Chemical products have been manufactured at Evonik's current site in Herne, Germany, for almost 100 years—with the help of fossil raw materials and fuels. In the future, new technologies will enable greater use of sustainable alternatives at the points marked in color

A PLANT IN TRANSI-TION

There are many ways to make chemical production sustainable. One of these ways is to convert not only the big reactors but also just about everything around them. Managing raw materials, energy or waste flows smartly can be the key to a green future. Evonik wants to demonstrate this with its Herne Green Deal. A site visit

TEXT **TOM RADEMACHER**

A case for two: Together with the head of Electrical, Instrumentation, and Control Technology, Lutz Komorowski (left), Plant Manager Rainer Stahl is driving forward the transformation of the Herne site

The roller shutter rattles up, Dr. Rainer Stahl spreads his arms wide and lets his gaze wander through the hall. "We have a lot of space here!" he exclaims. The huge hall extends 100 meters toward the left and right. In the past, fertilizer was stored here—thousands of cubic meters of special salts. But that was decades ago. Now, spare parts and some old equipment are stored in the hall's more than half a hectare of space. "We can free up these areas," says Stahl, who has big plans. Green hydrogen for the chemical plant will be produced in the hall. Construction of the electrolyzer will start this year.

Rainer Stahl holds a doctorate in chemistry and has been the head of Evonik's Herne site for three years. The plant in the heart of the Ruhr region has a long and eventful history, and the structures have grown over several generations. In the past, hard coal was mined here deep underground. Today, complex chemicals are produced for the world market, with manufacturing processes that are sophisticated down to the smallest detail. Things are to remain that way, but a number of measures have to be taken to ensure this is the case. After all, it is not just customers and governments who demand sustainable production. Evonik itself has made innovation and sustainability its strategic principles.

To make Evonik's Herne site climate-neutral and bring it into the circular economy, many things have to mesh together. The prospects here are particularly promising. "We don't have to fundamentally change our chemical processes," Stahl says. "All it takes is an adjustment of raw materials and energy." Moreover, economic and environmental interests are going hand in hand. "We are cutting costs and hedging raw material supplies and energy requirements more strongly against risks," adds Lutz Komorowski, the head of Electrical, Instrumentation, and Control Technology. "In addition, the technologies that are available today are more sustainable and future-proof."

The plan is comprehensive and aims to successively replace fossil sources of carbon and close material and energy cycles. With its holistic concept, the Herne plant could become a showcase for a defossilized chemical industry. Evonik calls it the Herne Green Deal.

PART OF THE ENERGY TRANSITION

The substance around which everything revolves in Herne is called isophorone. This molecule consists of a simple ring made of hydrogen, carbon, and oxygen. Evonik has been producing it from acetone in Herne for many years. In fact, this industrial process originated in Herne. In the 1960s, isophorone was sold primarily as a solvent. Today it is a much sought-after precursor product for the chemical industry.

However, Evonik's biggest business is with more complex downstream products. For this purpose, functional groups are added step by step to the isophorone molecule in the I-chains and T-chains. This produces isophorone diamine, for example, which wind turbine manufacturers need to cure special epoxy resins. Evonik is one of the world's most important manufacturers, and Herne is home to three of the Group's five I-chains.

"We produce chemicals for a rapidly growing global market, and with our products we are part of the green energy transition," says Lutz Komorowski, who is Stahl's right-hand man when it comes to technological matters. The two men are a well-rehearsed duo who like to joke together and verbally pass the ball to each other. Komorowski has been in Herne for nine years. Stahl came here three years ago as the site manager; before that he was responsible for production and technology at the Evonik location in Shanghai. The two are united by their technological background and the irrepressible fun they have in constantly questioning established processes. They also like to tinker with tricky technology questions after work, and Herne has plenty of such questions to offer.

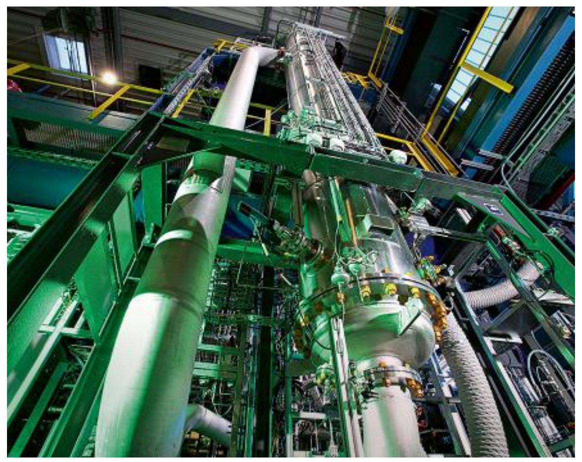
HOW MUCH DOES THE REVOLUTION COST?

Their plans are huge in scope, as Stahl and Komorowski want to make the location completely independent of fossil raw materials and fossil sources of energy. They already have plans in hand for more than a dozen construction projects, which could reduce CO_2 emissions by a total of 26,600 tons per year. It's also conceivable that the Herne location would become emission-free. These projects are a perfect fit for Evonik's strategy: The company aims to reduce Scope 1 and Scope 2 emissions by 25 percent by 2030. Scope 1 emissions include climate gases produced by Evonik itself. Scope 2 includes CO_2 from purchased energy. Evonik plans to invest €700 million throughout the company in Next Gen Technologies, which are technical measures that help conserve resources and reduce energy consumption and emissions while cutting costs.

"The chemical industry is the toughest nut to crack," says Professor Martin Stuchtey. "It is the ultimate fossil-based and energy-intensive industry." Stuchtey, who co-founded the consulting firm Systemiq, has published a study together with the University of Tokyo that shows how it could be done. According to this study, the global chemical sector could become not only climate-neutral but even climate-positive by 2050—in other words, it could relieve the atmosphere of carbon dioxide. To do this, instead of using carbon from oil and natural gas, it would have to use mainly carbon that is already in circulation—whether in the air, in plants or in waste. Ferdi Schüth, a professor at the renowned Max-Planck-Institut für Kohlenforschung (Max Planck Institute for →

“The chemical industry is the toughest nut to crack”

MARTIN STUCHTEY, CO-FOUNDER OF THE CONSULTING FIRM SYSTEMIQ



RHETICUS

SPECIALTY CHEMICALS MADE FROM CO_2

Evonik is working on various projects to biotechnologically convert waste and waste gas streams that contain CO_2 into valuable chemicals. One of the most promising projects is the Rheticus research project, which the company is running together with Siemens Energy. The project partners have developed a technology that uses artificial photosynthesis to produce valuable specialty chemicals from carbon dioxide (CO_2). Renewable electricity is used for this, along with water and bacteria. The test plant in Marl consists of a water electrolyzer and a bioreactor. In a first step, water (H_2O) is converted to hydrogen (H_2) using electricity. Special microorganisms combine this hydrogen with CO_2 into hexanoic acid. This can be used, for example, as a raw material for coatings, cosmetics or even lubricants. Evonik is holding talks with potential customers. The company is already cooperating with Beiersdorf on a research project on the use of Rheticus products as raw materials for cosmetics.

Coal Research) in Mülheim, is somewhat more skeptical. For him, climate neutrality for Europe is already a very ambitious goal (see the interview on p. 26). However, he believes that the path being taken in Herne is the right one. “It is important to move forward now as quickly as possible. In doing so, we have to maintain the links in the value chain, but focus on a sustainable basis,” says Schüth.

The fact that relatively few different and comparatively simple raw materials are used in Herne makes the plant an ideal candidate for testing. “Hydrogen, ammonia, methane, acetone, oxygen—we need almost nothing here at the site that you don’t know from basic chemistry class,” Komorowski says. “We could also get these raw materials from green sources—or produce them ourselves.” Even the CO_2 emissions and waste materials could be fed back into production as raw materials.

GREEN INSTEAD OF GRAY

We start off at the old salt warehouse. The location currently requires up to 30 million cubic meters of hydrogen per year. Until now, this has come by pipeline, produced from natural gas in steam reformers that spew out ten tons or more of CO_2 per ton of hydrogen. This is not only a concern for the climate, but also for ensuring reliable production, because a single pipeline supplies the entire location with over 3,500 cubic meters of hydrogen per hour at peak times. A pressure tank with a capacity of 6,000 cubic meters serves as a buffer. If the pipeline fails, Stahl’s employees in the control room have to shut down the facilities in an orderly manner. “Even if everything goes well and the supply resumes after a few hours, we’ll be standing still for a few days,” Komorowski says.

The solution is called H2annibal—in reference to H_2 for hydrogen and the abandoned Hannibal coal mine in the immediate vicinity. The planned water electrolysis system in the salt store is a cooperation project with Siemens Energy and is funded by the German Federal Ministry of Education and Research. It splits water into hydrogen and oxygen using electricity from renewable energy sources. The hydrogen output is expected to meet half the plant’s needs. If the pipeline should fail in the future, the site could continue to operate at a reduced rate. Electrolysis also supplies oxygen as a byproduct, which is used in production as well.

Green instead of gray: In the former salt storage facility, an electrolyzer will produce hydrogen from green electricity in the future. Construction is scheduled to begin this year

RECYCLING WASTE

Sustainable sources could also be developed for all the other raw materials used in Herne. Today, 50 tons of ammonia roll into the plant every day by tank car and more than 300 tons of acetone by truck. Both could soon be produced locally, at least in part, from waste and exhaust gas streams.

This is comparatively easy with ammonia. Stahl and Komorowski already have an idea for this. In front of the salt storage facility rises the site’s imposing skyline—a tangle of pipes, reactors, and chimneys, some of which stretch dozens of meters into the sky. Stahl points to two chimneys where his engineers are planning retrofits. In the HAmst:ER project, ammonium sulfate produced as a by-product is to be split back again by electrodialysis. The abbreviation stands for “Herne Ammonium →

The H2annibal project is funded by the German Federal Ministry of Education and Research under the code 03HY131B

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Federal Ministry of Education and Research

sulfate: Electrodialysis-based Recombination." Clearly, Komorowski and Stahl demonstrate their creativity not only in technical matters.

So far, the Herne location has found customers for its ammonium sulfate in agriculture, where it is used as a nitrogen fertilizer. But because farmers also want to get by with less nitrogen fertilizer in the future, the industry has to think about what it should do with the large quantities it has.

Continuing with ammonia, the second project is called HASe for "Herne Ammonia Separation." Residues of the raw material are to be separated from the waste gas streams prior to incineration and thus recovered. Incidentally, less nitrogen oxide is then produced during combustion.

The Herne location also has plans for acetone. Right next to the old salt warehouse, a handful of birch trees form a line on a green space. The possibly most revolutionary innovation of the Herne Green Deal could be created in the shade of these trees. It would consist of a facility for the production of acetone from carbon dioxide by biotechnological means using bacteria. Acetone is one of the most important raw materials for the isophorone chain. It also contributes the most to CO_2 emissions. Around half of the total Scope 3 emissions of the Crosslinkers business line come from acetone. Scope 3 includes, among other things, the climate impact of purchased raw materials.

Evonik already buys smaller quantities of bio-acetone from certified sustainable sources and feeds it into the production process. The company's customers can then buy downstream products with a lower carbon footprint from Evonik. This will be done on the basis of the mass balance method, similar to the approach used for green electricity (see box on the right). But recovering acetone even from exhaust gases or waste would be something like the gold standard of the circular economy.

"The technology for this exists," says Stahl. The US company Lanzatech has developed a process in which an anaerobic bacterium produces acetone from carbon dioxide and hydrogen. A plant that is not overly large would be enough to "kill two birds with one stone," as Stahl puts it. The fermentation process supplies acetone and swallows CO_2 emissions. "The green acetone thus provides an additional payoff, because we need fewer CO_2 certificates." Not surprisingly, there is already a suitable name for the project: SAcHer—"Sustainable Acetone for Herne."

HEATING FOR HERNE

Raw materials are a decisive factor, not only in Herne but at Evonik as a whole. The biggest climate burden of the entire company comes from purchased raw materials. But the second big lever is the energy supply. In Germany, chemical production currently accounts for around a quarter of industrial energy consumption. In

MASS BALANCE

GREEN ACCOUNTING

The chemical industry needs carbon. However, the carbon does not need to come from out of the ground. Today about 85 percent of the carbon in chemical products comes from fossil sources, especially petroleum. Evonik already relies on renewable resources for around eleven percent of its raw material base. In addition, Evonik currently offers customers the option of choosing from an increasing number of its products based on renewable and circular raw materials. For example, the company's portfolio includes isophorone and downstream products in which the acetone is derived exclusively from renewable or circular sources using the mass balance process. The mass balance process allows raw materials from different sources to be used in one and the same process. The amount of renewable starting materials used can nevertheless be clearly attributed to an end product, even along complex processing steps. Like green and conventional electricity, renewable and fossil raw materials flow through the same lines here and are processed together. The final balance is calculated at the end of the process. Independent institutes check and certify the mass balance result according to internationally recognized standards. This has the big advantage that instead of having to invest in new green facilities, companies can switch their production to sustainable raw materials piece by piece.

Herne too, the hunger for energy is enormous: The location currently draws ten megawatts of electricity from the grid at peak times, plus consuming 22 million cubic meters of natural gas per year. Although the natural gas is mainly used as a raw material, together with the plant's residues it is also used to supply energy.

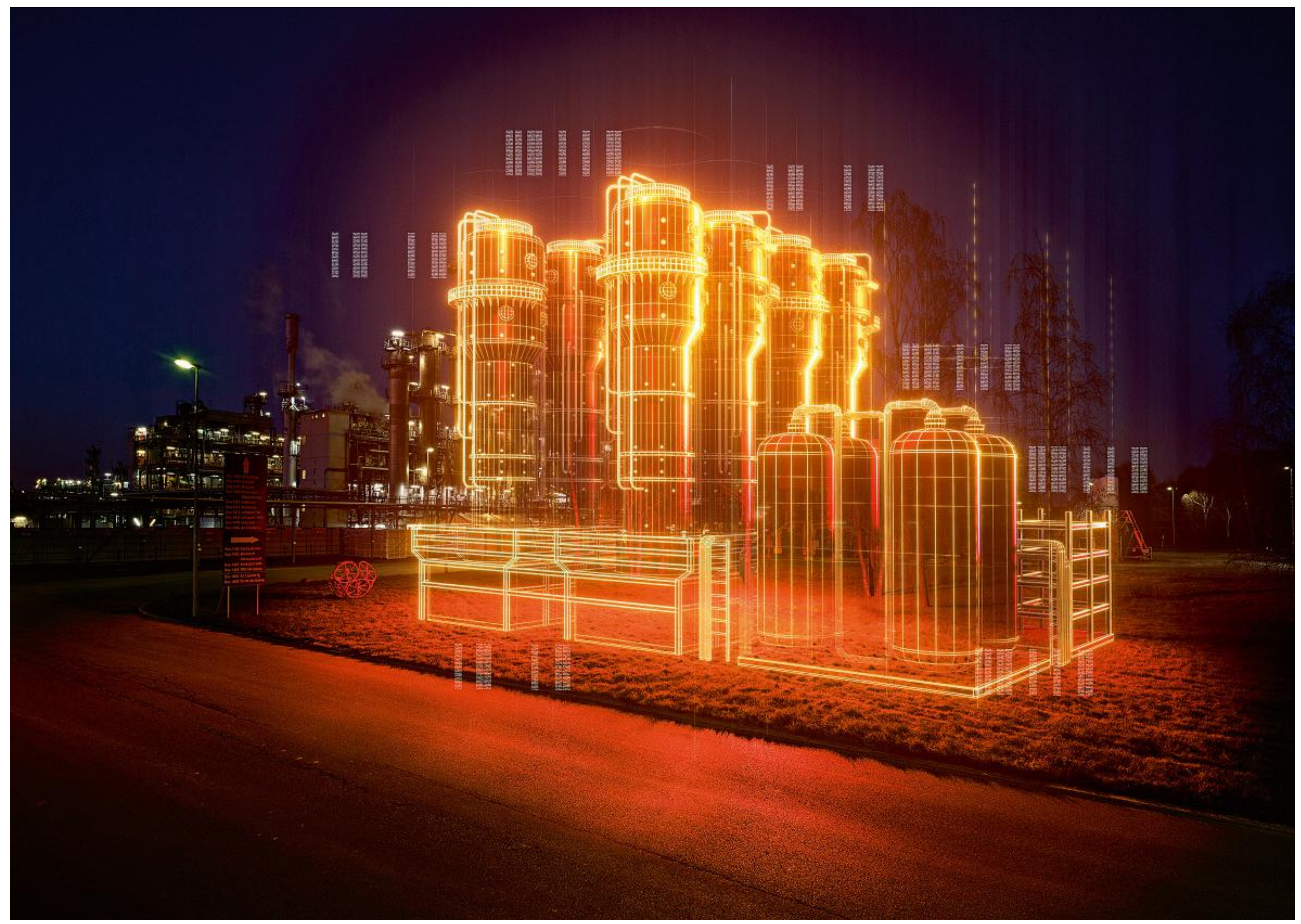
Across the company, Evonik already covers 27 percent of its externally sourced electricity requirements from renewable sources; from 2030, Evonik will only purchase electricity from renewable sources. The supply of green electricity is one thing, the efficient management of the energy used is another. Herne is laying the groundwork for this as well. The associated project is called TORTE ("Technical Options for the Recovery of Thermal Energy"). In the future, the site will feed large parts of its waste heat into the district heating network of the energy company Uniper. Initially, this will be enough for around 1,000 households.

The fact that the chemical and energy industries are so closely intertwined in the densely populated Ruhr region has advantages. "This is where the high-temperature heat pump will be located," says Stahl, pointing to a gap next to the cooling towers and just a few meters away from two thickly insulated district heating pipes snaking past. SAcHer would directly benefit from TORTE. According to Stahl, it's pure coincidence that the names of the two projects fit together so nicely (a Sachertorte is a type of cake). "The names were coined completely independently of each other, and it took us a while to realize how well they fit together," says Stahl.

The HerMES ("Herne Managing Emissions and Sustainability") construction project will also be launched this year. In this project, Evonik will install a state-of-the-art incineration plant for production residues.

TURBINES INSTEAD OF FURNACES

A good bit further into the future are plans for three of the existing incinerators. Stahl and Komorowski look up. Their gaze wanders up the brick factory chimney that towers over everything at the site. Right next to it, but much less prominent, is one of the site's three incinerators. "They make sure our production residues are incinerated," Stahl explains. "We also use it to heat thermal oil, which brings the necessary process heat to our plants," Komorowski adds. →



Energy from waste: In Herne, robust combustion turbines could generate process heat and up to six megawatts of electricity from production residues

FROM COAL TO GREEN HYDROGEN

The history of the Evonik's Herne location

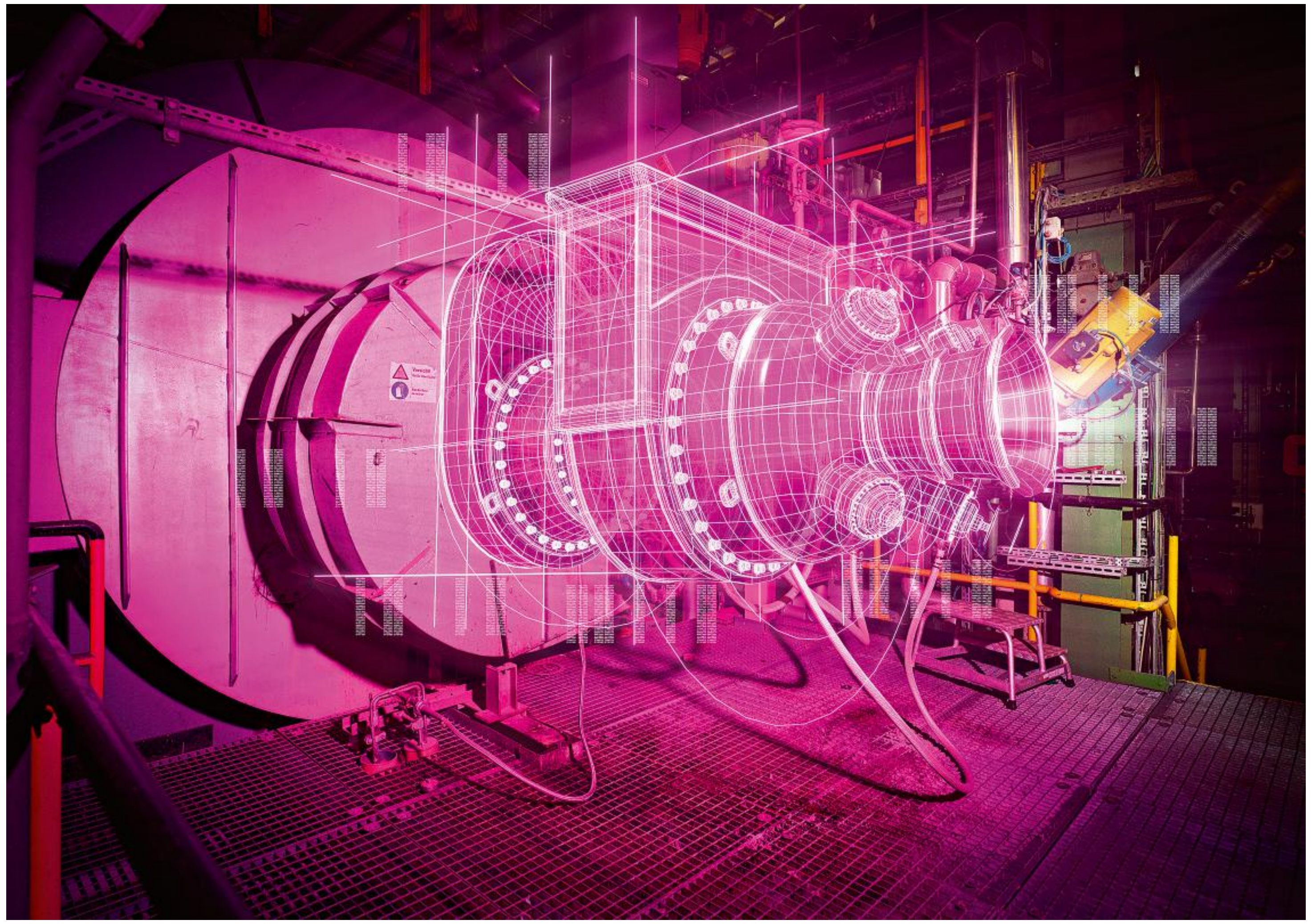
1872
COAL MINING
Shaft 2 of the Hannibal colliery is dug next to the site of today's Evonik plant. The colliery is one of eleven in Herne to attract industrial companies from the mid-19th century on.

1928
GAS GENERATION
Industries that use the coke gas are built around the collieries. The Hibernia nitrogen plant is built on the present site.

1935
GASOLINE FROM COAL
Prior to World War II, Krupp takes over the plant and shifts to coal-based production of tar, gasoline, and kerosene.

1945
A RUINOUS ENDING
After the site's destruction by the Allies, production is initially at a standstill. For a brief period, the plant then produces raw materials for soap.

1952
FERTILIZER AND WAX
In the postwar period, paraffins are produced first, followed by ammonia and ammonium sulfate.



Alternative acetone: The US company Lanzatech has developed a process in which a bacterium produces this important raw material from CO_2 and hydrogen

Here too, the two have something new in mind. They also want to generate electricity with the site's own waste. To this end, the current furnaces are to be replaced by combustion turbines. They will generate a total of up to six megawatts of electricity for the site from combustible production waste in addition to process heat. It goes without saying that this project also has a resounding name: HErOdoT, which stands for "Herne Energy-Optimization by means of an optional Turbine."

Stahl and Komorowski worked out the concept for this with turbine experts from the project partner Siemens Energy. "It wasn't easy," Stahl recalls. Today's turbines are highly sophisticated, trimmed for maximum electricity yield and minimum emissions. However, a drawback of this is that they can no longer consume all kinds of fuel. "Our project turns the requirements upside down," Komorowski says. In Herne, the main focus is on the targeted disposal of production residues. "It's not the last percentage point in efficiency that matters," says Komorowski. Siemens Energy and Evonik found a very robust turbine design, proven over decades, that could potentially make the plans a reality. Siemens Energy is currently testing in Sweden how well production residues can be used in a turbine—with residue samples sent by Evonik from Herne. Even the turbine's exhaust gases, which contain CO_2, can still be used for something. The nitrogen oxides are removed from the exhaust gases, and the carbon dioxide serves as nutrient for the acetone-producing bacteria.

ROTOR RECYCLING

In Herne, however, they don't only think about the cycles in their own plant, because the location's products are supplied to many industries. Among the most important are hardeners for epoxy resins used in the construction of large wind turbine blades. The first generation of wind turbines is now being decommissioned. Industry experts estimate that more than 100,000 tons of old rotor blades will accumulate in 2030—rising to around 700,000 tons in 2040. People in the industry are already asking themselves how the materials in these rotor blades can be recycled.

Researchers and developers at Evonik are currently working on processes to separate the organic components of end-of-life wind turbine blades from the glass or carbon fibers they contain and then break them down again into a raw material for new rotor blades or other applications. A residual organic fraction from this recycling process could be reused in Herne. "Synthesis gas can be obtained from it by means of pyrolysis. Or you can completely burn it right away into CO_2, which our microbes then process into acetone," Stahl explains.

A new life: Developers at Evonik are currently working on recovering the organic components of end-of-life wind turbine blades as a raw material

The many ideas at the Herne location fit into the surrounding environment. Herne's mayor, Dr. Frank Dudda, has set his city the goal of being climate-neutral by 2045. "We want to become the greenest industrial region in the world," Dudda says. "The chemical industry is playing a big role in this development and showing that it is on the right track." Traditionally, the residents of this region have had very close ties to industry. That's why Stahl wants to not only reconfigure the local Evonik plant to be more sustainable but also to open it up more. Regional universities are already eying collaborations and space for startups that could move into rooms in the old salt warehouse. An investor can build a photovoltaic system on the roof of the industrial building. It would be visible far and wide from the busy road next to the plant. To provide a view of the new hydrogen electrolysis plant, Stahl is considering installing a large window in the wall of the hall and having banners hung on the facade. "Everyone should see how much we're doing!" he exclaims.

Tom Rademacher is a freelance journalist based in Cologne. He writes about scientific and industrial topics, among others

1962

NEW PRODUCTS FROM ACETONE

Isophorone based on acetone is produced in Herne for the first time. In subsequent years, more and more expansion stages are added for new downstream products such as isophorone diamine and isophorone diisocyanate.

1979

THE PATH TO EVONIK

After several changes of name and ownership, the plant now belongs to Chemische Werke Hüls—later absorbed into Degussa, a direct predecessor of Evonik.

1992

EXPORT MODEL

In Mobile, Alabama (USA), an integrated isophorone production network (I-chain) is built according to the Herne model.

2012

EXPANSION IN CHINA

In Shanghai, China, Evonik Industries, which received this name in the previous year, builds an isophorone (I-chain) production network that is almost identical in design to the one in Herne. Production begins in 2014.

2023

HERNE GREEN DEAL

Planned start of construction for an electrolysis plant to supply the location with hydrogen.

Climate-friendly, Please

Solar power, green hydrogen, carbon dioxide from exhaust gases—energy and raw materials must increasingly be obtained from non-fossil sources in order to make chemical production more climate-friendly. This is an overview of the plans for Evonik's Herne location

INFOGRAPHIC **MAXIMILIAN NERTINGER**