bank, investments can be made with less risk.

Before we all subscribe to interior walls, all parties in the building chain must accept the residual value calculation. TNO works with several parties, including Deloitte, to properly assess the financial impact at different levels - from commercial financial statements to cash flow. This makes it possible for the parties to already agree to the residual value of building elements in the planning phase. ■

Who: TNO and C2C ExpoLAB work together with various parties in the façade industry and Deloitte.

Duration: since 2017, two six-month projects, with a third project underway.

Budget: to date, two amounts of about €130,000 each.

Follow-up: in 2020, TNO wants to set up a public-private partnership programme to further prove and test the methodology with various cases in the business community.

They also want to work with stakeholders such as financiers, builders, clients, and architects to have the financial residual value become a permanent aspect of (parts of) building projects.



Problem: What to do in the event of drought, flooding or possible salinization? To keep account of the consequences of water management measures in advance, water managers work with digital models. Until recently, this took a long time and had to be done separately for various soil deposits and regions.



TO2 Solution: Deltares and WUR are jointly working on the Dutch Hydrological Toolbox (Nederlands Hydrologisch Instrumentarium, NHI), which enables water managers to calculate effects of measures better and cheaper.



(Expected) impact: Water managers are better prepared for the effects of climate change. The NHI provides a faster and better insight into the effects of water management measures, and from 2021 onwards – when the system allows full open access – it will realise cost savings of €2.5 million per year in modelling costs. In the meanwhile, public authorities and a large number of consultancy firms are applying the software, data and derived models in practice.



All water management data and models accessible in one place and for everyone!

Deltares,
WUR

Climate change asks a great deal from our water management. What to do in the event of drought, flooding or possible salinization? Thanks to the Dutch Hydrological Toolbox (NHI), water managers are able to calculate the effects of measures better and cheaper. Improvements by Deltares and Wageningen University & Research (WUR) further increased the effectiveness in 2019.

What will another dry summer demand from our water management? What measures are needed? To find answers to such issues, water managers want to calculate and simulate potential solutions, for support and acceptance. This can be done with the Dutch Hydrological Toolbox (NHI), a collection of software and data for developing water models on a national and regional scale. These models will enable them to see the impact of measures on the water in the soil, the deeper subgrade and the surface water.

Indispensable instrument

By basing models on the NHI, everyone uses the same high-quality data and software, says Timo Kroon, NHI Project Leader at Deltares. This makes it possible to compare results from various regions. “Besides, a centralised development and centralised management are more efficient than if parties were to create models for themselves.”



of consequences for groundwater levels over a period of decades sometimes took a whole month. Nowadays, it can be done in about five days.

Another improvement is the coupling of models for groundwater, surface water and the unsaturated zone. This allows consequences for those different 'layers' to be included in a single calculation. This provides a better insight into the effects of measures such as dynamic level management and the calculation of groundwater levels.

Also in 2019, a plan was developed to provide 'open access' to the NHI data and software. Water managers have their own data, but to identify the effects at a regional and national level, cooperation is needed, says Kroon. An open source instrument provides benefits for all water boards, other government bodies and businesses such as water companies and consultancy firms. "It is unique worldwide that this data and these calculation models will soon be available to everyone. In other countries they are often shielded or traded commercially."

An open access availability of data and software also realises cost savings. Kroon: "hydrological modelling costs about €7.5 million per year. By consolidating the data and software, we believe we can save 30%." Two more years are needed

to provide open access to the NHI. This must be ready by the end of 2021. Here too, Deltares and WUR are jointly working closely with government bodies, water managers and water companies.

International interest

On an international level there is a great deal of interest in the toolbox. For instance, a pilot was recently started by the governments of Argentina and the Netherlands to use the toolbox on the Argentinian pampas. They want to balance land use with the groundwater system better, especially for cultivating soja. ■

More info at: www.nhi.nu

Who: Deltares and WUR, together with VEWIN (water companies), KWR, provinces, water boards, the Ministry of Infrastructure and Water Management, the Ministry of Agriculture, Nature and Food Quality, and an increasing number of consultancy firms.

Duration: since 2006, further improved in 2019.

Budget: €250,000 annually for TO2/government grant (allocated to the NHI software, since it became open source in 2014). In 2019 and 2020, an additional investment of €200,000.

Follow-up: further development and open access in 2021.

The NHI has become an indispensable instrument for supporting the policy of national and regional governments in the Netherlands. A large number of consultancy firms now apply the software, data and models derived from it. In 2006, the NHI started as a WUR and Deltares development, commissioned by Rijkwaterstaat, STOWA and PBL. In the meanwhile, the number of parties involved has expanded considerably: VEWIN (water companies), KWR, provinces, water boards, the Ministry of Infrastructure and Water Management, the Ministry of Agriculture, Nature and Food Quality, and an increasing number of consultancy firms.

Faster, better and in the public domain

Thanks to the additional TO2/government grant, the NHI could improve even more with the appointment of hydrologists and data specialists in 2019. Deltares and WUR worked together on an aspect such as faster software for groundwater models (iMOD). Previously, the calculation

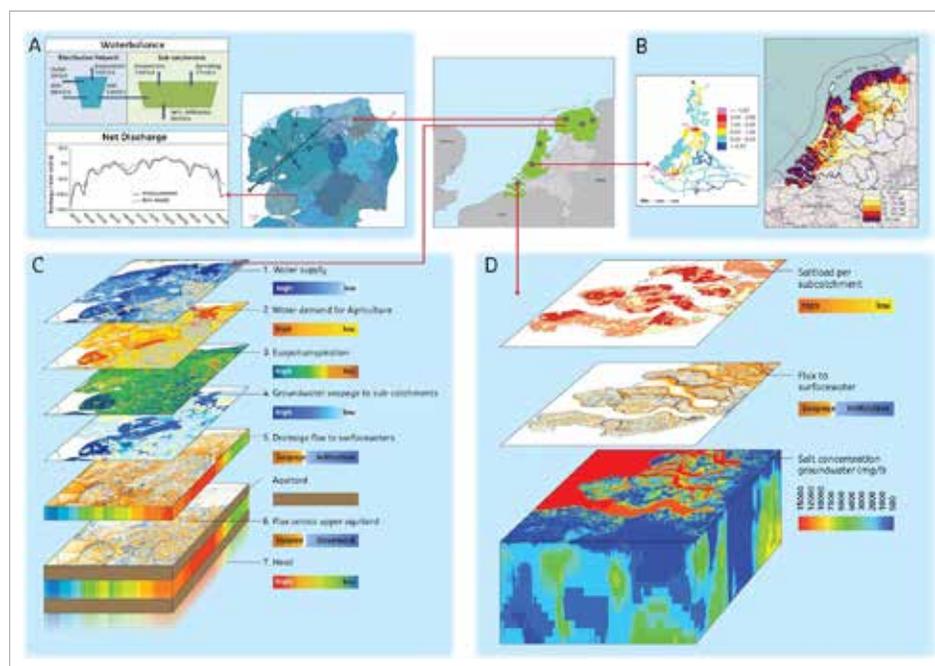


Figure 1: overview of NHI results: A) Water balance of sub-catchments; B) Salt in surface water system; C) Fluxes and heads in unsaturated and saturated groundwater; D) Salt concentration in saturated groundwater and salt flux to surface water.



Problem: To continue feeding the world's population in the long term, it is necessary for consumers to eat fewer animal proteins and more vegetable proteins. The transition does not appear to be so easy, because meat is a popular product among many people.



TO₂ Solution: WUR and TU Delft developed a meat substitute based on vegetable products that is similar in texture to meat.



(Expected) impact: A healthy balance between the consumption of animal and vegetable proteins is better both for humans and for the environment. Consumers will sooner switch to plant-based meat substitutes. The new technology is also attractive to market parties, since it is much cheaper and simpler than current techniques and it allows for new products.

New meat substitutes are 100% plant-based



WUR

A diet with fewer animal proteins and more vegetable proteins. This is a necessity to continue feeding the world's population. But consumers are reluctant. A new generation of meat substitutes should facilitate the turnaround. Thanks to new technology developed by Wageningen University & Research (WUR) and TU Delft.

The Western diet has changed drastically over the last fifty years. In the past, 40% of the proteins we ate were animal-based, nowadays that is 60%. Whereas the current production of meat requires a lot where it concerns usage of land, water and raw materials. Our health and the health of our planet benefit from a higher consumption of vegetable-based proteins and fewer animal-based proteins. For the time being, consumers prefer vegetable-based products that look like meat.

Replicating meat texture

Together with colleagues from TU Delft, researchers from Wageningen developed a method to make 'vegetable-based meat'. By using innovative Shear Cell Technology, ingredients from pulses such as soybeans were processed in such a way that a meat texture with the fineness and fibrous texture of a steak, was

created. The texture of this meat is finer than could have been achieved until now with available technology (extrusion). Professor Atze Jan van der Goot at WUR produced the first 100% vegetable-based steak. That was not an easy undertaking. "The texture of steak changes while cooking: being medium on the inside and crispy on the outside. It's really difficult to replicate that effect." The new product eliminates the need for animal-based ingredients such as egg or whey as a binding agent, and there are no size restrictions.

According to WUR, the new technique is much cheaper and simpler than the techniques used to make meat substitutes. Production costs only 10% of

This technology makes it possible to create other textures, such as pork



the energy used for meat. Moreover, the products become very different, says Van der Goot: "meat substitutes that are currently in the market look similar to chicken meat, or they are minced meat-like products. Our technology makes it possible to create other textures, such as pork."

Consumer behaviour

For protein suppliers and food manufacturers, there are plenty of opportunities to include new proteins into their product portfolio and to translate them into new and better products. WUR supports them by providing tailored recommendations, based on the latest scientific perceptions and technologies, and many years of experience in disciplines that are closely related to each other. WUR has also been researching consumer behaviour for more than thirty years.

Studies show that restaurant guests eat up to 113% more vegetables and up to 13% less meat or fish if the hospitality establishment offers this in an appealing way. The guest's appreciation stays the same or increases. The studies form part of Food Value Impact; a public-private partnership comprising nineteen knowledge institutes, businesses and non-profit organisations.

Bite

Van der Goot observed that producers are still very focused on replicating the bite and texture of real meat. Hopefully, this will change when most of us have switched to vegetable-based meat. "Perhaps the consumer will then be open to flavours and textures that really differ from meat." ■

Who: WUR in cooperation with businesses (machine builders, ingredient suppliers, food producers, hospitality establishments) and other research institutes, including TU Delft.

Duration: ongoing.



Problem: In dairy farming, minerals (soil, manure, feed) are not used optimally and burden the environment.



TO2 solution: WUR is developing the *KringloopWijzer* (recycling guide), an online tool for dairy farmers to efficiently use minerals.



(Expected) impact: Circular dairy farming. Better use of minerals in dairy farming improves the quality of soil, air and water. Since 2016, it has been mandatory for almost all dairy farmers to fill in the *KringloopWijzer*. This will enable them to gain financial benefits for good performances.



KringloopWijzer: benefits for dairy farmers and nature

WUR

Using minerals in the business (soil, manure, feed) as efficiently as possible. That is the essential element of circular agriculture and an important ambition of the dairy sector. The *KringloopWijzer* helps dairy farmers to do so. Since 2016, it has been mandatory for almost all dairy farmers to fill in this tool developed by Wageningen University & Research (WUR).

The *KringloopWijzer* identifies the environmental performance of the entire dairy farm. Thanks to open access software, dairy farmers can automatically read data and make calculations. The calculation modules developed for this purpose by WUR are continuously supported by the most up-to-date scientific data. A dashboard comprises six environmental indicators on a business scale: nitrogen surplus, ammonia, greenhouse gas emissions per kilogram of fat and protein corrected milk, percentage of permanent pasture, and percentage of domestic protein.

More crop yield

By focusing on these six indicators, the

dairy sector wants to work toward better soil, air and water quality. There is still enough room for improvement, like the flushing out of unused nitrogen in the form of nitrate into the groundwater. The substance can also evaporate in the form of nitrous oxide or ammonia. In addition, the percentage of protein in domestically produced fodder offers a perspective into the self-sufficiency of the own farm. The *KringloopWijzer* also provides areas for improvement. That could be beneficial for nature, but also for the dairy farmer himself. By using the tool, for example, the grass yield could increase, reducing the amount of manure to be disposed of or reducing the amount of fertilizer to be pur-

chased. If a farm actually manages to achieve a greater crop yield, it could also spend less on coarse fodder and feed concentrates.

Earning points

The dairy farmer can earn points from the milk processor by having a good nitrogen, phosphate and greenhouse gas performance. This earns a few cents per 100 kilograms of milk. If a farmer qualifies for a hallmark (such as *On the way to planet proof*), then this will yield even more financial benefit. Rabobank also gives discounts on interest rates to dairy farmers who score well on key figures in the *KringloopWijzer*. ■

More info at: mijnkringloopwijzer.nl

Who: WUR in collaboration with the dairy sector, the dairy industry, animal feed companies, information organisations *PPPAgroAdvies* and *Boerenverstand*, the Ministry of Agriculture, Nature and Food Quality, and the Ministry of Infrastructure and Water Management, among others.

Duration: ongoing since 2012.

How steel and soil can interact better



Problem: The Netherlands is faced with the biggest dyke reinforcement operation ever. It concerns strengthening about 1300 km of water restraints to comply with tightened safety requirements. Steel sheet pile walls, which are expensive and difficult to install, are needed for about 100 kilometres.



TO₂ Solution: Deltares developed and tested a concept based on installing thinner sheet pile walls in the middle of the dyke, to create interaction between the soil dyke and steel pile wall.



(Expected) impact: The Expertise Network on Flood Protection (ENW) in the meanwhile, uses Deltares' design of sheet pile walls as the new standard. By using the Deltares models, the thickness of the sheet pile walls can be reduced by 30%. This also reduces costs, partly because dyke reinforcement operations can be carried out easier and faster.



In Eemdijk a sheet pile wall was installed in a test dyke and failure was precipitated.

Deltares

Steel sheet pile walls have been used for a long time in water restraints in built-up areas. Thanks to the new Deltares software models, we now know that these walls can be a lot thinner. That is just as safe, cheaper and causes less nuisance during construction.

Large parts of the water restraints in the Netherlands will be strengthened in the coming years to comply with tightened safety requirements. It concerns about 1300 kilometres, for which reinforcement with steel sheet pile walls is required for 100 kilometres. It mainly concerns built-up areas, where strengthening with soil alone is not possible due to lack of space.

Strengthening each other

These steel sheet pile walls are expensive and difficult to install. Experts had already realised many years ago that it would be better to have the steel interact with the soil. Meindert Van at Deltares explains how it works: "instead of installing a thick metal wall in the dyke that independently stops the water, we want to construct a

thinner one in the middle of the dyke. This creates interaction between the soil dyke and the steel pile wall."

Software and test dyke

The idea was implemented with the help of a TO₂/government grant, and Deltares developed the strategies and software models. In the High Water Protection Programme of Rijkswaterstaat and the water boards, it was incorporated in the Project Transcendent Exploration on Macro-stability (POVM). In a large partnership of government bodies, knowledge institutes, engineering firms and contractors, a test was then conducted at Eemdijk on a test dyke especially built for this purpose. It showed that the models for interaction between the soil and steel were made sense.

By using the new models, the thickness of the sheet pile walls can be reduced by 30%. According to Meindert Van, this also reduces a third of the costs, partly because implementation of the dyke reinforcement is easier and faster. Moreover, there is less construction nuisance, because less heavy machines are needed. In the meantime, designing sheet pile walls in this way is now standard and has been documented in a practical guide which is recommended by the Expertise Network on Flood Protection (ENW). Its application has begun. Meindert Van: "internationally, this development has showcased the Netherlands in the field of dyke protection." ■

Who: Deltares in collaboration with government bodies, knowledge institutes, engineering firms and contractors.

Duration: from initial idea to design guide: ten years.

Budget: €400,000 TO₂/government grant on a total of €8 million for 2017-2019 (mostly for the field trial).

Follow-up: models are now used for application.



Problem: Finding the right combination of drugs for HIV patients is difficult. Patient data helps to predict how well a drug will catch on, but because of privacy laws, it is difficult to share this data.



TO2 Solution: TNO, the University of Amsterdam and the National Research Institute for Mathematics and Computer Science (CWI) developed an encryption method that enables physicians to use sensitive data without ever seeing the details.



(Expected) impact: Optimum treatments for HIV patients will reduce side effects, improve the quality of life and possibly reduce the cost of drugs. The method could also improve other complex treatments, such as type 2 diabetes.

Encrypting patient data to decipher proper HIV treatment

TNO

Treating HIV is complex: the wrong treatment causes side effects and can make the virus mutate faster. The National Research Institute for Mathematics and Computer Science (CWI), the University of Amsterdam and TNO have developed a system that helps physicians find the right combination of drugs.

There are about 23,100 HIV patients living in the Netherlands. The treatment consists of a combination of different drugs that inhibit the virus and must be precisely adapted to the patient. That is because there are millions of HIV variations and there are many different drug treatments. TNO researcher Thomas Attema explains: “the genetic structure of the virus determines how effective drugs are. This may vary from patient to patient. Besides, the virus may mutate and become resistant under the influence of drugs. That process should be postponed for as long as possible, but it is a careful balancing act.”

Data

How does a physician determine which drugs work best for an individual patient? With data. Clinical Decision Support Systems (CDSS) support clinicians in making complex decisions about the treatment of HIV patients. These systems try to predict the effectiveness



of treatments based on results from clinical trials.

The more data, the more accurate the prediction. Attema: “you preferably want to use data about the treatment of other patients. How long they used a particular drug before the virus mutated, for example, or what side effects occurred. That is highly valuable information. Unfortunately, this privacy-sensitive data is difficult to share with other hospitals or practitioners.”

In theory, a trusted third party can view patient data, predict the effectiveness of a future treatment, and share the result with the physician. Because of privacy legislation alone, this is not a solution that is feasible.

Barrier

The CWI, University of Amsterdam and TNO have jointly developed a way to safely use privacy-sensitive patient data in the Clinical Decision Support System (CDSS). The three entities worked on

a CDSS that works with encryption i.e. cryptography. It works thanks to Secure Multi-Party Computation (MPC), a cryptographic protocol. “We also call it cryptomagic,” says Attema. “If someone intercepts the data, they cannot do anything with it.” With MPC, an important barrier in finding the optimum HIV treatment has been overcome.

Improved treatments will reduce side effects, improve the quality of life, and may perhaps ensure cheaper drugs in the future. Attema: “there are many different drugs for all stages of the virus. Some are a lot cheaper. The longer a patient can use it, the more economical it becomes.”

Extra layer

Calculations are performed on a large, encrypted database and no data exchange takes place. Only the results of the analysis are shared. To ensure that users trust this outcome, researchers have added an extra layer, which provides evidence that this calculation has actually been carried out.

Attema: “this study shows that cryptography works in the medical field. In our proof of concept, we worked with fictitious data of 20,000 patients. This is more or less the number of HIV patients in the Netherlands. Within 24 minutes the system provided analysis results. In a next phase, we’d like to improve the system by testing with real patient data.”

New method of working

In future, this system will require physicians to use a new method of working, says Attema. “Clinicians often know a lot about their own patient

records. That valuable data must be entered so that others can use the data to improve treatments.”

Cryptography also has the potential to improve other treatments such as type 2 diabetes. Attema: “comparable systems can help with complex treatments where many different drugs or variations of a disease exist.”

To apply Multi-Party Computation (MPC) is still not free of charge. In addition, there are many different cryptographic protocols, each with advantages and disadvantages. This means that for each application, from HIV to diabetes, it is necessary to look at which protocol works best. However, the advantages of improved treatments outweigh these disadvantages. ■

Who: Philips, the National Research Institute for Mathematics and Computer Science (CWI), the University of Amsterdam and TNO.

Duration: 15 months, began in summer 2017.

Budget: €588.500

Follow-up: the encryption method has been proven to work. Follow-up research with real patient data is needed to further improve the method. After that, it can also be used for other complex treatments, such as type 2 diabetes.



Problem: The Netherlands is not well prepared for infectious diseases transmitted from animals to humans (zoonoses). This is a risk to public health.



TO₂ Solution: To prevent epidemics caused by zoonoses in future, WUR prepared cost-benefit analyses of conceivable measures. All additional factors have been identified.



(Expected) impact: The Netherlands is better prepared for epidemics in which animals are the source of infection, which could be prevented in the future. The Ministry of Agriculture and Food Quality is now making use of the WUR cost-benefit analyses. For instance, it is now mandatory for professional goat farmers to vaccinate their goats.

Inhibiting Q fever and Lyme disease



WUR

For infectious diseases such as Q fever and Lyme disease, animals are the source of infection. Virologists at Wageningen University and Research (WUR) are studying how better to respond to these zoonoses. When drawing up the intervention analyses, they looked at both the biological factors and at human behaviour. Climate change is also proving to be a factor.

In 2008 and 2009 there was a severe epidemic of Q fever in the Netherlands. This infectious disease has long been considered a risk during the kidding season of dairy goats and lambing season of dairy sheep. Generally, around fifteen people were infected each year, especially goat farmers and their family members. Now the disease suddenly affected hundreds of people at once: 95 patients died of Q fever and many others became chronically ill. How can a zoonosis occur so suddenly? And if that can be determined, can it be predicted and influenced? These are the research questions that WUR virologist Wim van der Poel posed. All additional factors were thus identified.

Social factors

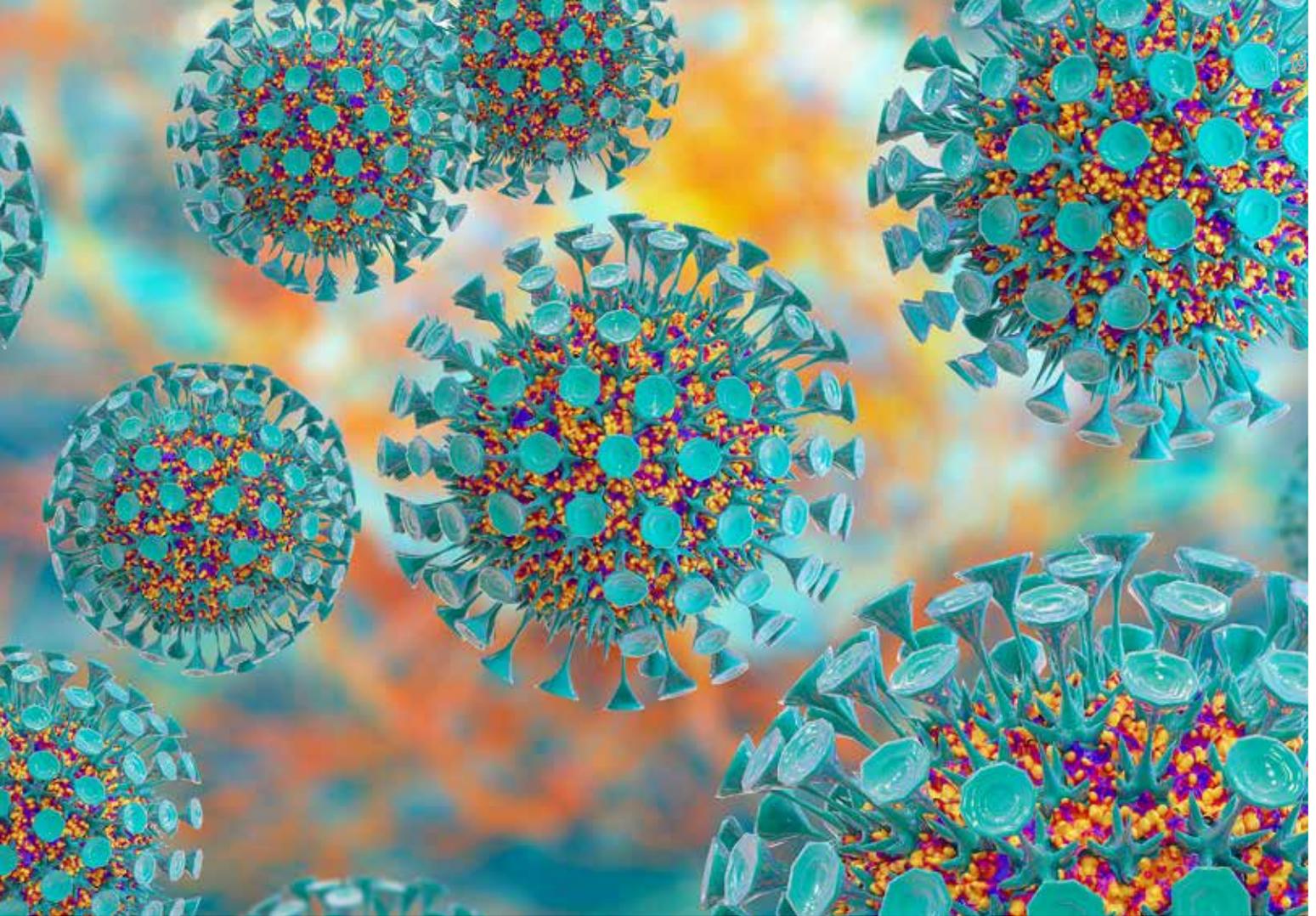
WUR mapped out which aspects require intervention to prevent future epidemics. They did so not only for

Q fever, but also for rabies and Lyme disease.

The latter is caused by pathogenic bacteria and transmitted via infected ticks. Due to climate change, Lyme disease's dissemination area gradually spreads towards the north. There is no vaccine for Lyme disease. Possible measures can range from the reduction of ticks by adapting the vegetation of nature reserves, to more frequent monitoring of visitors or dogs or closing nature reserves to the public.

According to Van der Poel, the number of infections can already be significantly reduced by relatively simple means, such as public information. "We have noticed that the public is increasingly aware of the chance of zoonoses, which does not always mean that they also take appropriate measures, for example, by wearing long sleeves and long





New research needs to better predict which pathogens are a threat in the future

trousers.” Yet he sees a shift in the ability to accept. “In cases of newly emerging diseases, people are usually more willing to follow advice than in cases of diseases that have existed for a long time. Those are the types of social factors that must also be taken into account.”

The researchers made a cost-benefit analysis of conceivable measures, which included weighing up the ‘burden of disease’, such as the risk of lifelong disability. Protection products against Lyme are also being developed, and these are also being examined in relation to the costs and how effective they are. The Ministry of Agriculture and Food



Quality is now making use of these cost-benefit analyses. For instance, it is now mandatory for professional goat farmers to vaccinate their goats.

Research of microbes

A new study is now ready to start to better predict which new pathogens may be a threat in the future. In doing so, researchers not only include biological and socio-economic factors, but also the microbes that are naturally present in humans or animals. Those microbes are collectively called the microbiome. Van der Poel: “we suspect that this microbial composition can play a role in explaining individual differences in susceptibility to infectious diseases.

The majority of microbes that we carry with us are completely innocent.

The important question is: why a small amount of pathogens can suddenly get the

upper hand.” A new and exciting field of research. “If we understand better how this palette of micro-organisms is created, we can better combat the transmission of infectious diseases and the emergence of antibiotic resistance.” ■

Who: WUR in collaboration with infectious disease experts at the National Institute for Public Health and Environmental Protection (RIVM), the Municipal Health Service (GGD), the Faculty of Veterinary Medicine, veterinarians at the Netherlands Food and Consumer Product Safety Authority (NVWA)/Veterinary Incident and Crisis Centre (VIC) and the Animal Health Services (GD).

Duration: ongoing.

Follow-up: research into existing and newly emerging zoonoses as a result of climate change.



Problem: Developing new drugs takes a long time and costs are immense. It is often late in the development process that a candidate drug proves to be not safe or is less effective than expected.



TO2 Solution: TNO developed a combination of two techniques – microtracing and Accelerator Mass Spectrometer technology – to test the effects of new drugs much earlier in the human body.



(Expected) impact: Contributing to more efficient care. The TNO innovation can reduce the development process of new drugs by years. It also reduces the use of laboratory animals. Besides, pharmaceutical companies can save millions later by investing more in an early stage.



A set-up of microtracing technology equipment.

Getting drugs from the lab onto the shelf faster

TNO

The path taken by a new drug – from idea to pharmacy – takes an average of ten years. TNO works with the pharmaceutical manufacturer Pfizer to drastically accelerate this process.

Researchers test new drugs often and for a long time before they may enter the market. Initially in the lab and finally on human guinea pigs. It is often late in the development process that a candidate drug proves to be not safe or is less effective than expected. That is why developing new drugs takes a long time and the costs are immense. The Council for Public Health and Society identified these problems in a report at the end of 2017. They believe that the process can be faster, better and cheaper.

Microtracing

One way to do this is with TNO's Accelerator Mass Spectrometer (AMS) technology. The US pharmaceutical

company Pfizer has been working on this for two years now, and they're successful too: Pfizer has concluded four studies and new studies have been scheduled. How does it work? At an early stage, researchers add a very low dose of the drug's radioactive substance to the usual dosage for a small group of healthy volunteers. This is called microtracing. Then they use an AMS – a sensitive measuring method – to examine what the human body does with a drug and how the drug leaves the body. The combination of these two techniques reduces the use of laboratory animals and – perhaps most importantly – shortens the development process of new drugs. This approach makes data on

concentration and effects of substances available years earlier than conventional methods. This will enable researchers to accurately assess much faster whether a candidate drug has a chance of success.

Fast analysis

TNO is the only organisation in Europe that uses a biomedical AMS. The institute has already developed many services in the field of drug processing in the body. Moreover, TNO can quickly analyse samples and provide feedback to Pfizer's clinical team.

AMS and microtracing change the order of conventional drug development processes considerably. Therefore, switching is still exciting for pharmaceutical companies. Once they dare to invest more at an early stage, they can save millions or even billions at a later stage. ■

Who: TNO and pharmaceutical company Pfizer.

Duration: 1–3 months.

Budget: from €100,000 to €600,000

Follow-up: in the meanwhile, TNO works more extensively with Pfizer on pre-clinical studies, among other things.



Problem: The dark web is loved by criminals: they believe they are anonymous there and are therefore elusive. They trade in special markets – obscure markets – with illegal goods such as drugs, weapons or child pornography in exchange for digital currencies.



TO₂ Solution: TNO develops techniques to link anonymous digital wallets to criminals and their organisations.



(Expected) impact: Contributing to the fight against crime. With TNO's help, criminals can be found online and can therefore be prosecuted offline.

Catching criminals on the dark web

TNO

Criminals believe they are anonymous on the dark web, so they feel safe. With the help of TNO, the government is gaining more and more insight into this protected part of the internet. They link criminals to 'anonymous' digital cash flows and illegal goods.

Internet is like an ocean. The visible part where you browse, for example through Google, is like the very tip of an iceberg. A large part of the internet is 'under water'. This is called the deep web. The deep web is not visible to regular search engines and only accessible to people who have the exact web address or a username with password. For instance, this is where databases of companies or organisations are located.

Dark web

Part of the deep web is concealed even further. This 'obscure' internet is called the dark web. You cannot get there with regular browsers like Chrome, Firefox or Edge. This requires special software, such as the TOR browser. Users of this network are as good as anonymous and therefore difficult to track down.

That makes the dark web popular with criminals. They trade in special markets – obscure markets – with illegal goods such as drugs, weapons or child pornography in exchange for digital currencies. Payment can be made relatively anonymously with cryptocurrency such as bitcoin. That is why criminals believe they are elusive on the dark web.

Specialist knowledge

To combat crime on the dark web, TNO cybercrime researchers work closely

with investigation services and the Public Prosecution Service. TNO has experts with specialized knowledge about obscure markets and associated payment methods such as bitcoin and monero. Researchers are also working on techniques to map these digital money flows. The difficulty is to link the anonymous digital wallets to the criminals and their organisations. Fortunately, there are ways to do this. Sooner or later, users have to exchange their digital money for real money or goods. Then they lose their anonymity and are vulnerable. In this way, applied research makes a practical contribution to the fight against crime. Conversely: the researchers draw on anonymised information from judicial authorities and the police, which is normally inaccessible to them, and can thus improve their techniques. ■

Who: TNO, Public Prosecution Service and investigation services.

Duration: 2018 – 2021.

Follow-up: this research is part of the wider cooperation between TNO and investigation services.





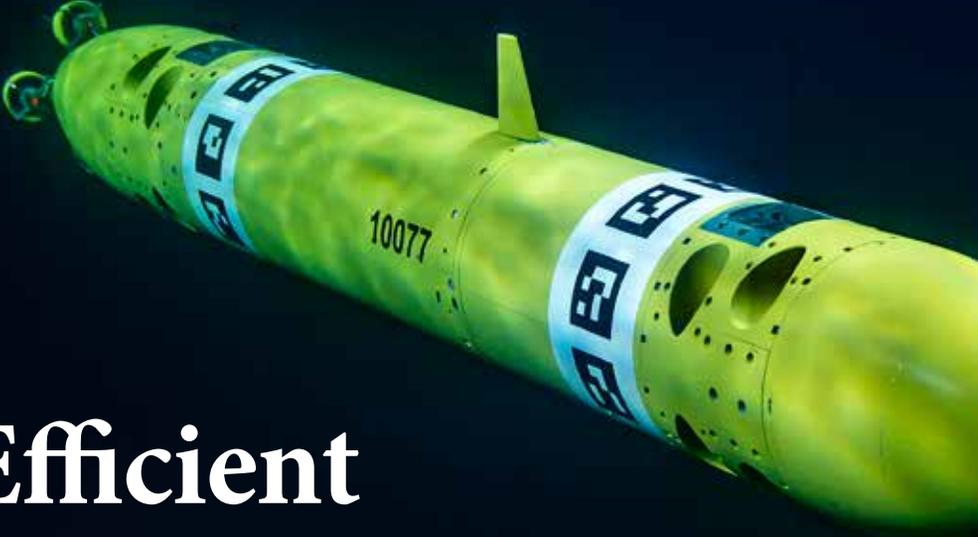
Problem: Increased use of autonomous systems is necessary, as it is getting increasingly difficult to find qualified personnel. Furthermore, autonomous systems can cost-effectively take over dull, dirty or dangerous jobs from people.



TO2 Solution: In collaboration with TNO and NLR, MARIN is starting various projects for research into autonomous sailing, such as development of the mAUV (modular Autonomous Underwater Vehicle) an underwater vessel that will be carrying out assignments autonomously.



(Expected) impact: In the long term, it ensures more efficient shipping and now enables new applications, such as the monitoring of major underwater power lines from wind farms that are increasingly becoming our primary source of energy supply.



Efficient deployment of vessels to sail autonomously

MARIN,
TNO, NLR

Greater autonomy ensures the efficient deployment of vessels: from independent inspection of quay walls to the detection and disabling of sea mines. MARIN developed the mAUUV, the first step towards autonomous sailing.

Autonomous vessels? It's already in its name: just like self-steering cars, they are vessels that sail independently and carry out assignments without a crew. It is expected that autonomous sailing will eventually also contribute to a more efficient deployment of ships. Autonomous systems can help people perform "dull, dirty & dangerous jobs". And in some cases, there is a fourth 'd': "distant". Those are situations where control by a person is not an option and remote-controlled and monitored systems take over. One of the often-mentioned reasons for introducing autonomous vessels is to improve safety. According to the statistics, people could be involved in

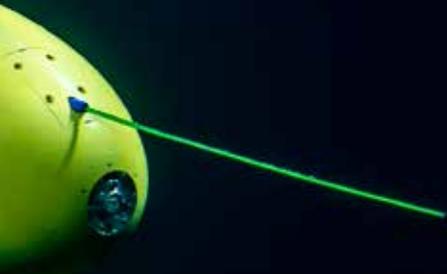
accidents at sea relatively often, either directly or indirectly, and many accidents are also prevented precisely because there are people on board. Unfortunately, no statistics are maintained of the latter. "The aim is to achieve a comparable level of safety," says Egbert Ypma, MARIN's Autonomy & Decision Support Team Leader.

Under water: mAUUV

In collaboration with TNO and NLR, MARIN has started various projects for research into autonomous sailing. Last year, the Research Institute in Wageningen developed the mAUUV: the modular, or multifunctional, Autonomous Underwater Vehicle. This underwater

vessel has the appearance of a torpedo and can accurately track a course under water. In addition, it has the ability to stay in its place in currents and waves. Autonomous functions will be added next year. "The combination of these features allows for a multitude of applications," says Ypma. "We will execute various scenarios in the next phase. One of these scenarios is that a torpedo launched from an underwater vessel can return independently to the launch tube." Many applications are possible. This not only includes the underwater inspection of quay walls and ships, but also mapping the seabed, which can play a role in the detection, identification and disabling of sea mines. Autonomous underwater patrols are also possible, to guarantee

A bridge simulator was used in a test to compare decision-making behaviour of an autonomous system with a 'human' captain



The mAUV: modular, or multi-functional, Autonomous Underwater Vehicle



This test vessel is deployed to carry out tests with autonomous systems.

the safety of navigational routes and piping. To enable these long-term missions, underwater charging of the batteries is very important. This also applies to the ability to check position and speed properly.

At the water's surface

Small vessels are used to take the initial steps. Large ships out at sea are still far from being able to sail autonomously. To gain relevant knowledge – under the banner of Joint Industry Project Autonomous Shipping – nearly twenty companies, knowledge and educational institutes and government bodies have worked together to research autonomous sailing. “For this project, we have done tests on our bridge simulator to compare decision-making behaviour of an autonomous system with a ‘human’ captain,” says Egbert Ypma.

In the past year, MARIN developed and deployed a vessel (RHIB) to carry out tests with autonomous systems. This

test vessel plays an important role in evaluating the automation systems on board of autonomous vessels. An example of this is the decision-making algorithms that must prevent collisions. They must behave predictably, taking into account the regulations for preventing collisions at sea (COLREGS). If necessary, they should be able to deviate from this, deal with uncertain information, and be flexible enough to cope with complex situations.

Data exchange

The introduction of autonomous maritime vessels not only involves the vessel itself, but also the ‘environmental factors’ cyber security, ownership of the data, and standardisation of data exchange. The latter is necessary to monitor these ships, but also to enable safe and efficient traffic management. Several parties must be involved in this: the coast guard, pilotage, port services, the ship itself, shipping companies, and the shore station which monitors the autonomous ship and can take over the controls. Collaboration

and the role of these parties will change. Key research questions are: how to manage this properly, what information does each party need, how should this be made available and presented, and who is responsible for what? Here, MARIN’s simulation models and facilities are an indispensable instrument. ■

Who: MARIN, in collaboration with other parties (government, research institutes TNO, NLR, the national & international maritime business community).

Duration: mAUV was developed in 2018 and will receive new autonomous applications in 2020 (and the years thereafter).

Budget: €800,000 to date. The amount of budget needed for follow-up projects is reviewed each year.



Problem: Maintaining aircraft is crucial to passenger safety. Aircraft checks require a great deal of time and knowledge. As more and more people fly, more aircraft and well-trained technicians are needed in the future.



TO2 Solution: NLR devised three innovations to maintain aircraft smarter. They increase aircraft availability by reducing time on the ground.



(Expected) impact: Smarter maintenance increases aircraft deployability. This reduces the need for additional technicians and aircraft. This means that the increasing demand for flights can be met and quality and safety remain guaranteed.



Flying safely and efficiently starts on the ground

NLR

Aircraft are often on the ground undergoing maintenance. NLR is developing three tools for smarter aircraft maintenance, allowing more flying time.

Checks, repairs, servicing and inspections of individual parts; servicing and checking aircraft requires a great deal of time and knowledge.

As more and more people fly, more aircraft and well-trained technicians are needed to maintain them in the future. The lack of technical staff and the increasing demand for flights places high demands on civil and military aviation, also to ensure that this does not compromise quality and safety.

Three innovations

What if they do not need to expand their fleet, by allowing existing aircraft

to fly more often? NLR is developing three innovations that increase aircraft availability by reducing time on the ground.

1 Coordinating maintenance schedules to flight schedules, instead of the other way round.

Schedules for major service maintenance are easy to plan but keep aircraft on the ground for a long time. That is why NLR is developing FlexPlan: flight schedule-driven maintenance planning. FlexPlan works with artificial intelligence (AI). The software reads and interprets maintenance scheduling. It divides major service maintenance into small, optimally clustered task packages and schedules them between flights. This improves the availability of an aircraft.

2 Faster detection of failing parts and predicting repairs. Aircraft technicians who need to resolve defects or complaints often have no insight into the prior history. Failure Diagnostics using eXplainable Artificial Intelligence helps them make the correct diagnosis. This smart software, called FD XAI, looks at failure modes of previous repairs and air-

craft usage to determine the actual failure using artificial intelligence. The software then explains why it detects the one failure and not another. This helps technicians understand the diagnosis and to trust it.

3 Assessing the impact of maintenance costs better.

Maintenance staff, operators and aircraft owners find it difficult to estimate the cost of maintenance and the fleet's availability. Maintenance is uncertain: it is unknown in advance when a complaint occurs and what the consequences will be. Besides, decisions on maintenance operations often have several effects. Aircraft availability and resource estimator (AARE) helps managers make decisions in the event of uncertainty. ■

Who: NLR in collaboration with users.

Duration: 2017 until a final date to be determined.

Budget: from own resources.

Follow-up: NLR is discussing further development of the tools in collaboration with some users.



Problem: Making flexible display screens is expensive and complicated. Often something goes wrong during the manufacturing process, which causes many screens to be discarded.



TO2 solution: New technology developed by TNO to create flexible, foldable or even fully rollable smartphones.



(Expected) impact: Allows certain layers of OLED display screens to be manufactured 50 to 100 times faster, resulting in fewer manufacturing defects and higher yields. Aside from smartphones, on which the focus now lies, this technology may be used in future to manufacture OLED TVs.

Display screens re-invented

TNO

Telephones with bendable screens already exist. The technology to produce them is not yet fully matured. With the help of TNO, a start-up in Eindhoven is developing a machine that can make flexible display screens much faster and better.

The smartphone's screen is made up of different layers. Display screens increasingly contain Organic LEDs, i.e. OLED, which are very thin. The thinner the layers, the easier to bend them. But how do you make the layers ultra-thin? What's more, how do you make them strong enough, affordable as well as suitable for mass production?

SALD

Various tech companies are examining this question. For more than a decade, TNO has worked on a solution at Holst Centre in Eindhoven. They developed an absolutely new technology: Spatial Atomic Layer Deposition (SALD). This allows certain layers for OLED display screens to be manufactured 50 to 100 times faster than with 'conventional' atomic layer deposition. Hence, plasma is the magic ingredient. That adds extra energy and thus accelerates the process. What's more, SALD can reduce manufacturing errors. This means that far fewer broken screens need to be discarded. Improvements of a few percent can already result in tens of millions of euro more in revenue. However, most screen factories are already full of machines. In this industry, technology must first prove itself in



SALDtech is negotiating with all major OLED manufacturers to have this technology tested

every way possible before a new machine is incorporated into the production line. To accelerate placing innovations in the market, TNO uses the Tech Transfer Programme. SALDtech is a start-up ensuing from this. TNO is one of the shareholders in the start-up and is closely involved in further development of the technology. SALDtech is currently developing a SALD manufacturing machine for OLED display screens for smartphones. SALDtech is negotiating with all major OLED manufacturers to have this technology tested. The technology has great potential, but needs to develop at the right pace. For

example, the company must ensure that there will be enough service technicians available in the Asian countries where the bulk of the machines will be installed.

Rollable smartphones

Initially, manufacturers will use SALDtech's machines primarily to produce flexible, foldable or even completely rollable smartphones. The technology offers so many savings in time and costs that it can also be a worthwhile option for manufacturing OLED TVs. ■

Who: TNO and start-up SALDtech.

Duration: the company SALDtech was established in 2018.

Follow-up: by making use of SALD, manufacturers can produce flexible display screens as well as flat screens for a wide range of devices faster and cheaper. In future, manufacturers might also have a different outlook on the manufacturing process of conventional display screens.



Problem: Plants are not adequately equipped to deal with weeds, diseases, pests and climatic changes without pesticides. A solution is needed that helps growers to be less dependent on chemical crop protection.



TO₂ Solution: WUR is engaged in a partnership (NPEC) that makes use of key technologies such as robotics, sensor technology and bioinformatics to identify how plants behave under different circumstances and the role that genetics plays in this (digital phenotyping).



(Expected) impact: The research results are used to develop smart tools for sustainable agriculture that reduces the growers' dependency on chemical crop protection. Aside from gaining knowledge about sustainable cultivation measures and systems, research also leads to improved plant varieties. For instance, they have adapted better to changing climatic conditions, or they meet the higher demands expected from plant species, such as higher yields in more sustainable cultivating conditions.



Heading for more robust plants

WUR

What factors play a role in the growth of plants in the field? The answer to this question could lead to more robust species, requiring less crop protection. In a state-of-the-art research facility, Wageningen University & Research (WUR) is examining how plants perform under different circumstances.

To keep plants healthy, crop protection products are needed, but preferably as little as possible. The agricultural sector has made considerable progress in this regard over the past few decades. In many cases the dosage could be reduced and the protection products became less harmful to the environment. This approach has reached its limit, so it is time to look at other options. Alternative pesticides, for example. Preferably without reducing the crop yield. At present there are no potato varieties that are resistant to fungi (*P. infestans*) and nematodes (*G. pallida*). In a state-of-the-art research facility of the Netherlands Plant Eco-phenotyping Center (NPEC), researchers are unravelling the genetics behind the interactions between the environment and plant genes. This is called phenotyping. Precise studies of plant performance in climatic chambers and greenhouses as well as in the field, reveal the relationships between



“GROEN”

The results of NPEC’s fundamental research are put into practice in the project “GROEN” (*Gewasbescherming Robuust Optimaal Economisch & Natuurlijk* which means ‘robust optimum economic & natural crop protection’). A public-private partnership between WUR (coordinator) and growers, seed suppliers, processors of arable products, producers of plant protection products and nature organisations. Together, they develop tools for sustainable open field cultivation. These are then tested at the experimental site for AgroEcology and Technology in Lelystad.

relevant factors. This concerns both biotic (microbial interactions, competition, disease) and abiotic (light intensity and quality, nutrients, temperature, moisture, pH content in the soil and CO₂ level in the atmosphere) factors.

New domain

At the NPEC facility, information about the plant phenotype is collected by automated systems. Digital phenotyping of plants is a relatively new domain within plant sciences. In identifying anatomical, physiological and biochemical properties, researchers use key technologies such as robotics, sensor technology and bio-informatics. To gain a better understanding of the reaction of plants to their environment and its genetic control, NPEC performs large-scale and accurate monitoring to generate and collect the necessary data. This could be the interaction between plants and the microbiome (microorganisms such

If new genes are found, then this could improve varieties

as bacteria, viruses and yeasts), the interplay of plants, plant diseases and exposure to a multitude of variable abiotic environmental conditions, such as light quality, radiation levels, nutrient supply, temperature, humidity, pH content in the soil, and CO₂ level in the atmosphere.

Quinoa

NPEC works with six modules to measure the phenotypes correctly. Each offers specific possibilities to study the plant environment interaction. Ranging from the molecular level to crop growth in the field. If new genes are found, then this could improve varieties. This has, for example, enabled them to adapt better to changing climate conditions,

and they are able to meet the higher demands expected from plant species, such as higher yields in more sustainable cultivating conditions. Studies include for example, examining the (high) salt tolerance of various quinoa varieties. In ‘normal’ plants, a high uptake of salt causes the plant to wilt. Research should reveal the secret of this plant species. ■

More info at: www.npec.nl

Who: NPEC, a public-private partnership between WUR, Utrecht University and NWO (the Dutch Research Council).

Duration: ‘GROEN’ public-private partnership 2017-2021, NPEC since 2018.

Budget: TO2/government grant in a consortium with other financiers.



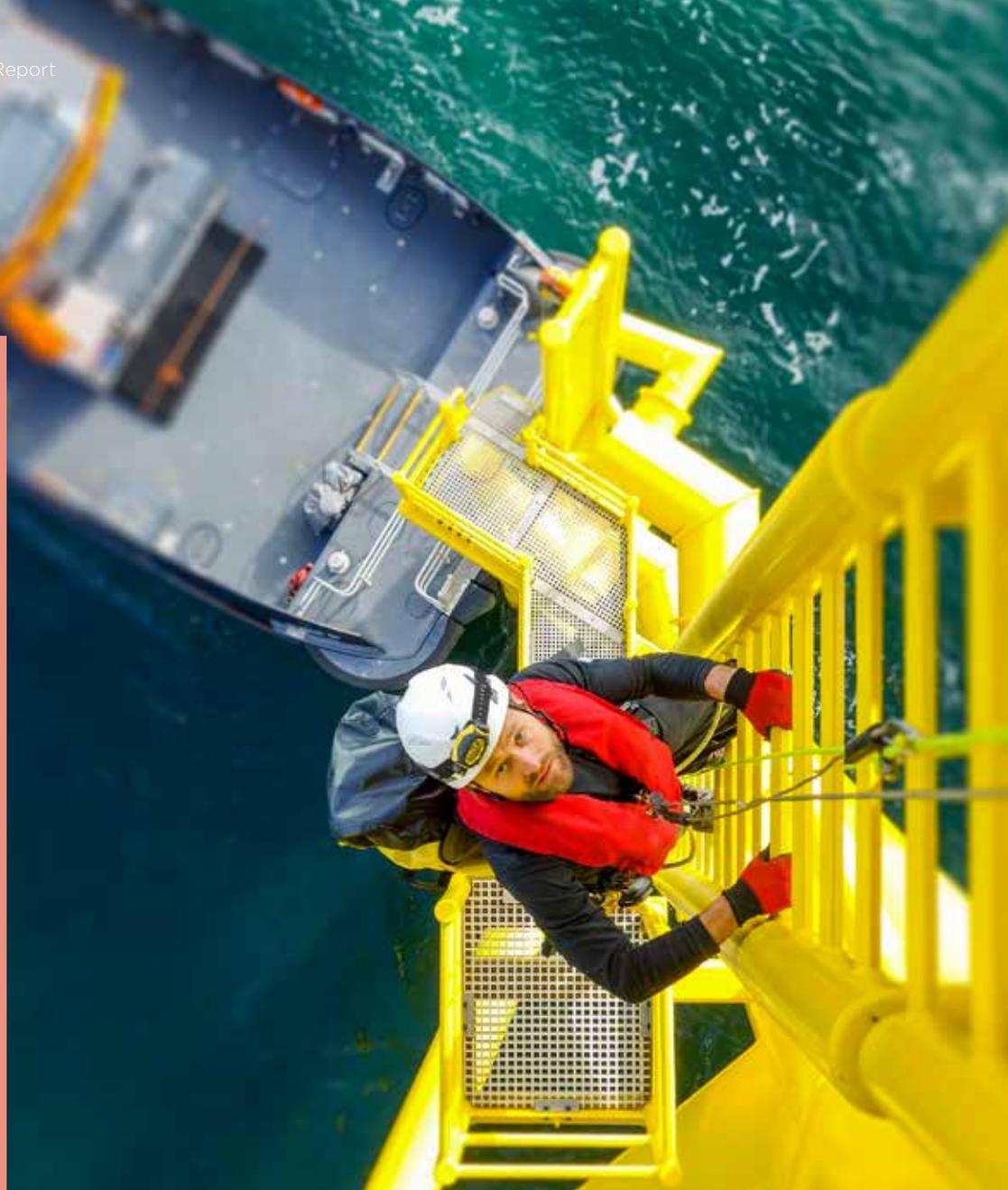
Problem: The share of wind energy in the Netherlands and with it the number of offshore wind turbines, will increase considerably in the coming years. Inspection and maintenance of offshore wind turbines, however, costs a great deal of time and money. A smart solution to this maintenance issue is urgently needed.



TO₂ Solution: Together with partners such as ECN part of TNO, TU Delft and Hogeschool Zeeland (university of applied science), NLR is working on a drone equipped with the latest sensors, which is controllable from a ship. The drone is able to independently perform inspections and repairs on wind turbine blades.



(Expected) impact: The drone ensures that maintenance of wind turbines becomes cheaper and more efficient. Data collected by the drone can help predict when maintenance is needed in future and prevent turbines from stopping unexpectedly.



Drone as a new inspector of offshore wind farms

NLR, ECN
part of TNO

In 2020, there are 3,240 wind turbines located in the North Sea. Some are located more than a hundred kilometres away from the coast. Maintenance is expensive and time consuming. The Royal Netherlands Aerospace Centre (NLR) is working on a drone that can independently inspect the white blades and is able to repair damage.

The drone should not only be able to fly accurately. It must hover steadily, land on the blades and even drive around on them

ists are needed, for instance: two or three men have to descend on ropes along the turbine blade, sometimes at a height of 120 metres.

What if you can inspect and repair the blades from ground level? NLR is working with sixteen parties on an ambitious drone – a kind of unmanned helicopter – for Automatic Inspection and Repair of Turbine Blades (AIRTuB). This can be controlled from a ship.

The drone flies to each wind turbine and inspects the blades with special sensors. The data is stored, which makes it easier to predict when maintenance is needed.

Steady hovering

The plan sounds simple, in practice it is complex. Joosse: “the drone should not only be able to fly accurately. It must hover steadily, land on the blades and even drive around on them, and do all of that without blowing away.” That is a high demand for a prototype. NLR is building the drone and Hogeschool Zeeland is working on a crawler; a system underneath the drone with which it can drive over the blade.

“We are talking about a giant object of as much as two by two metres,” says Joosse. “The drone has to carry various sensors and easily weighs 40 kilos. To land something like this on a narrow blade at a height of 120 metres, from a small boat on rough seas... that is almost like landing on the moon.”

The drone is equipped with several cameras to create an accurate 3D image of the outer layer. In addition, it has a sensor that acts like a kind of echo to inspect the inner layers. To do so, it must touch the blade.

Joosse: “NLR has been making such sensors for aviation inspections for many years. Together with partners such as TU Delft and ECN part of TNO, we are now trying to make these as small and as light as possible so that they fit underneath a drone.”

Landing automatically

The idea is that these gadgets enable the drone to ultimately determine its own position so it can land automatically. But for the time being, the pilot still controls the drone, says the engineer. “We are first testing it at NLR’s drone centre. That is where it must land on a turbine blade. The next phase is testing at an onshore wind turbine. Finally, we will take a boat out to the sea to test the drone at Amalia, a wind farm off the coast of Scheveningen. We hope to complete all these tests within three years.”

The data collected by the drone will be used to make a model of erosion. “The rate at which a blade wears at a particular location is still unknown. We are going to place a blade in our wind tunnel and study how damage develops.” NLR will combine this with the drone data in a computer model. This allows you to predict damage development and to match up inspections and maintenance accordingly.

“Preferably, you plan such maintenance on days that the wind has died down. There could be harsh conditions out at sea. This drone should prevent a turbine from stopping unexpectedly and sometimes you have to wait for days for the wind to die down for repairs. That energy would go to waste.” ■

Offshore winds are strong and frequently: ideal conditions for generating green energy. The Netherlands and other European countries are rapidly constructing offshore wind farms to supply households with renewable electricity.

The wind turbine’s blades wear from the impact of rain, ice and salt. For instance, pits and gouges in the leading edge of the blade or damage to the various synthetic composite layers in the structure of a blade. “This will cause the blades to spin more slowly and eventually damage the generator or mechanics,” explains Martin Joosse of NLR.

AIRTuB

Inspection and maintenance of offshore wind turbines is vital, but costs a great deal of time and money. Several special-

Who: NLR, ECN part of TNO and fifteen partners including Eneco, TU Delft, three universities of applied science, and various businesses and foundations.

Duration: September 2019 to December 2022.

Budget: €4 million, of which almost €1 million for NLR’s grant.

Follow-up: eventually NLR wants to develop the drone so that it can independently repair wind turbine blades. One of the project partners, QLayers, is already working on a coating that the drone can spray on the blades for repairs.



Problem: (1) it is difficult to perform blood tests quickly and without a laboratory or electricity; (2) unusually shaped lenses and mirrors e.g. for aerospace, are impossible to measure; and (3) in the manufacture of chips, contamination with the tiniest particle already leads to an unusable product. But that is not visible to the naked eye.



TO2 Solution: TNO is working with TU Delft on the development of light-based technology: photonics. This is (1) the basis for an optical biosensor that can make a diagnosis with a drop of blood; (2) the NANOFEMOS measuring instrument for freeform optics; and (3) particle scanner Fast-micro that can detect the tiniest impurities.



(Expected) impact: Technology for future earning capacity. The Netherlands develops a great deal of knowledge and innovations in the field of photonics. The photonic market is expected to grow by 40% worldwide in the coming years and already represents 300 Dutch companies with an estimated total turnover of more than €4 billion.

Light: the solution to almost everything

TNO

Photonics. The Netherlands invests a great deal in photonics. It is a priority focus of the coalition agreement and there is even a National Photonics Agenda. What makes this technology so special? This can be seen in three actual applications that have been developed in the Netherlands.

Photonics is technology aimed at generating, transporting and detecting light waves and particles (photons). Light plays an important role in all kinds of products and processes. These could be fibre-optic cables for the internet, solar panels, chips for smartphones or precision-farming sensors.

The technology is still relatively new and is already helping to solve many problems. The Netherlands has a great deal of knowledge about photonics and is working continuously to keep it that way. In doing so, TNO established the Dutch Optics Centre (DOC), together with TU Delft in 2016. Together with technological companies and knowledge institutes, they work on innovative products and continue to advance optical and photonic intelligence in the Netherlands.

This is also important from an economic point of view: there are almost 300 Dutch companies with an estimated total turnover of more than €4 billion.

Three examples of photonics versatility.

1 Making a diagnosis with one drop of blood

Using a single drop of blood to determine whether someone has an infectious disease, for example. TNO is developing an optical biosensor that can do this. They have found a way to detect biomarkers using light: proteins that, in certain concentrations in blood, urine or saliva, indicate diseases. The biosensor is able to detect all kinds of ailments. These could include the multi-resistant hospital bacteria MRSA,

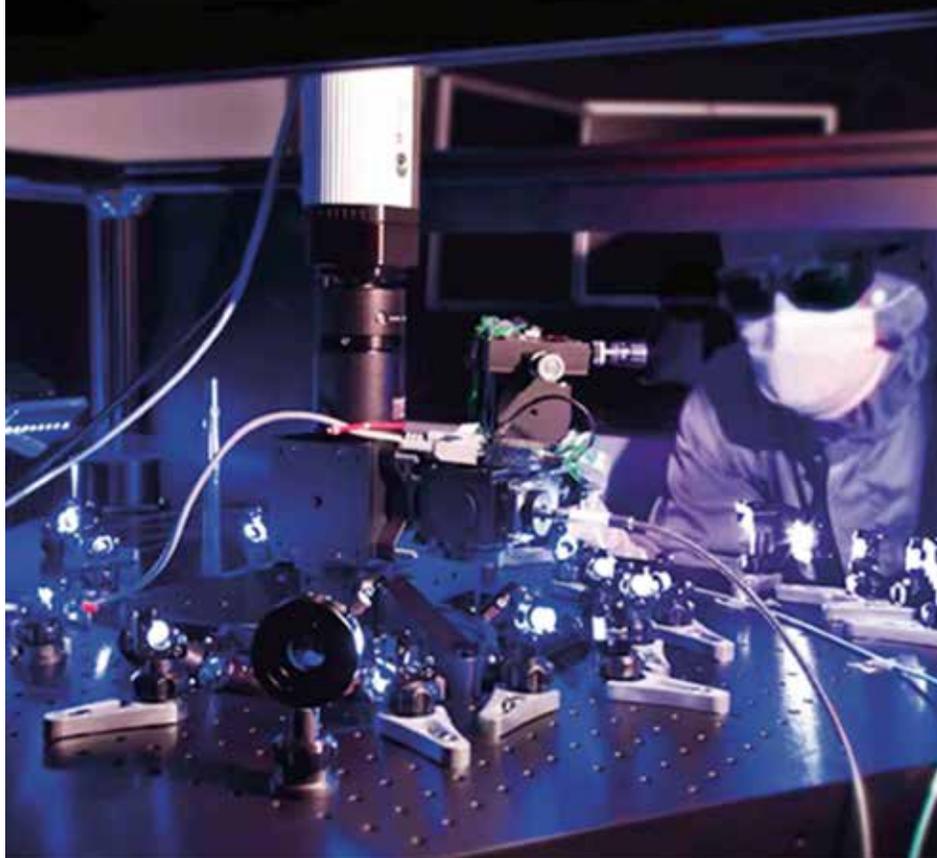
the ebola or zika virus, but also exposure to nerve gas.

The current prototype is still too big and too expensive to produce on a large scale. TNO has set up Delta Diagnostics to develop the sensor further. DOC is helping them to do this. The idea is to create a box in which a disposable sensor cartridge containing a drop of blood can be placed. Optical sensors then record the protein concentrations in the sample within a few minutes and help in making a diagnosis. In acute situations, you can quickly determine whether a person has had a heart attack or stroke. Even in

Photonics is a priority focus of the coalition agreement



NATIONALE AGENDA FOTONICA



remote areas without a laboratory or electricity, the biosensor can be of help. Furthermore, in the long run the sensor could even determine whether a person has a condition even before there are any symptoms.

2 Being able to measure bizarre lenses and mirrors for telescopes and aerospace

3D printers allow materials to be “printed” in any form. Lenses and mirrors can thus be made in freeform. They are increasingly being used in advanced systems such as large mirrors, telescopes and aerospace.

These unusual shapes are difficult to

measure and the measuring is vital to calculate the lens power, for example, or to fit it into a device.

NANOMEFOS is able to measure these forms very quickly and accurately. The non-contact machine acts as a large CD player, placing the surface to be tested on a spindle while an optical probe – a kind of flexible rod with mini camera – moves over it.

This special measuring instrument is made by DOC and Demcon. Dutch United Instruments has been established to market this product.

3 Detecting invisible dust particles

There are chips in every electronic

device. By using nanotechnology, these are made smaller and smaller; almost a hundred nanometres in size. That is minuscule.

In the manufacture of these chips, contamination with the tiniest particle already results in an unusable product. Such impurities are not visible to the naked eye. That is why DOC and Lans Engineering have developed the particle scanner Fast-micro. This “particle scanner” enables you to see if a part, module or component is clean enough to be allowed in a chip machine.

The partners also want to develop the scanners for other sectors where very small impurities lead to design errors. For example, in the production of TV screens, or in application of the aerodynamic layer over aeroplanes.

Together with DOC, Lans Engineering hopes to make a whole series of scanners and prototypes. The first step has been taken: the centre has been granted a subsidy to further develop the particle scanners.

Who: Dutch Optics Centre, established by TNO and TU Delft, Dutch United Instruments and Lans Engineering.

Duration: since 2016, indefinitely.

Budget: projects of several millions per year.

Follow-up: all three applications can be developed further for the market.



De samenwerkende organisaties
in toegepast onderzoek