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ACHEMA PULSE

Join the digital flagship event for the process industry, 15–16 June 2021.
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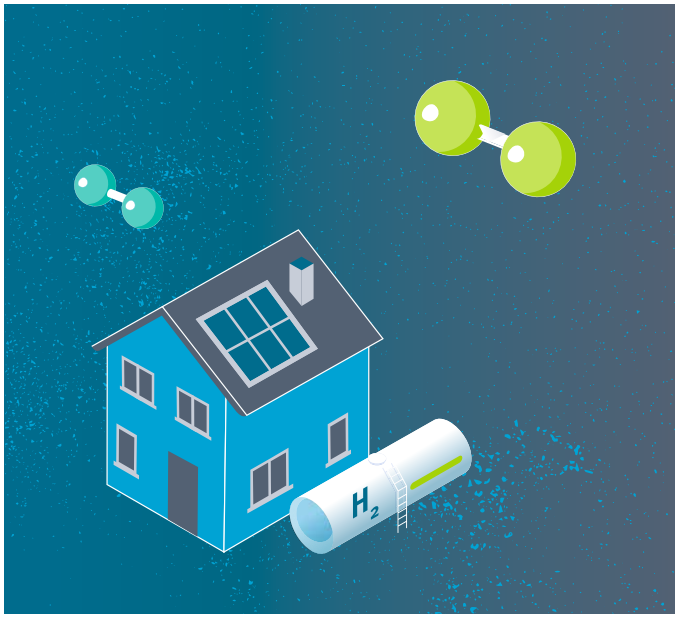

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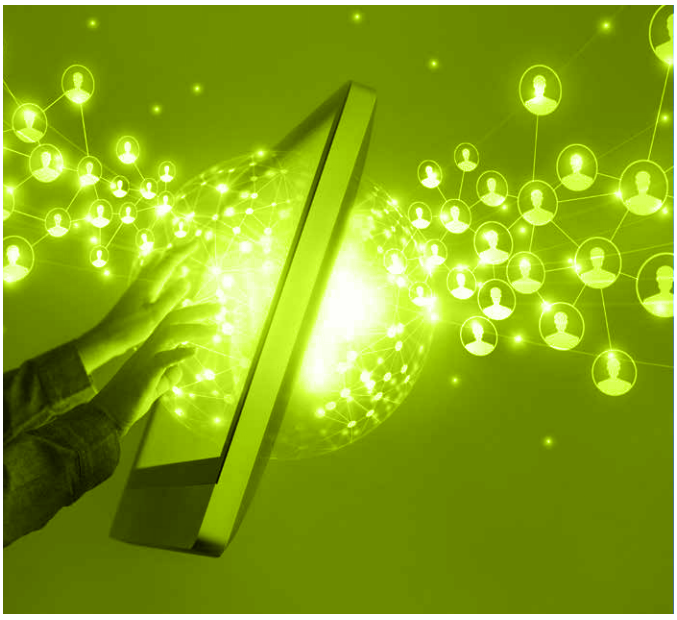

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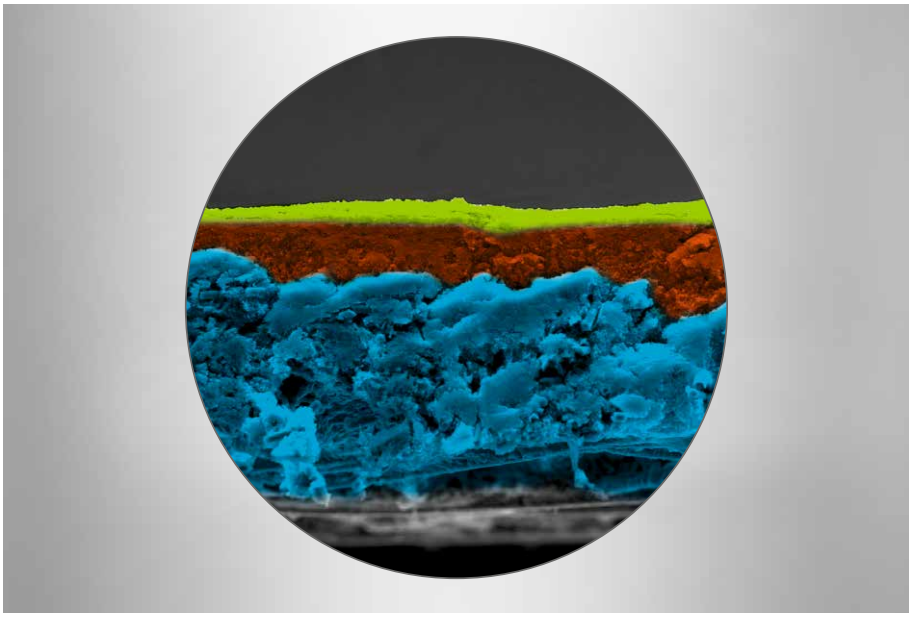

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EDITORIAL

Dear readers,

The COVID-19 pandemic has now upset our private and work lives for an entire year. We may not meet in person, yet we need to connect somehow. Sometimes, the digital alternatives work just fine – business meetings – and sometimes not so much – chatting with a large family.

The world of trade shows had to adapt as well. After postponing ACHEMA to 2022, we observed the market closely and have seen the okay, the bad and the ugly when it comes to online events. We have also listened attentively to what our exhibitors have experienced.

That's why ACHEMA Pulse will be different. Find out how different beginning on page 16.

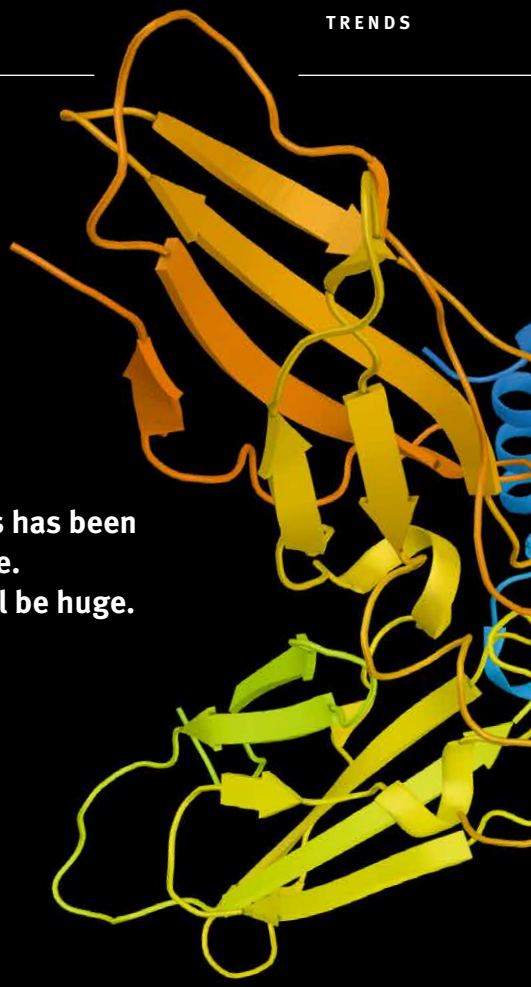
One thing will stay the same, however: Just like ACHEMA, ACHEMA Pulse will feature the topics that are shaping the future of the process industry; hydrogen is only one example. Read the Spotlight section of this magazine and get a foretaste of what to expect at ACHEMA Pulse, 15–16 June 2021. I am looking forward to meeting you there!

Yours,

Marlene Etschmann
Editor-in-Chief

THE "HOLY GRAIL" OF STRUCTURAL BIOLOGY

For decades, the computational prediction of 3D structures of proteins has been considered the Holy Grail of structural biology. Progress was moderate. Now, advanced computing is finally making difference. The impact will be huge.



Imagine that you have a chain made of 100 links of different sizes, and some of these links are magnetic. Others bear a patch of Velcro® tape. If you let this chain tumble down on the floor – would you be able to predict the shape of the heap and where which link would end up?

That is, in a nutshell, the problem scientists face when trying to predict the structure of proteins. Proteins are the building blocks and the machinery of cells. They consist of amino acids, some of which can form bonds with each other beyond the two-dimensional sequence within the protein. As "form dictates function" is the axiom of molecular biology, the elucidation of the resulting three-dimensional structures of proteins is key to understanding their biological functions: mode of action studies in drug discovery, the engineering of binding properties or enzymatic activities – all modern medical and biotechnical applications depend on accurate structural information.

PREDICTING PROTEIN STRUCTURES IS COMPLICATED

During the past 100 years, powerful experimental methods have been developed to analyse the 3D structure of proteins: X-ray crystallography, nuclear magnetic resonance (n.m.r.) spectroscopy, and recently, cryo-electron microscopy have matured to high levels of performance. However, they suffer from inherent limitations, and some methods, crystallography with synchrotron beams in particular, come with a chilling price-tag. The experiments require a lot of lengthy, tedious work – and luck, starting with the preparation of the material. The crystallisation of proteins is a major bottleneck usually requiring an artist's skills and patience, sometimes over years. Numerous proteins, mostly found in cell membranes, refuse to crystallise at all. Fortunately, recent cryo-EM methods can bypass this barrier.

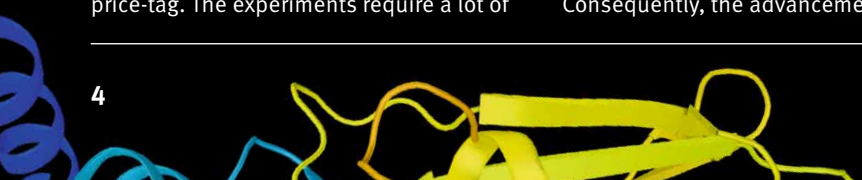
Computationally predicting the correct 3D structures of proteins from their amino-acid sequences would be the ideal method. It has been considered the Holy Grail of structural biology for decades and would certainly be a huge boon to life sciences and drug discovery. Unfortunately, it is a very hard scientific problem owing to the literally infinitely large number of possible conformations on equal energy levels. Consequently, the advancements have been moderate despite increasing computing power and a growing stream of structural data.

> **"AlphaFold is the first software that can generally predict protein structures as accurately as experiments"**
>
> DR KARSTEN SCHÜRRLE

The biennial Critical Assessment of Techniques for Protein Structure Prediction (CASP) contest has been monitoring the progress in the field since 1994. Scoring the median accuracy of structures predicted by the leading software solutions, the benchmarks never exceeded a threshold of 40 in the Global Distance Test (GDT), whose values range from 0 to 100, representing the percentage of amino acid residues within a threshold distance from the correct position. A GDT score of 90 and above is considered to be competitive with experimental methods of protein structure elucidation.

In 2018, Deep Mind's AlphaFold software entered the 2016-18 competition and raised the bar to about 60. In November 2020, the latest version achieved a median score of 92.4 across all targets and a median score of 87.0 for the very hardest protein targets from the "free modelling" category.

For the first time, software generally achieved the accuracy levels of the experi-



mental methods. Besides the fact that computing took only a few days, this achievement marks a sensational breakthrough that many scientists expected never to happen during their lifetime. The impact will be huge: Theoretically, several millions of protein sequences stored in genome data bases could be structurally analyzed, far exceeding the 160,000 structures stored in the Protein Data Bank (PDB) that have been collected since 1971. Novel proteins from pathogens, for example, could be studied almost immediately, accelerating drug discovery to unknown speed, and the development of biocatalysts would benefit enormously from the availability of the 3D structures of the variants of an enzyme.

HOW DOES ALPHAFOLD WORK?

A full research paper is expected to be published in the first half of 2021, but the company has already provided an overview. A folded protein can be thought of as a "spatial graph", with nodes representing residues and edges connecting the residues in close proximity. It is essential for understanding the physical interactions within proteins as well as as their evolutionary history. The latest version of AlphaFold is an attention-based neural network system attempting to interpret the structure of this graph while "reasoning" over the implicit graph it is building. Evolutionarily related sequences, multiple sequence alignment, and a representation of amino acid residue pairs are used to refine it. The system iteratively develops strong predictions of the underlying physical structure of the protein resulting in highly accurate structures. Using an internal confidence measure, the software can also predict the reliability of partial structures. The system was trained on the 160,000 publicly available protein structures from the Protein Data Bank together with a large number of protein sequences of unknown structure. It used sixteen third-generation tensor processing units (TPUv3s) designed for machine learning computations and roughly equivalent to the performance of 100 to 200 graphic processor units (GPUs) used in PCs.

The rational de novo design of proteins with desired functions in silico is the logical next step, which may possibly take decades once again. However, its eventual integration into an in silico workflow of strain development by metabolic engineering, genome synthesis and computational bioprocess development will certainly mark the era of completely digital biotechnology." •

p. 4–5: Photos: ibreakstock /Adobe Stock, Karsten Schürrle

DR KARSTEN SCHÜRRLE

Dr Karsten Schürrle is a bioeconomy expert and spokesman at DECHEMA e.V. He coordinates the activities of several working groups from DECHEMA's biotechnology division, e.g. bioinformatics, synthetic biology and chemical biology, and is involved in publicly funded research projects.

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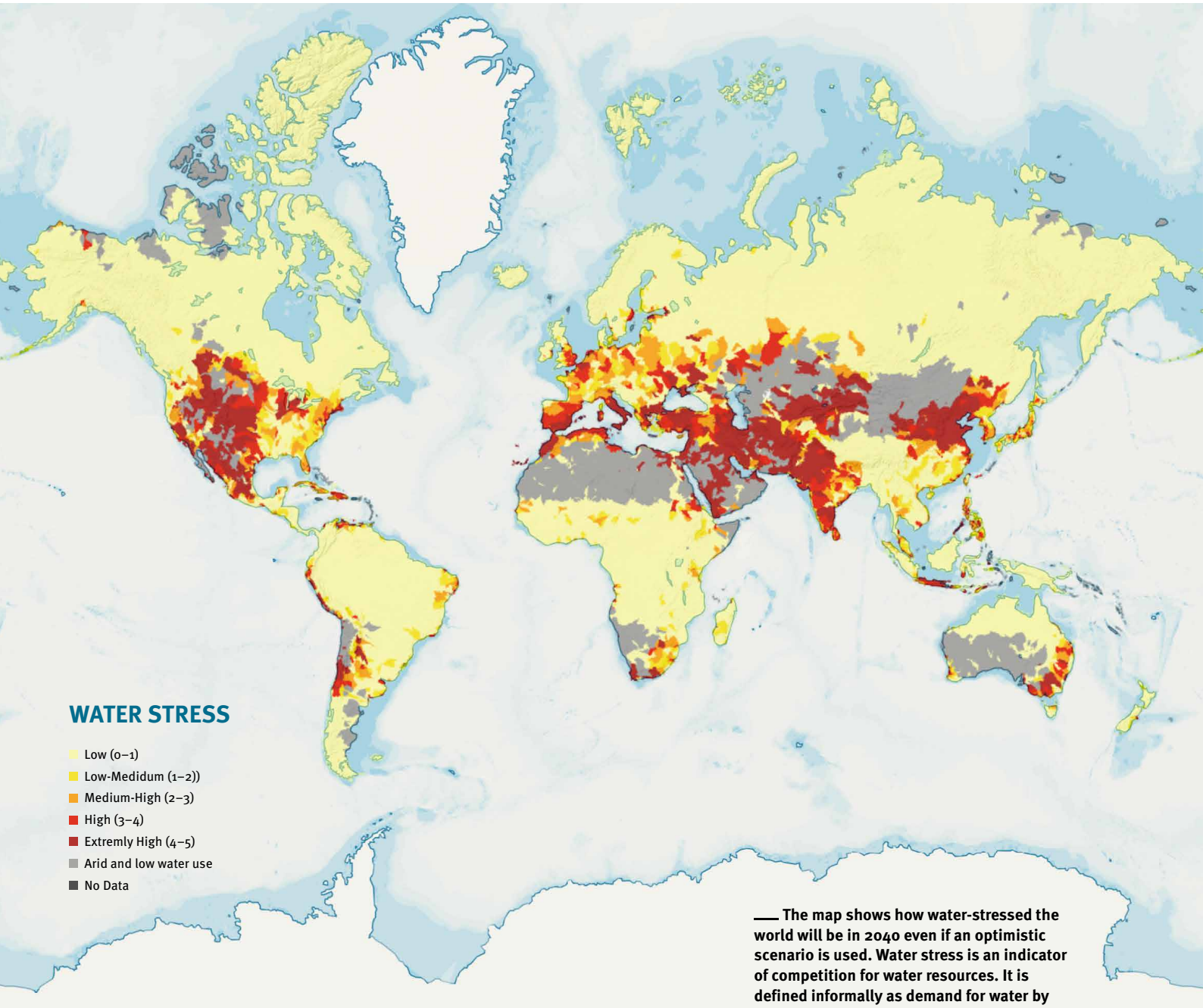
THE FUTURE OF WATER

The harbingers of climate change are starting to affect the process industry. How can industrial water management help to prepare for future water stress?



Source: WRI Aqueduct, accessed on 22 January 2021, www.aqueduct.wri.org.

The map shows how water-stressed the world will be in 2040 even if an optimistic scenario is used. Water stress is an indicator of competition for water resources. It is defined informally as demand for water by human society divided by available water.

“Water is a key issue at our production sites worldwide.”

DR CHRISTOPH BLÖCHER, COVESTRO AG

A drought? In Europe? With major effects on the process industry? The low water of the river Rhine in 2018 gave the dramatic answer to the hitherto unthinkable. Critically low water levels halted shipping traffic on one of Europe’s most important waterways, which connects the North Sea with inland locations in Germany, France and Switzerland.

Consequently, BASF in Ludwigshafen had to declare force majeure, as did Arcelor Mittal, Thyssenkrupp Steel Europe, Evonik, Ineos and Solvay. Loading capacity of the ships decreased, thus not enough raw materials such as iron ore, coking coal and salt could be ferried to the industrial centres. Furthermore, the low water level forced the companies to reduce production as there wasn’t enough river water to cool the plants.

LOCATION, LOCATION, WATER!

The dry spell from 2018 to 2020 has pushed an important fact to the front and centre of our attention: Water is a critical location factor, and the consequences of climate change will make it even more crucial. This holds true all around the globe and especially in the chemical, petrochemical, pharmaceutical and food sectors.

Europe is now learning the hard way what well-known water stress regions in Asia, Southern Europe, Middle East, Africa, North America and Australia have been experiencing for a long time: Forward-looking, efficient industrial water management can very quickly become a key factor for safe industrial production.

72% of all water withdrawals are used by agriculture

16% of all water is distributed to municipalities for use in households and services

12% of all water is used by industries

Source: www.unwater.org

Water-efficient process industry sites can score in many ways if they become less dependent on natural water resources: In the global competition for economic efficiency, with a view to compliance and also in terms of security for site investments.

In addition to the process industry itself, technology providers and developers have also recognised the value of water as a resource for production. “Water is a key issue at our production sites worldwide. Efficient water management is one pillar of our license to operate and sustainable competitiveness,” emphasises Dr Christoph Blöcher, Head of CO/H_2/ Infrastructure Process Technology at Covestro Deutschland AG.

PRODUCTION AND WATER MANAGEMENT GO HAND IN HAND

The challenges for the process industry in the topical field of water suggest that production and industrial water management should be integrated even further. This will enable the industry to act in a way that is economically strong, regulatorily safe and ecologically sustainable in the long term. “Integrated and intelligent industrial water management solutions offer outstanding benefits for stable production and economic efficiency. They support the responsible use of water, energy and valuable resources,” says Elmar Billenkamp, Head of Design and Sales at EnviroChemie GmbH.

Current focal points are the topics of digitalisation, water reuse, zero liquid discharge and handling the concentrates that remain after water treatment.

Especially digitalisation in industrial water management, coined “Industrial Water 4.0”, offers huge potential to increase efficiency. Decreasing the amount of water and cleaners needed to clean industrial containers with the help of a digital twin, as EnviroChemie has done at a German cosmetics company (see page 8), may seem like a small success. Adding up these small successes can make a huge difference.

Endress+Hauser was commissioned to digitalise the drinking water system of a small town near Frankfurt am Main, Germany. Read on page 9 how this saves one of the most important resources: time. The municipality’s highly qualified water engineers can now spend their time on tasks more important than routine inspections. •

DR THOMAS TRACK
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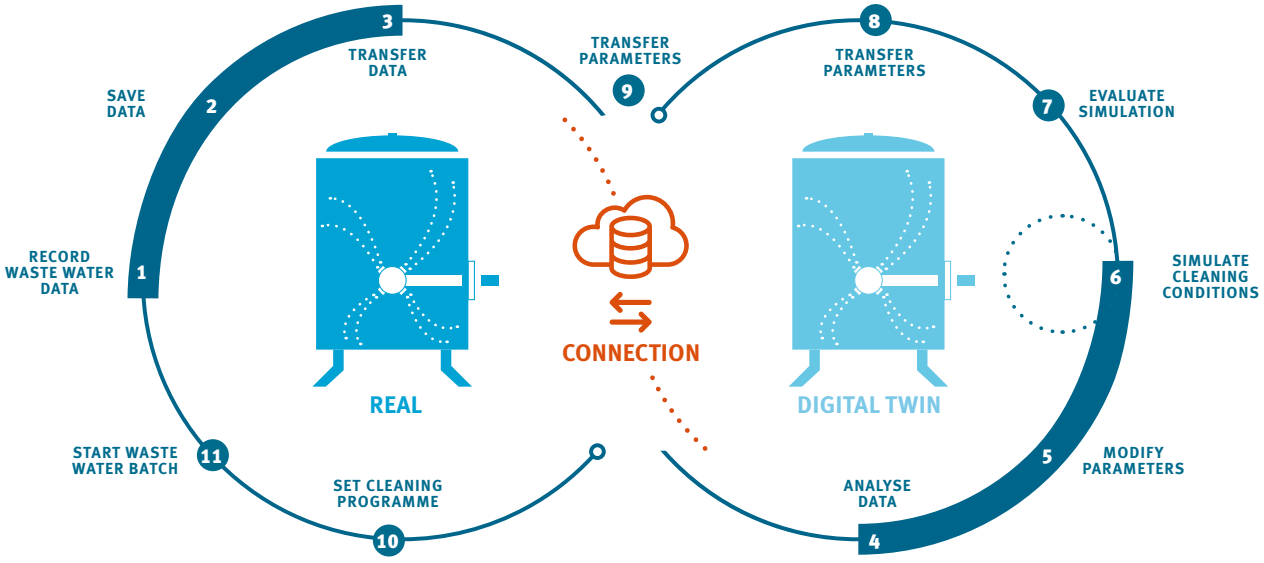
DR THOMAS TRACK

Thomas Track is head of water technologies at DECHEMA e.V. He brings together the expertise of professionals from the process industry and industrial water technology.

p. 6: Map: www.aqueduct.wri.org; p.7: Photo: Thomas Track; Icons: Made by Made, lastspark, Juraj Sedlák / Noun Project

DIGITAL TWIN MAKES FOR CLEAN COSMETICS TANKS

An EnviroChemie plant models processes in real time to tailor the treatment of waste water from cosmetics production at Kneipp GmbH



At Kneipp GmbH in Würzburg, Germany, even the waste water smells good – of spruce needles, lavender flowers and lemon. Not a surprise for a producer of body care and health products. Nevertheless, the residues from production of bath oil, shower gel and skin cream have to be carefully removed from the waste water. The company pays a lot of attention to the sustainable use of resources, thus noteworthy amounts of waste water occur only at the cleaning station for the containers in which the raw materials are delivered: fragrant essential oils, but also vegetable oils and surfactants. Apart from the raw material residues, the waste water also contains cleaning agents that are used to clean the containers.

ONLY AS MUCH CHEMISTRY AS NECESSARY

The waste water is cleaned with a Split-O-Mat® system from EnviroChemie GmbH and can then be promptly be discharged into the sewage system. A digital twin is now being developed for this plant, which will in the future contain information about the water that accumulates in the cleaning station. Via a scanned barcode, the twin learns whether a container is currently being cleaned of shower gel, lavender oil or bubble bath, among others. Simultaneously, it receives online measurement data from the EnviroChemie system on the quantity and typical parameters of the waste water such as redox potential, conductivity, turbidity and pH value. The system then calculates the amount and composition of the resulting waste water and models the chemical-physical processes of the waste water treatment plant in real time. With this information, the cleaning programme is selected so that only as few chemicals as necessary are used, and the process is as sustainable as possible. The goal is always to keep the waste water quality consistently high.

The waste water treatment plant is operated in batches; thus, the optimal treatment programme can be selected for each waste water batch – and the necessary reaction time can be maintained.

LEARNING FROM HUMANS

The operators initially evaluate the recommendations of the digital twin. This evaluation is used by the digital twin to further improve the calculations and selection of the appropriate cleaning programme. •

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EVA BITTER

is head of the Process Engineering, Research and Development department at EnviroChemie GmbH, a plant manufacturer of sustainable system solutions for all tasks in the field of industrial water.

p. 8: Photo: Eva Bitter, EnviroChemie

MONITORING WATER NETWORKS DIGITALLY

Checking drinking water reservoirs and networks manually is a time-consuming and inefficient job. Endress+Hauser delivers the right digital solution even for small and rural municipalities.

PIRMIN LICKERT

Pirmin Lickert studied electrical engineering at Cooperative State University Lörrach. Since 2019, he has been a Product Manager Automation Solutions at Endress+Hauser Germany.

Like in every large community, water distribution is also important in the German city of Oberzent, close to Frankfurt am Main. There are several water springs, some of them even providing mineral water. Various small municipalities have joined to form the town of Oberzent, which has a total of 10,000 inhabitants, but is spread over an area almost three times the size of Manhattan, New York.

TOP PRIORITY: SAFE WATER SUPPLY

Providing each of the town's 19 districts reliably with water is therefore a top priority for the local water supplier. Four water masters make sure that the water supply network is running smoothly at all times. In the past, they spent a large portion of their workday driving around to the 19 facilities spread out over 165 km² to gather and process information for water treatment and storage – time they couldn't spend on more important tasks.

35

FLOWMETERS

were installed in the city of Oberzent, Germany, as part of the drinking water monitoring system

The water masters can retrieve measurements conveniently on tablets.

COLLECTING DATA DIGITALLY

The municipality instructed Endress+Hauser to digitalise the water networks. Using the Netilion IIoT ecosystem, Endress+Hauser delivered a fully digital solution. Netilion provides all the basic data needed for creating and programming individual dashboards that display the entire process of water treatment and storage. This is implemented in the online service Netilion Water Network Insights. Using this service, the water networks can be monitored as well as optimized while no leak goes undetected.

Even the lack of stable cellular service coverage in rural Germany could be overcome. A long-range wide area network (LoRaWAN) allows for secure wireless data transmission that needs little to no energy.

MORE TIME FOR MORE IMPORTANT THINGS

From now on, the water masters can retrieve all relevant information on their smartphones, tablets and laptops: data from 35 flowmeters, 17 level meters, 7 pressure meters and 2 analysis panels for quality monitoring. Time-consuming daily visits to the reservoirs and water treatment stations are a thing of the past. The highly qualified experts can now use their time much more effectively ensuring a reliable water supply for the town of Oberzent. •

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p. 9: Photos: Tobias Arhelger / Adobe Stock, Endress Hauser.

HYDROGEN IS THE ANSW – WHAT WAS THE QUESTION?

The ongoing discussions seems to suggest that hydrogen, especially "green" hydrogen, is the solution to all the challenges we currently face with respect to our future energy supply.


ER
HYDROGEN COLOR SCHEMES
GREY HYDROGEN
is produced by steam reforming of natural gas, by far the most common process up to date.
TURQUOISE HYDROGEN
is produced by pyrolysis of natural gas into hydrogen and carbon.
BLUE HYDROGEN
"Grey" changes to "blue" if the resulting CO_2 emissions are captured and stored.
GREEN HYDROGEN
is produced by water electrolysis using only electricity generated by renewable sources.
DROGEN T
H_2
H_2
CLEAN ENERGY
CLEAN FUTURE

Hydrogen, as an energy carrier, can be nearly universally applied to supply energy to all sectors. Furthermore, it can be used as a raw material and reduction agent in the energy-intensive process industries, thereby substituting emission-intensive fossil alternatives.

Germany's national hydrogen strategy paints hydrogen in bright colors depending on how it is produced. "Grey" hydrogen is produced by steam reforming of natural gas, by far the most common process to date. "Grey" changes to "blue" if the resulting CO_2 emissions are captured and stored (CCS), an option currently not exploited in Germany. "Green" hydrogen is produced by water electrolysis using only electricity generated by renewable sources. "Turquoise" hydrogen is produced by pyrolysis of natural gas into hydrogen and carbon.

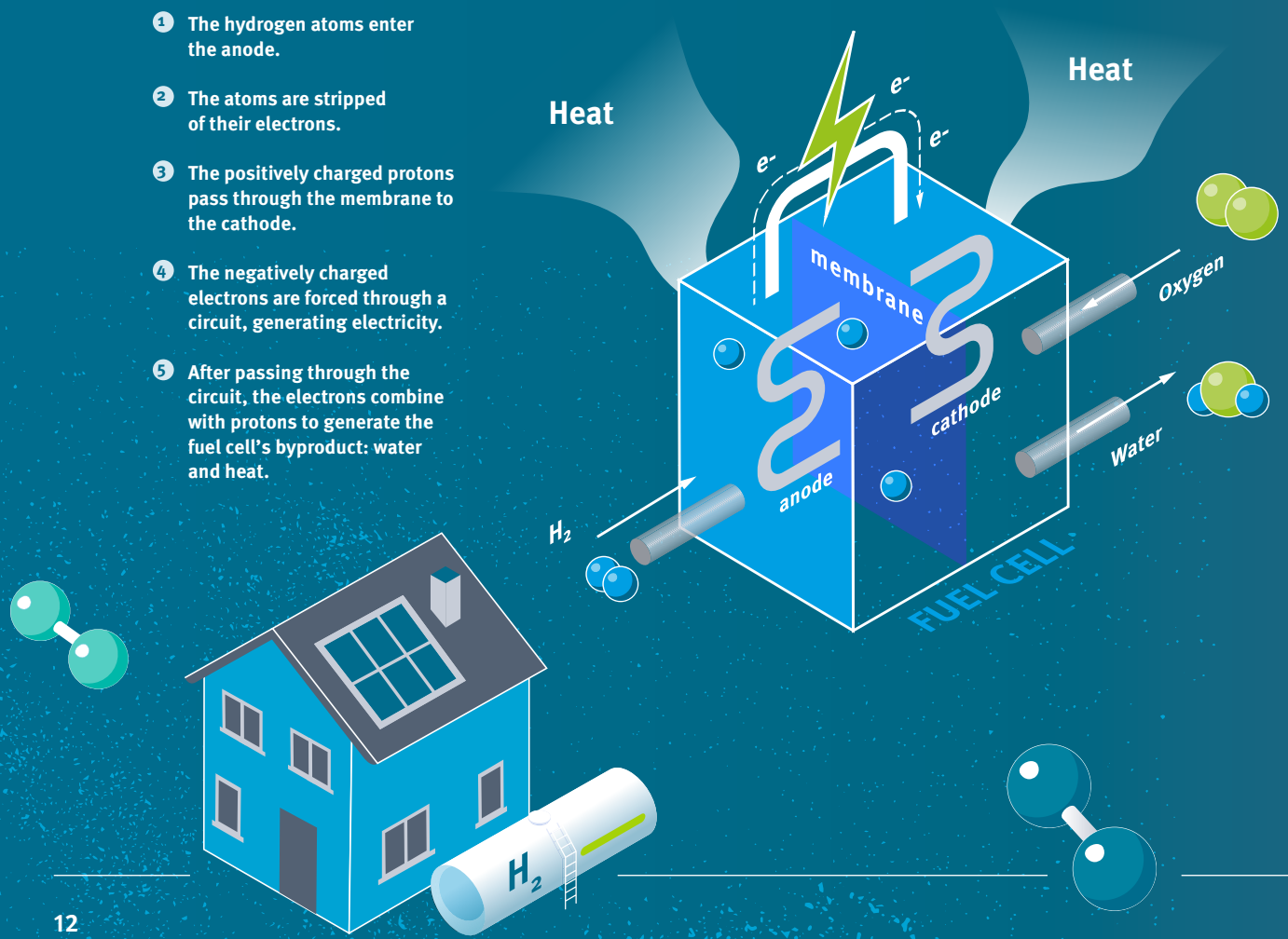
DIFFERENT POTENTIAL USERS OF HYDROGEN HAVE DIFFERING INTERESTS:
For stakeholders from the power sector, hydrogen holds the promise of storing electricity from fluctuating and intermittent renewable sources via water electrolysis and regenerating the electricity from hydrogen in times of low renewable supply.

Within the transport sector, fuel cell technology can make light and heavy road vehicles, even boats, essentially emission-free. Chemical transformation of hydrogen also allows for the production of alternative fuels that may act as substitutes for current fossil fuels. This might be a future path for the refinery sector.

Hydrogen can be, within some limitations, introduced into current natural gas transport structures and thereby supply a

HOW A FUEL CELL WORKS

1. The hydrogen atoms enter the anode.
2. The atoms are stripped of their electrons.
3. The positively charged protons pass through the membrane to the cathode.
4. The negatively charged electrons are forced through a circuit, generating electricity.
5. After passing through the circuit, the electrons combine with protons to generate the fuel cell's byproduct: water and heat.



p. 10: Photos: malp / Adobe Stock; p. 12: Illustration: MPM using material from elenabsl / Adobe Stock; p. 13: AA+W / Adobe Stock

fuel for district heating to households and commercial applications.

The process industries on the other hand face a multitude of challenges on their path to reach greenhouse gas neutrality in the future; some of them might be addressed by hydrogen.

Iron, for instance, is currently produced by blast furnaces with coke as a reducing agent; up to now, there are no alternatives to hydrogen for achieving greenhouse-gas-neutral production via direct reduction.

High-temperature processes, as are used in ceramics and glass production, require fuels that supply heat but also generate desired process conditions, i.e. a certain atmosphere. These characteristics cannot be supplied by electricity alone because they require molecular (synthetic) fuels.

The chemical industry has a long history of using hydrogen in its processes, such as the production of ammonia and methanol, but also generates it as a by-product, e.g. in the chlorine alkaline process.

WHAT WILL BE THE CHEMICAL FEEDSTOCK OF THE FUTURE?

One option is the production of synthetic naphtha from CO_2 and hydrogen. If this admittedly very energy-intensive option is chosen, the German chemical industry, with a current demand of around one million tons a year, is looking at a potential future demand for hydrogen in the order of up to 7 million tons, depending on which scenario is considered.

Electrolytic processes are at the heart of this development. The latest headlines indicate that the industry is rising to the challenge: In January, Linde announced the construction of the world's largest PEM-based electrolyser plant in Leuna, Germany, (PEM stands for "proton exchange membrane") with a capacity of 24 MW. A week later, Air Liquide commissioned a 20 MW PEM electrolyser in Canada. At about the same time, a project consortium of 15 partners presented its plans to build a 100 MW alkaline electrolyser plant at an industrial site run by Repsol.

ECONOMIES OF SCALE

A major challenge still lies in the scale-up of electrolysis technologies. As complex multiphase transportation processes are involved, simply doubling or quadrupling the surface area of an electrode doesn't do the trick. The most popular approach currently is stacking the electrolyser cells. Siemens Energy is optimistic. With 100 MW plants currently under development, the company is investigating 1 GW technologies in cooperation with the chemical industry. This could be one contribution to decreasing the cost of electrolysis. Although the cost has already toppled due to falling prices of renewable energy, the International Renewable Energy Agency (IRENA) identified in a report published in December 2020 several areas that need to be addressed to make "green" hydrogen competitive. Economies of scale play a major role, both regarding the size of electrolyser plants and the automated serial stack production in "gigawatt-scale manufacturing facilities". This should go hand in hand with electrolysis systems that are optimised for specific applications in different industries. Based on learning rates in the solar photovoltaics industry, IRENA expects cost declines of 16–21%.

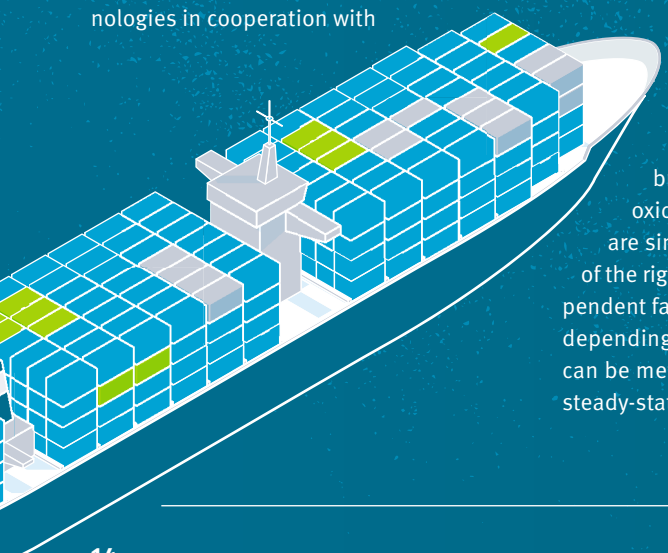
98%

of hydrogen is currently produced from coal and natural gas

70

MILLION TONS

of pure hydrogen were produced in 2020



So far, the different electrolysis technologies are still running a fierce race for volume and competitive prices. According to a review published in fall, energy demands for alkaline electrolysis (AEL), proton exchance membrane (PEM) electrolysis and solid oxide electrodes (SOEC) electrolysis are similar. Decisive for the selection of the right process were external site-dependent factors such as required flexibility depending on energy sources, which can be met better by AEL and PEM. Under steady-state conditions, however, SOEC could be a feasible alternative. These results indicate that a specification of the electrolysis process to applications might indeed be a feasible pathway. Electrode materials are also closely under investigation. To avoid the cost of precious metals, companies like NEL Hydrogen employ nickel as the basis for their electrodes.

RELIABLE INFRASTRUCTURE

Security of (continuous) supply is a major issue to be resolved in order to use hydrogen in the process industries and requires infrastructure investment. In the case of a defossilised chemical industry, what requirements must future energy infrastructures meet by 2050? The highly industrialised Antwerp-Rotterdam-Rhine-Ruhr-Area (ARRRA) in the triangle between Germany, Belgium and the Netherlands is today very well developed and includes three major chemical sites. But what are the future demands on the existing and especially the cross-border energy infrastructures? This question is at the heart of a study that was jointly undertaken with institutions from Belgium, the Netherlands and Germany.The conclusion in a nutshell: The transformation to the hydrogen economy has to take into account systemic parameters; many industrial sites are closely interlinked and rely on a common infrastructure. A systemic approach is highly recommended.

"German researchers are currently investigating how to process hydrogen where it is generated."

FLORIAN AUSFELDER

p. 14–15: Photo: AA+W / Adobe Stock, DECHEMA; Illustration: MPM using material from Golden Sikorka / Adobe Stock

_ Green hydrogen production at sea: The electrolyser is integrated into the base of an offshore wind turbine.

PROCESSING HYDROGEN ON-SITE

With the generation of large volumes of hydrogen, the next question that arises is how to transport and convert it into fuels or chemicals. As are other countries, Germany is currently investigating concepts of processing hydrogen at the site of its generation. This goes so far as to include autonomous plants located in offshore windparks. In the initiative "Wasserstoffrepublik Deutschland", driven by the Federal Ministry of Education and Research, three main projects have been commissioned: H_2Giga joins all major technology owners of electrolytic technologies in order to promote production technology of electrolysers towards mass production on GW scale. H2Mare will develop PtX-technologies in offshore conditions to open up a new field for renewable energy use and the production of fuels and chemicals. The TransHyDe project investigates the interaction of energy carrier demand and infrastructures on a European level for all relevant process industries. •

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*includes full Pulse access to the platform

PULSE TICKET

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** excludes live stages and tech congress

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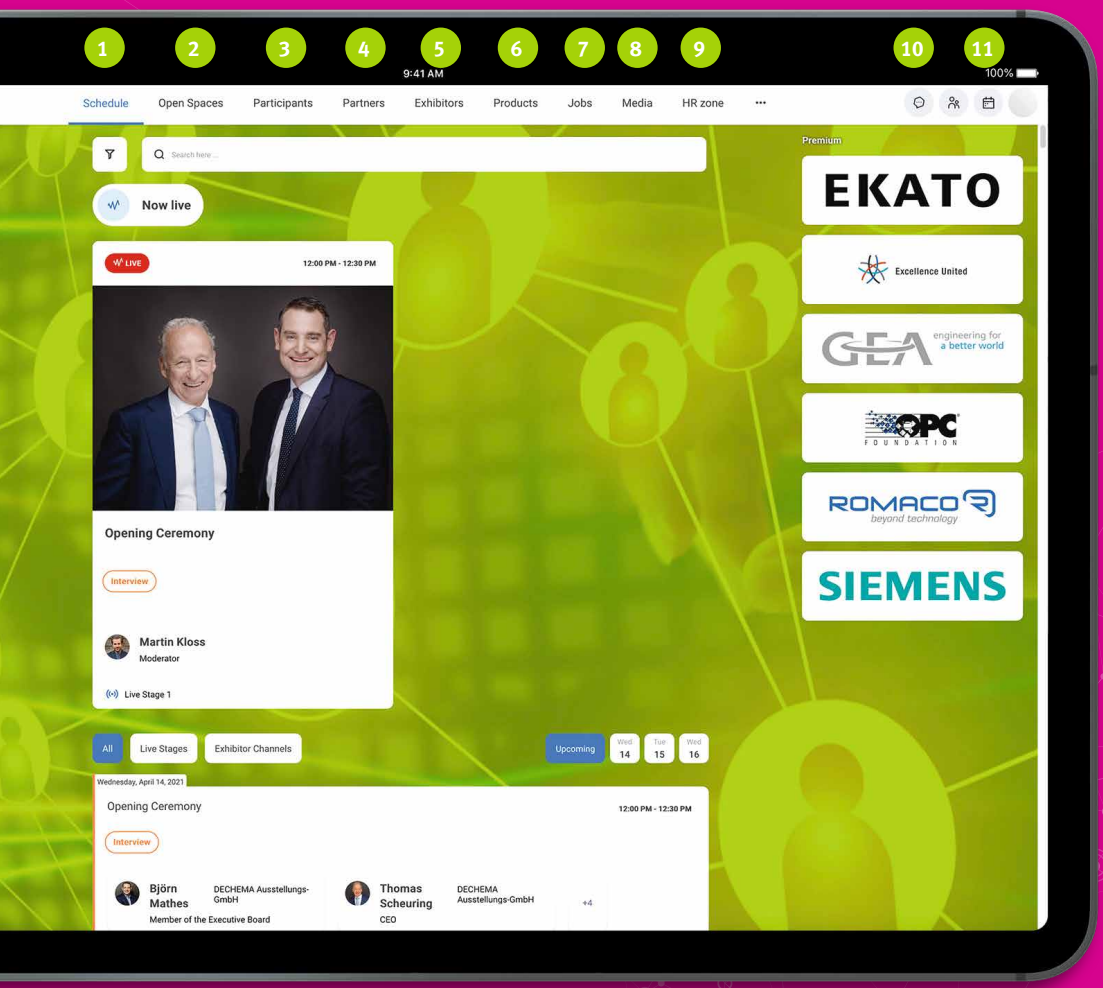
GET CONNECTED

Tap into our community of experts, thought leaders, practitioners, decision-makers, recruiters and solution providers around the world – from home, at work or on the move.

GET INSPIRED

Take part in the most intense agenda shaping the global process industry today and laying out the path to a new tomorrow, ranging from hands-on insights to top-class highlights – live and on demand.



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1 + 2 = ∞

ACHEMA Pulse will offer you infinite opportunities. Picture one full month of online expo experiences and networking with a global community of experts, decision-makers, and solution providers from the process industry. Add an intense two-day live event packed with inspiring knowledge, expertise and ingenuity unparalleled in-depth, density and diversity. Put it all on a cutting-edge digital platform that is actually fun and easy to use. Then, just imagine the rest. Can you see it now?

INNOVATIVE SOLUTION PROVIDERS

850+ exhibitors bring all their experts and latest developments onto the virtual platform to provide you with the latest market and technology updates.

LIVE STREAMS AND WORKSHOPS

150+ hours of streaming – live and on demand – and 160+ interactive live workshops with solution providers let you dive deep into market-ready technology and insights.

UNIQUE EXPERIENCE

Become active, be open, contribute and share – or just sit back and enjoy the show. Either way you like, ACHEMA Pulse will let you design your own unique event experience.
Because after all: You are our most essential ingredient.

LIVE STAGES

3 hybrid stages with inspiring key notes, high-level interviews, live talks to the point and visionary tech demos, both on-site and remote from all around the globe.

CONGRESS SESSIONS

80+ hours of high-calibre congress sessions informing about the most recent applied research developments coming to market readiness in the near future.

HOW EXHIBITORS BENEFIT FROM ACHEMA PULSE

SHARPEN YOUR PROFILE

- Present your company and innovative solutions to the industry with an individual, expressive profile
- Pull in your audiences by providing value-adding content (incl. videos, white papers etc.) in world-class context

CREATE AWARENESS

- Benefit from the globally unique reach of ACHEMA as the world forum and leading show for the process industry
- Deliver fascinating brand, sales and HR experiences using our cutting-edge yet easy-to-use platform

BUILD UP ENGAGEMENT

- Start new conversations by delivering attention-grabbing live talks, panels, case studies, pitches and workshops
- Grow your network and generate the right leads with algorithm-based matchmaking and unlimited networking

THE VOICE OF THE INDUSTRY

The topics currently on the top of its agenda are as global as the process industry itself. ACHEMA Pulse offers a hub for all those who want to participate in the discussion – whether on the interactive platform, the congress or the live stages.

DIGITALISATION

Sometimes it looks like almost every innovation is a digital one. It is not, but the shift to a truly digital process industry is inexorable. AI, VR, IoT, 5G – all these buzz words and abbreviations promise a better (technical) future, but some projects are stopped when it comes to security and investment costs. We bring the discussion back down to earth and will discuss how far we have come and where we go from here.

SUSTAINABILITY

#NetZero and sustainable production will be some of the critical drivers for our industry in the near future. Which technologies and equipment do we need to enable carbon-neutral production? How can we foster investments into clean energy and green tech? Is Europe ready for the Green Deal? Can the process industry at all help to achieve the world's climate ambitions? Question after question discussed with thought leaders and visionaries.

FAST-TRACKED VACCINES

Faster, bigger, more global: Vaccine development and the establishment of large-scale vaccine production have shown what is possible when research, development and production are accelerated. Can experiences be transferred, and how does this change the industry? This will be discussed by developers, producers and suppliers of equipment and machinery deeply involved in these processes.

DIVERSITY AND GENDER EQUALITY

A change is gradually taking place on the chemical and pharmaceutical industries' boards – women are taking over technical portfolios and board chairmanships. Current surveys show that this is by no means the end of the matter. How can diversity be firmly anchored in the business world, and how do companies benefit from it?

HYDROGEN

Is hydrogen a gamechanger or just the next hype? Are we entering the hydrogen economy? How can the necessary electrolysis capacity be built up, and how does hydrogen interact with other technologies and other industries? The programme includes a look at the global hydrogen activities from the Americas to Asia and a discussion of the smallest molecule's real potential with leading executives.

MODULAR PRODUCTION

Plant operators, module manufacturers, and automation engineers have been working for years to agree on standards, methods, models and procedures for modular production. They all agree that a modular plant is operated efficiently only if the modular units are intelligently interconnected, coordinated, controlled and regulated. We will show best practices and discuss the economic and tech future of modular and flexible production.

SPEAKERS? THOUGHT LEADERS!

ACHEMA Pulse speakers are not only C-level executives, visionary tech experts and renowned researchers but, after all, also thought leaders. They do not just talk about leadership, innovation, sustainability or digital transformation. They actively shape our industry and will win the attendees over with their strong message. Join the event and get inspired by some of the global process industry's movers and shakers. Find some of them below and more on www.achema.de

NELSON BARTON

Senior Vice President of Research and Development of Genomatica

THIERRY CARTAGE

Process Performance & Digital Director of Solvay

CEDRIK NEIKE

Member of the Managing Board and CEO Digital Industries, Siemens AG

JÜRGEN NOWICKI

Executive Vice President of Linde plc and CEO of Linde Engineering

KLAUS SCHÄFER

Chief Technology Officer of Covestro

ANDREAS WIDL

CEO and Chairman of the Executive Board of Samson Group

ANYONE

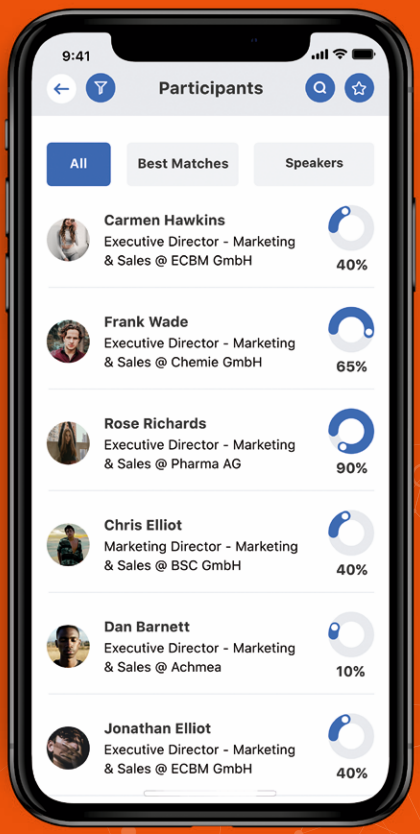
Get connected to any exhibitor, participant or speaker on the Pulse platform – what are you waiting for?

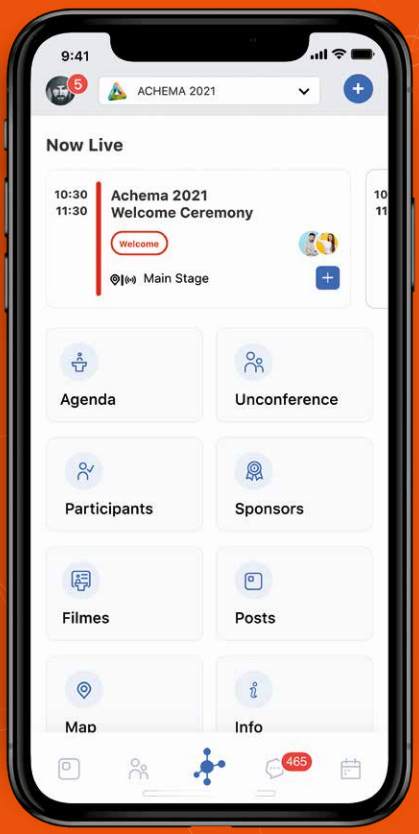
ANYTIME

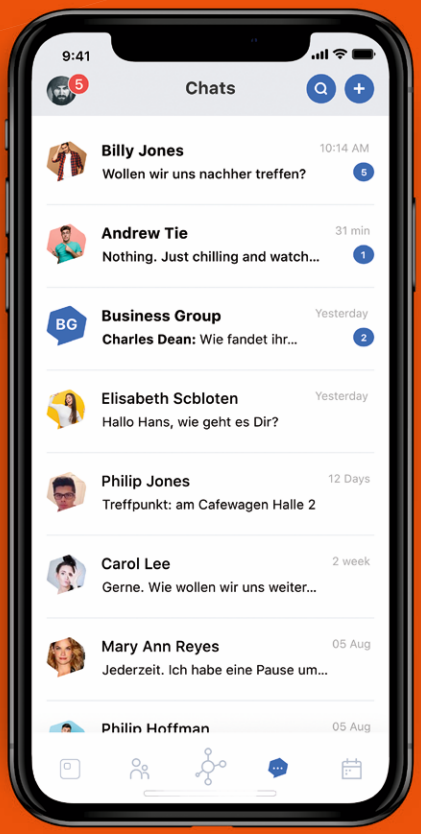
Get inspired by the most intense industry streaming agenda anytime you like – live and on demand!

ANYWHERE

Get involved with new connections around the world via chat or video call – no matter where you are!







AVAILABLE IN YOUR APP STORE FROM 31 MAY

GET IT ON Google Play

Available on the App Store

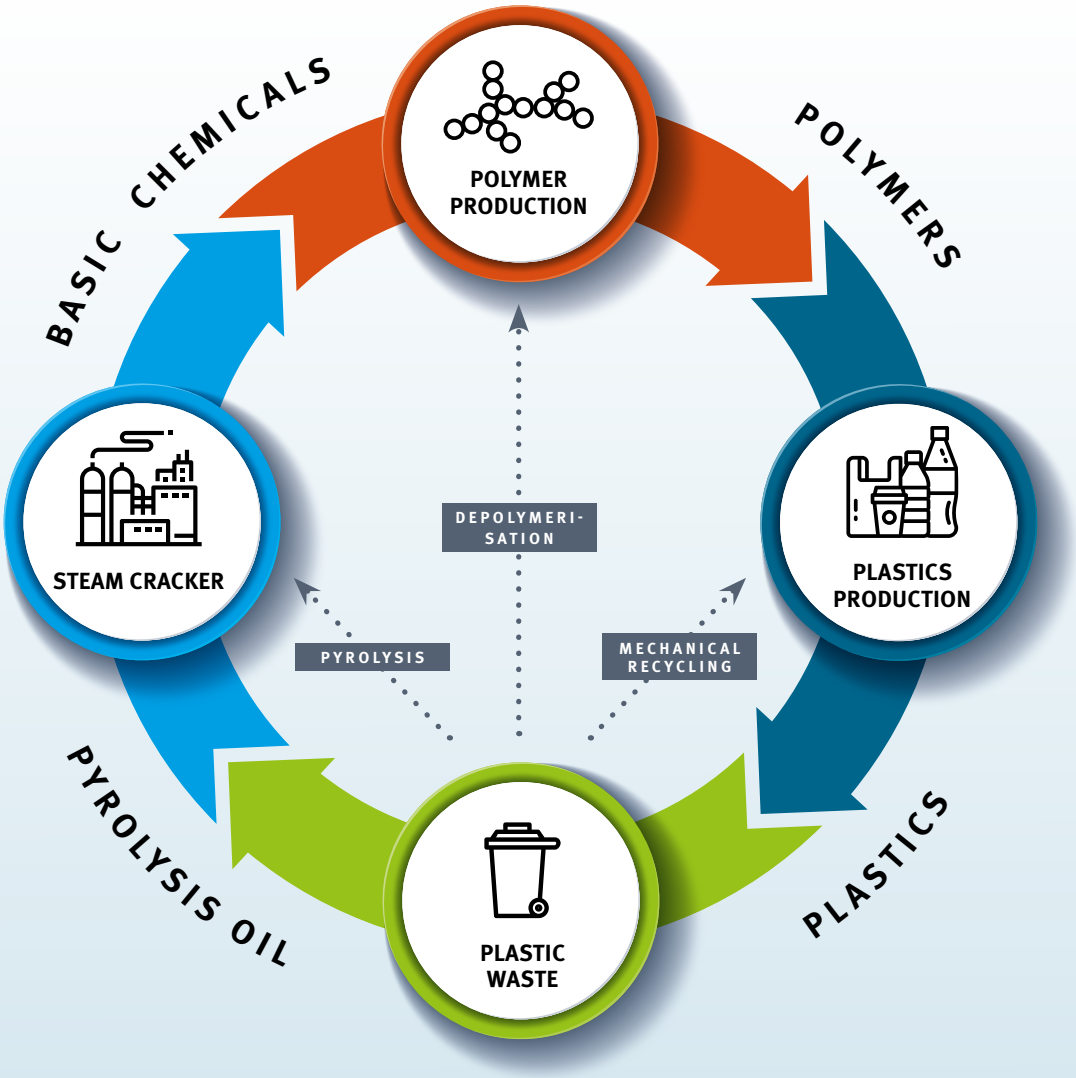
READY TO EXPERIENCE ACHEMA PULSE?

Register your myACHEMA account and get your ticket at tickets.achema.de

GET YOUR TICKET NOW!

WILL CHEMICAL RECYCLING CLOSE THE LOOP FOR PLASTICS?

Circularity is one of the megatrends featured in Highlight Sessions at ACHEMA Pulse. Can the plastics industry succeed in reusing its products in a reasonable way? And what types of recycling are there anyway? We talked to Dr Andreas Kicherer, Director Corporate Sustainability at BASF.



CHEMICAL RECYCLING

Pyrolysis: mixed plastic waste is heated to 450–650°C in the absence of oxygen to yield an oil that can be used as feedstock in chemical plants, e.g., steam crackers. The resulting products are virgin grade and fit for use in food packaging, automotive parts or medical applications.

Depolymerisation: a single polymer waste like polyurethanes or polyamides is needed (e.g., carpet fibers or mattresses). The polymers are broken down into their monomers, from which the polymer can be rebuilt. The final products are often virgin grade.

MECHANICAL RECYCLING

Polymer waste is recycled to the same polymer, e.g. PET bottle to PET bottle. The waste stream needs to be clean and single polymer. However, in some cases, the resulting products are of lower quality and are therefore used for fences, flower pots, benches and the like.

Is chemical recycling the ultimate answer to plastic waste?

DR ANDREAS KICHERER: *I would not say that it's the ultimate answer, and further on I don't think that any single technology can be the ultimate answer to the plastic waste challenge. To cope with this challenge and create a circular economy, we need every available solution: This includes, for example, long-lasting products that can be reused. If reuse is impossible, we need mechanical recycling, chemical recycling and even energy recovery as well. If somebody says that they have the ultimate solution to plastic waste, I personally would have serious doubts.*

Why don't we just recycle everything chemically? If you break the polymer down anyway, you need not worry about any impurities.

Firstly, there are excellent mechanical recycling schemes, such as for polyethylene terephthalate (PET) bottles, in Germany and other European countries. If you can transform a water bottle into a water bottle again – what's not to love? The other reason is that you cannot recycle all types of plastics chemically. The PET molecule, for example, contains oxygen, but pyrolysis works only in an oxygen-free environment. Mechanical recycling is by far the best option in this case.

However, there are many other plastic waste streams with a mix of all sorts of polymers, e.g., leftovers of municipal plastic waste sorting, that are very well suited for chemical recycling. Nowadays, these waste streams are usually energetically recovered. Bringing them back into the loop through chemical recycling is the better option. All in all, chemical recycling can complement mechanical recycling. We should always chose the most eco-efficient recycling option.

Is chemical recycling applicable in developing countries where waste collection and separation isn't all that elaborate?

The first commercial plants are located in Europe. Nevertheless, we are looking for options to also use the technology in other regions in the future. However, it is important that a functioning waste collection infrastructure exists or is established.

DR ANDREAS KICHERER

Andreas Kicherer is an expert on recycling technologies, and in his current role has been leading projects at the Ellen MacArthur foundation. He also represents BASF within the Alliance to End Plastic Waste.

At BASF, we are strongly committed to increase the amount of plastic waste that is collected and recycled and are therefore engaging in various projects and initiatives that strengthen the idea of the circular economy and prevent plastics from entering the environment. For example, BASF is a founding member of the Alliance to End Plastic Waste, and we take that commitment seriously.

How about the production of pyrolysis oil? Have you changed your supply chains, and have there been new business alliances along the way?

Collecting and recycling waste is definitely not our core business, thus we have partners who operate pyrolysis plants. These new partnerships are very intense, to the extent that we deploy experts to support them with our technological expertise. Our Norwegian partner Quantafuel, for example, turns mixed household plastic waste into pyrolysis oil. However, the raw pyrolysis oil is not yet suitable for chemical production. It's much more like raw mineral oil, which you can't send directly into a chemical plant straight from the oil well either. This is where BASF's expertise comes in. We support our partner Quantafuel in developing suitable catalysts to purify the pyrolysis oil. Only then, the oil fulfils the specifications that it needs to be used in our chemical plants.

Chemical recycling is criticised as greenwashing because it is very energy intensive. What do you answer to this?

Currently, the commercial pyrolysis plants run at an efficiency of 71%. That means that 71% of the plastic waste is converted to oil, and we expect to raise the efficiency to 75% to 80%. The remaining 20% is turned into a gas that fuels the whole pyrolysis process, so we need almost no external energy for that.

And by the way: Chemical recycling can also contribute to the reduction of CO_2 emission, because the pyrolysis of mixed plastic waste emits 50% less carbon dioxide than its incineration. This is the conclusion of a life cycle assessment (LCA) carried out by the consulting company Sphera on behalf of BASF, which was reviewed by independent experts.

You explained very well that chemical recycling is only part of the whole plastics world. What would be your guess about the share of chemical recycling ten years from now?

I do not think that it will be dominating. It depends on whether the regulatory framework supports chemical recycling and in the EU that's definitely the case. I think that the rate of chemical recycling in 2030 could be 20 to 30%. •

QUESTIONS ASKED BY KATHRIN RÜBBERDT

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PORTRAIT

ACHEMA'S FRENCH AND BELGIAN CONNECTION

Vickie Nikolaou has been representing ACHEMA Worldwide Events in France & Belgium since 2001. Let's join in on her ACHEMA journey to date.

Do you remember the first time you ever heard about ACHEMA?

VICKIE NIKOLAOU: *I first heard about ACHEMA in 1994 when I worked for a French Laboratory and Biotechnology trade show. From the start, I noticed that ACHEMA had an excellent reputation and had no equivalent in France or Belgium. Even today, you need to visit several French and Belgian events to make up for one ACHEMA. It was also the only trade show recognised outside of Europe and the only process industry event that Americans specifically named when we exhibited in the United States.*

And can you remember your first time entering the exhibition halls?

Of course – it had a big impact on me! At ACHEMA 1997, I was an exhibitor in hall 6.2. The first time I entered the exhibition halls was during the set-up, where I walked into a beehive of construction work. The following morning, I was truly mesmerised by the transformation from the previous afternoon: the stands were finished to perfection, the staff all dressed up, often in

p. 24–25: Photos: Vickie Nikolaou

company colors, the different nationalities present, the attractiveness and professionalism all around. All that technical equipment in action with cheerful personnel ready to explain their trade. It can be overwhelming for some, but, as an extravert, it was right up my alley!

What is different at ACHEMA today from when you started?

The Frankfurt fairgrounds have been upgraded quite a bit. I've seen the Forum and halls 3 and 11 integrated into the show, and I am looking forward to discovering new hall 12 at ACHEMA 2022.

And of course, the show mirrors the digitalisation in our daily personal and professional lives, which makes for a lighter load – no need to drag a wheelie suitcase around anymore for all those documents. Even the voluminous ACHEMA catalogue now conveniently fits into a smartphone.

And what has stayed the same?

The inspiration to be found everywhere at the show. The fresh topics covered in the extensive conference program. The scope of exhibits on offer. The qualifications of the exhibitors and visitors. The advantage of discovering the process industry innovations launched for the first time on the world-stage.

Is there an event in the context of ACHEMA that is especially memorable to you?

I am very fond of the "Meet your friends" party at the end of each ACHEMA Monday. Our exhibitors appreciate this opportunity to enjoy a nice meal and live entertainment with their peers. Whether it's pouring rain like in 2018 or we see a fantastic sunset as in 2015, it's always lots of fun.

I was also very pleased and proud when my daughter came to visit ACHEMA for the first time in 2018. She is studying interior design, and the exhibitor stands are always very inspiring. I'm hoping to have my son visit the next ACHEMA and ignite the science and technology spark in him.

What challenges have you encountered in your role as ACHEMA's representative in France and Belgium?

Like everyone else, my customers would like to have a prime location, and they are disappointed when the best spots are snatched up very early. Other than that, the French have a keen eye for detail and are very in tune with the beauty of things; sometimes to the extent that form may take precedence over substance. In that regard, ACHEMA is a very good product for the French public, as the quality standards are high in every respect.

And then there are the forewarnings I've been hearing since I started in the trade show business: that people will no longer travel to trade shows since they can surf the web and shop online from the comfort of their own home. Perhaps this is true for smaller investments than those made at ACHEMA. But, as our surveys of exhibitors and visitors alike prove: ACHEMA is still a very valuable meeting place for anyone working in the process industry. This same argument has gained momentum recently with the current pandemic situation. However, I remain convinced that once the situation is stabilised, we will be even more enthusiastic to get out of our laboratories, factories and (home) offices to meet in person, discuss new trends and see real-life demonstrations. As a descendant of Greek immigrants to Canada who adopted Europe as my new home, I cannot help but hear the echo of Aristotle's teachings that humans are "social animal(s) by nature". And I guess we can add today that meeting virtually is the next best thing because nothing compares to social interaction in real life.

Please finish the following sentences...

If I wasn't a representative for ACHEMA, I would like to *organise well-being retreats including yoga, meditation and other proven relaxation techniques for stressed out executives!*

A first-time visitor to ACHEMA should take care to *prepare their visit via the ACHEMA app for smartphones. Not to mention the new ACHEMA Pulse event, which will be a valuable opportunity to prepare for ACHEMA 2022.*

I am looking forward to ACHEMA 2022 because *it will be the last ACHEMA of my fellow representative Alan Morris. It has been such a pleasure seeing him at every ACHEMA since I started out.*

I am looking forward to ACHEMA Pulse because *I will be able to engage first-hand in a digital event that shall boost ACHEMA 2022.*

Where would we usually find you outside of work?

Nordic walking in the beautiful forest near my home or in my back garden tending my flower garden, shrubs and trees.

What are you reading right now?

I like audiobooks read by the author. At present, I'm enjoying listening to Michelle Obama read me her "Becoming" novel.

A fun fact that most people don't know about you?

Every summer, I handpick several wheelbarrows of apples, cherries and mirabelle plums from my own trees to make pies, jams and jellies, which I also share with family and friends. •

QUESTIONS ASKED BY MARLENE ETSCHMANN

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VICKIE NIKOLAOU

Vickie Nikolaou studied French Language and Literature at the University of Saskatchewan, Canada and the Sorbonne, Paris, France. She has been promoting trade shows for most of her professional life.

SUSTAINABLY ON THE ROAD WITH RECYCLED PLATINUM

Heraeus and DECHEMA research institute collaborate to recover platinum from PEM fuel cells at the end of cell life. Closing the platinum loop would push e-mobility and is a prime example for circular economy.

Someday the coal rooms of steamers and the tenders of locomotives will, instead of coal, be stored with these two condensed gases [hydrogen and oxygen], which will burn in the furnaces with enormous calorific power." Jules Vernes was quite the visionary, when he described the future of transport vehicles as early as 1875 in his novel "The Mysterious Island".

We have learned since that bringing hydrogen and oxygen next to each other is not advisable, and using electrochemical process in fuel cell technology is much safer.

PLATINUM

Pt
Symbol

21.5 g/cm³
Density at 20°C

1,772°C
Melting point

0.005 ppm
Concentration in the earth´s crust

Trains get indeed attention as fuel-cell-powered vehicles. As of now, cars and buses in public transport are yet major applications.

THE CHALLENGE OF PLATINUM RECOVERY

Polymer Electrolyte Membrane Fuel Cell (PEMFC) is the most efficient option for transportation such as passenger cars, busses and regional trains. This technology, however, still relies on the expensive precious metal platinum as catalyst for both hydrogen oxidation and oxygen reduction reactions. Around 190 tons of platinum are mined per year worldwide, from which 40% are used in catalytic converters for exhaust systems of combustion engines. If only 100 t platinum per year is available for new hydrogen transportation technologies inclusive PEM electrolysis, a systematic and efficient recycling strategy for catalyst reuse is a prerequisite for a long-term, sustainable H_2 economy. While thermal recycling of catalytic converters is quite straightforward and state-of-the-art, recovery of about 30 grams of the precious metal from a 115 kW fuel cell stack (e.g. Mirai, Toyota) remains still challenging not only technically but also economically.

PUSHING E-MOBILITY

The firm Heraeus and the DECHEMA research institute have now joined their expertise to work on platinum recycling from fuel cells and thus ultimately help to push e-mobility.

Christian Gebauer, Head of Hydrogen Systems at Heraeus Precious Metals says "Although we at Heraeus have decades of experience in precious metal recycling, the end-of-life material streams from PEM fuel cells raise new challenges. With this project, our Recycling Innovation department is taking a closer look on their specific properties and aim to close the gap between scientific lab experiments and industrial processes."

"Efficient platinum recycling is a prerequisite for a long-term, sustainable hydrogen economy."

JEAN-FRANCOIS DRILLET

The experts at DECHEMA research institute are exploring whether the platinum in gas diffusion electrodes and catalyst-coated membranes can be dissolved by applying high cathodic polarisation in alkaline solution. Another important step towards sustainability is to extend the life of the catalyst particles during fuel cell operation by using mesoporous carbon as support. Since no commercial products fulfil the required properties yet, DFI team is also developing mesoporous carbon with an optimised pore size. •

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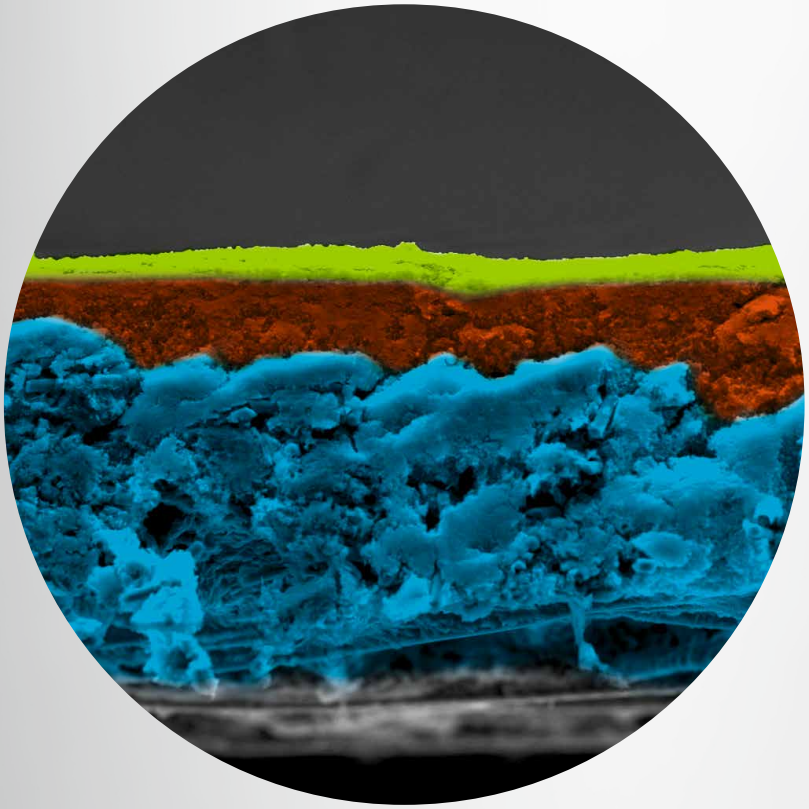
THE PLATINUM HIDES IN THE POLYMER ELECTROLYTE MEMBRANE OF THE FUEL CELL



PLATINUM/CARBON CATALYST LAYER (15 µm)

4–10 nm platinum particles enable hydrogen molecules to be split into protons and electrons.

MICROPOROUS LAYER (60 µm)

50–100 nm carbon particles facilitate better water management at the cathode, especially at high current densities

GAS DIFFUSION LAYER (125 µm)

10 µm carbon fibers / PTFE network transports the gases into the catalyst layer and liquid water from the reaction centers. It also acts as current collector.

PLATINUM CONSUMPTION

by industry in 2019 in metric tons. Total amount 244 tons.

100	68	27	15	7	27
EXHAUST TREATMENT SYSTEMS	JEWELRY	CHEMICAL CATALYSTS	GLASS PRODUCTION	ELECTRONICS	OTHER APPLICATIONS

Source: Norilsk Nickel © Statista 2020

SINGLE-USE SYSTEMS: "A QUESTION OF CHARACTER"

According to a recent study, the market for single-use equipment in biopharmaceutical production will reach $33.0 billion by 2027. The fast market penetration leads to practical questions regarding the selection and characterisation of single-use systems.

Over the past 15 years, single-use systems (SUS) have become an integral part of biopharmaceutical production. Today they come in various sizes and specifications and for many different processes. Single-use technology is of considerable importance especially at laboratory and pilot scale, but also for the production of biopharmaceuticals and biosimilars. In addition, continuous production strategies with single-use-systems are becoming more relevant. The main application focus of SUS is on the manufacturing of protein-based biotherapeutics from mammalian cell cultures. But they also play a role in the cultivation of plant cell cultures, microorganisms and algae as well as for special products in the food and cosmetics sector. The rapid development with a broad range of technological options has lead to new questions: How do users select the appropriate equipment? How can different single-use systems be compared with each other and to "conventional" equipment?

> **"Single-use systems are popular for growing mammalian cell cultures."**

THE FOCUS LIES ON:

- A standardised catalogue of experimental methods to determine relevant parameters for the characterisation of single-use bioreactors and mixers
- Evaluation and validation of these methods
- Models and criteria for characterisation and scale-up of single-use bioreactors and mixers, mainly in relation to mass transfer

CHARACTERISATION FROM A PROCESS ENGINEERING PERSPECTIVE

A variety of disposable bioreactors and mixing systems with a volume of up to 6,000 litres (for bioreactors) or 5,000 litres (for mixers) are currently available. These systems differ in terms of the type of power input, mixing and gassing strategy. It is therefore not easy to compare or select a system for a planned application. These questions are addressed in the recent publication "Recommendations for process engineering characterisation of single-use bioreactors and mixing systems by using experimental methods (2nd edition)". The authors are members of the working group "Up-stream processing" of the DECHEMA expert group "Single-use technology in biopharmaceutical manufacturing", in which experts from industry and academia work together to provide the community with knowledge-based guidelines. These recommendations are intended to make single-use bioreactors and mixers easier to compare among each other and with conventional glass and stainless steel bioreactors. Standardised test methods are used and provide manufacturers and users with objective criteria for comparison.

The validated standard operating procedures described in the publication provide users with a uniform set of methods to characterise single-use bioreactors and mixers from a process engineering point of view. They can also be applied to reusable systems.

The methods are applicable to single-use systems in different scales and designs and for cell culture and microbial applications. Compared to the 1st edition of the publication, a new method for the determination of the volumetric mass transfer coefficient (k_La value) has been introduced and formulated in a generally applicable manner. The experimental evaluation method now corresponds with the underlying theory of mass transfer as it is presented in relevant textbooks on the subject. To support the users of single-use equipment in the application of the new experimental method for determining the k_La value, the working group has also developed an evaluation tool based on Microsoft Excel.

CHARACTERISATION WITH BIOLOGICAL APPROACHES

Process engineering characterisation as described above is of utmost importance – but it often provides information on only the ideal bioreactor design or scale-up. A useful supplement is the biological microbial characterisation of bioreactors. This approach is concerned with the evaluation and comparison of the biological performance of a system.

With using a model organism in combination with a standardised cultivation strategy, a bioreactor can be evaluated for a desired process from a biological perspective. The DECHEMA working group "Single-Use microbial" within the expert group "Single-use technology in biopharmaceutical manufacturing" developed a standard process model based on *Escherichia coli*. This microorganism is readily available, grows quickly and has great relevance in the biopharmaceutical industry. The use of a classical medium and a defined process under real and standardised conditions with substrate concentrations changing over time also enables the dynamic investigation of the driving force of oxygen. The classical k_La value measurement method according to the process engineering characterisation can lead to problems at high oxygen inputs. The reason is the often slow response time of the pO_2 probe, which can strongly falsify the measurement results and thus limit the measuring range. Since microbial processes in particular place high demands on the bioreactor system with regard to oxygen transfer, this has a special significance. Thus, the *E. coli* model process makes it possible to overcome such problems by determining the k_La value during cultivation. Moreover, heat removal can also be investigated in parallel. The *E. coli* model process is a simple batch process which can be conducted within one working day. An Excel tool for standardised data evaluation is also available. With this approach, single use and reusable bioreactors can be compared under real process conditions, thus supporting the investigation and evaluation of various growth-related parameters. •

33

BILLION US$

is the market projection 2027 for single-use equipment in biopharmaceutical production.

_ KARIN TIEMANN
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Karin Tiemann is subject matter expert pharmaceuticals at DECHEMA e.V.

_ DECHEMA.DE/SINGLE_USE_PE_CHARACTERIZATION.HTML

p. 29: Photo: Pall Corporation

Allegro™ STR single-use stirred-tank bioreactors (50 l and 200 l)

THE PERFECTION OF CIRCULARITY

This is a true story. About a year ago, I saw an advert for a bag in a glossy magazine at the hairdresser. It was a particularly colourful and somewhat eccentric bag that was available only from an online shop. As I spontaneously fell in love with it, ordered it via the internet.

When I was informed that delivery is imminent, I alerted my family to open the door should the delivery person ring, but nothing happened. We went about our usual business, clearing out the postbox and putting the recycling bins out to be collected in the morning.

The next day, our doorbell remained silent. I went to retrieve the post. Somewhere between brochures for wine from the south of France and the electricity bill, I found a nondescript piece of paper that said, "Package in wastepaper bin".

I sprinted to the street corner, where our wastepaper – miraculously! – was still waiting for collection. Buried by a package of newspapers and some pizza cartons, I found a somewhat crumpled white parcel (paper, perfectly matched to its surroundings) containing my missing bag.

Since then, I have been wondering whether this was not actually a revelation of a future where the circular economy will have been perfected: Instead of buying things, using them (thereby dirtying the material and adding all sorts of impurities) and then wondering about where to put them in the sophisticated German recycling system, wouldn't it be much better to close the loop without actually using the products? It wouldn't put the economy under unnecessary strain, as consumers would still regularly buy new goods. Even better, products could be designed for optimal recyclability: No compounding, no additives to make a bottle softer or nicer to look at, but just a simple bottle made of one pure material that doesn't have to meet any requirements for holding liquids or protecting vitamins and can be recycled with minimal cleaning and no sorting.

"Circularity would be much easier to achieve if we didn't actually use the products."

KATHRIN RÜBBERDT

One might take this thought even further: The German automotive industry is worried about being left sitting on thousands and thousands of cars with combustion engines. However, using combustion engines is regarded quite unfavourably by many due to the negative impact on climate. So why not buy cars, send them directly to recycling and ride your bike instead? This would be beneficial to the global climate and to the personal health at the same time. And the car could be produced so that it could be dismantled without much effort, and it would contain no oil or other fluids that pose problems in recycling. A true win-win-win-win situation!

Somehow, though, I doubt whether our mail delivery man intended to open my eyes in quite this fundamental way. Maybe he just thought "package – dry place – easily accessible – check!" But sometimes big ideas start small – a first step on the way to perfect circularity. •

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MEET THE COMMUNITY

ISIC 21 – 21ST INTERNATIONAL SYMPOSIUM ON INDUSTRIAL CRYSTALLIZATION

30 August–2 September 2021, online

Crystallization is a core process in the chemical and pharmaceutical industry. This conference provides a broad overview of the current science and technology.

DECHEMA.DE/ISIC_2021.HTML

4TH EUROMOF (EUROPEAN CONFERENCE ON METAL ORGANIC FRAMEWORKS AND POROUS POLYMERS)

12–15 September 2021 Krakow, Poland

The conference is aimed at bringing together scientists and other enthusiasts of open framework materials and related compounds to share and discuss their recent research.

EUROMOF2021.CONFER.UJ.EDU.PL/EN_GB/HOME

13TH EUROPEAN CONGRESS OF CHEMICAL ENGINEERING AND 6TH EUROPEAN CONGRESS OF APPLIED BIOTECHNOLOGY

20–23 September 2021, online

Engineering the future – what can technical chemists, process engineers and biotechnologists contribute to tackle climate change, the circular economy and optimal pharmaceutical production?

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