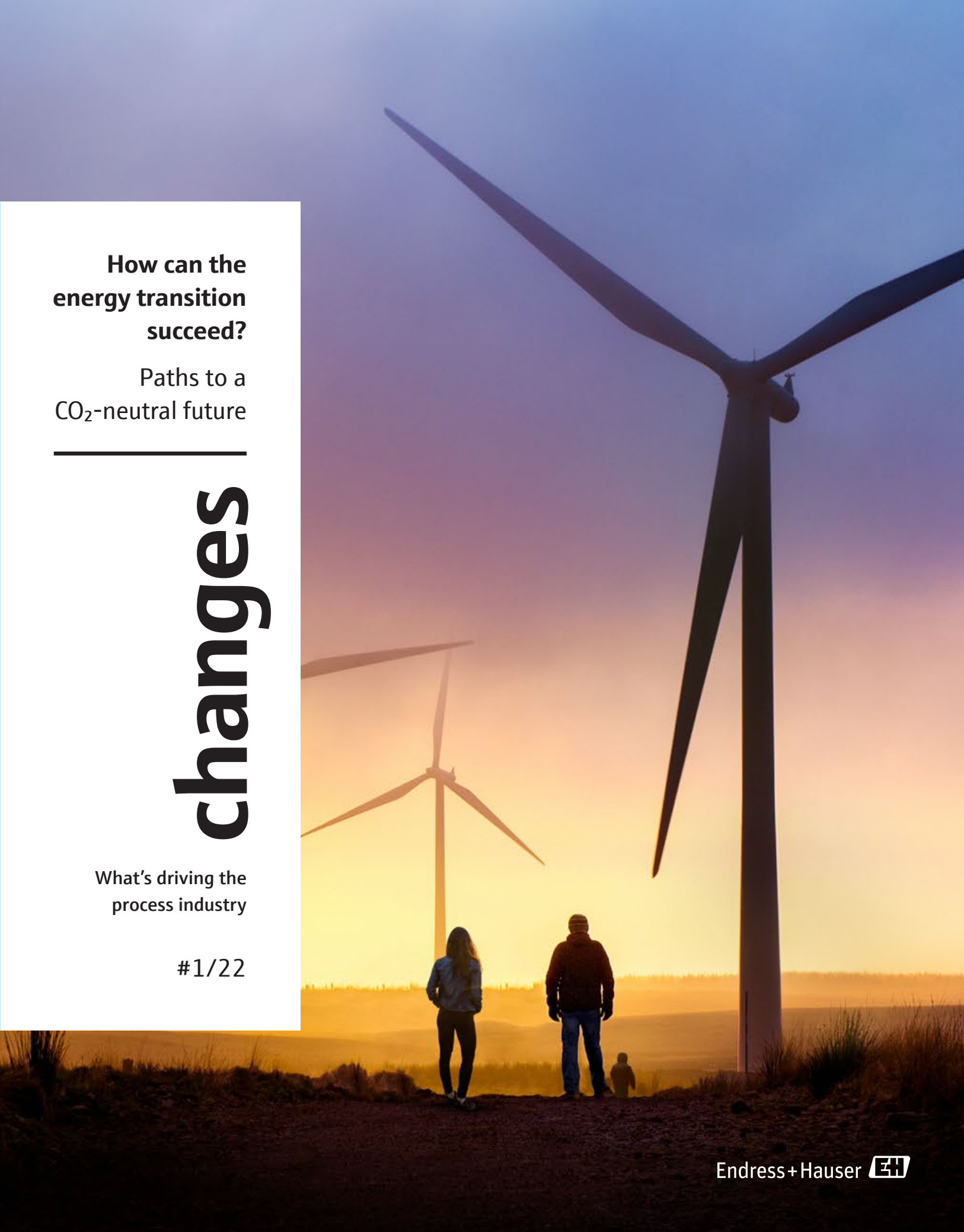


changes

How can the energy transition succeed?

Paths to a CO_2-neutral future

What's driving the process industry

#1/22

Endress+Hauser

The world is in agreement: our energy supply should be sustainable. Although the path to this goal is yet to be found, industry is working on key solutions – and has already begun the energy transition.

How is the process industry managing the energy transition?

Record-breaking heat in Canada, thawing permafrost in Russia, devastating floods in Germany. Scientists are convinced that the accumulation of extreme weather events points to climate change driven by human activity. An overwhelming proportion of the international community has therefore agreed to reduce greenhouse gas emissions. The goal is to achieve climate neutrality – truly the task of the century!

The path to net zero inevitably passes through the energy transition. The world is still dependent on fossil-based energy sources. And it's not only electricity, heat and mobility that must become emissions-free: the process industry is challenged with substituting hydrocarbon-based raw materials. Pressure to act is growing. And this pressure has long since come not only from societal discourse and scientific findings but also from investors and shareholders who are pushing for sustainable business models.

So how is industry dealing with this? By once again demonstrating its strengths. Industry is showing initiative and creativity and implementing concrete measures. It's also using innovative technologies, improving established processes and developing new solutions. Every company I visit is busy adapting and transforming itself in one fashion or another. And I'm pleased that Endress+Hauser is positioned to help many of its customers with this process. You will find numerous examples of that in this edition of 'changes'.

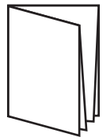
Today, not all questions have a good answer and not every solution is economically feasible. Without a doubt, major tasks for managing the transition still lie ahead. I nonetheless sense strong resolve and confidence within the process industry that the energy transition will succeed and that climate neutrality is achievable. That's why I'm convinced we are currently experiencing nothing less than a green industrial revolution based on behavioral changes and technological progress.

Here's wishing you a stimulating reading experience!

Matthias Altendorf
CEO of the Endress+Hauser Group

Industry is once again demonstrating its strengths. It's showing initiative and creativity and implementing concrete measures.

A project for the generations



What the energy transition of tomorrow might look like: the wall poster!

Industry's take on the energy transition.
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Energy and its many faces.
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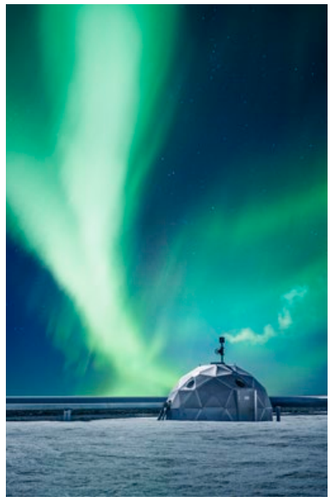
It's time to pull together!



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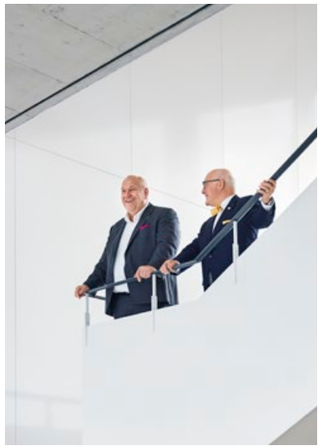
Strong relationship



Klaus Endress and Matthias Altendorf look back at a successful 2021.
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Hitting the gas for hydrogen

Hydrogen is on the way to becoming a key technology.
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Adaptable

Before we turn to industry's climate-friendly solutions, we'd like to address a few questions. How much renewable energy is available to us? What does our diet have to do with the energy transition? And finally, can lightsabers help?

Text: Lisa Schwarz, Robert Habi
Photography and graphics: Getty Images, Shutterstock, Tobias Cornille (Unsplash)

7,500 times

more energy than humans use annually – that's how much the sun supplies in one year. That equates to 1.5×10^{18} kWh. For the future supply of energy, **it appears to be enough.**

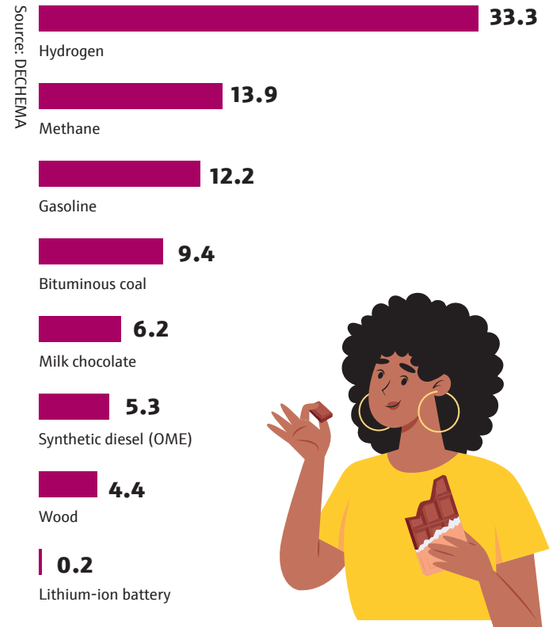
Computing power

While artificial intelligence and digitalization are touted as helping the drive to save energy and every gram of CO_2, the technology itself actually has a considerable footprint. Internet surfing, together with all the computers in use – from manufacture to disposal – is responsible for 2 to 4 percent of CO_2 emissions worldwide. That's more than the amount caused by all air traffic. Roughly 80 percent of the energy used by the internet is attributable to video streaming alone.

Full of energy

Why hydrogen is considered a promising source of energy can be illustrated by comparing heat values. Chocolate is likely to remain the top source of fuel for humans.

(in kWh per kg)



Source: DECHEMA

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

Thomas Alva Edison, with a prescient warning, 1931

Our growing personal demand for energy

As hunters, gatherers and fishers, humans used three to six times the basal metabolic rate (3 kWh) as fuel, mostly as energy for feeding themselves, for clothing and in the form of wood.

6-fold

In the agrarian society (in cooler latitudes), that value grew to between 18 and 24 times the basal metabolic rate with the addition of domestic animals and field laborers.

18-fold

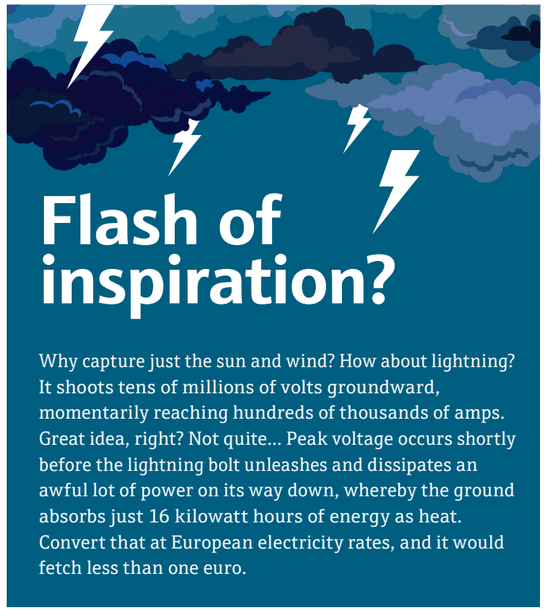
In industrial countries, a human uses 80 times the average basal metabolic rate, above all for fossil fuels. In parts of India or Africa, where heating is rarely required, every human uses around 20 kWh of energy per day. In China the figure is 75 kWh and in the US, roughly 220 kWh per day.

80-fold

2,034,065

kilometers

that's the impressive total length of the world's pipeline network, according to GlobalData. It is a system that would wrap nearly 51 times around the equator. More than half of that is attributable to natural gas pipelines, in addition to others carrying crude oil and natural gas liquids. The high-voltage grid, which is set to become more important still as electrification increases, measures roughly 5.5 million electrical circuit kilometers (multiple phases are factored in). Both figures will likely see significant growth due to the worldwide energy transition.



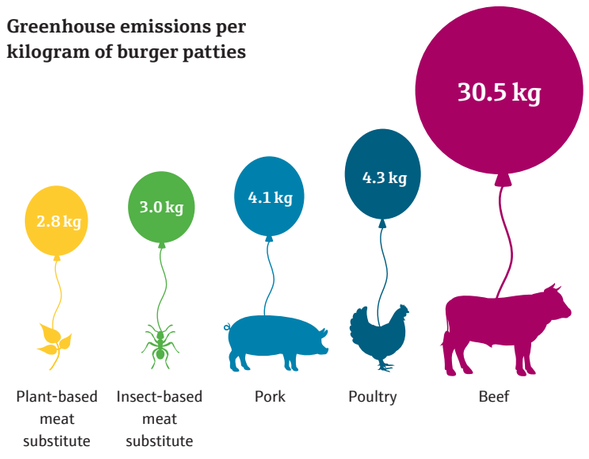
Flash of inspiration?

Why capture just the sun and wind? How about lightning? It shoots tens of millions of volts groundward, momentarily reaching hundreds of thousands of amps. Great idea, right? Not quite… Peak voltage occurs shortly before the lightning bolt unleashes and dissipates an awful lot of power on its way down, whereby the ground absorbs just 16 kilowatt hours of energy as heat. Convert that at European electricity rates, and it would fetch less than one euro.

Leaving a good taste

The human diet's role in protecting the climate is a highly debated topic. There is much to suggest that vegan diets offer great leverage in reducing energy use by agriculture and in diminishing personal CO_2 footprints. This becomes readily apparent when you compare a burger made with beef to other alternatives.

Greenhouse emissions per kilogram of burger patties



Red =
5.5 MW

Green =
7.0 MW

Blue =
8.0 MW

Violet =
9.3 MW

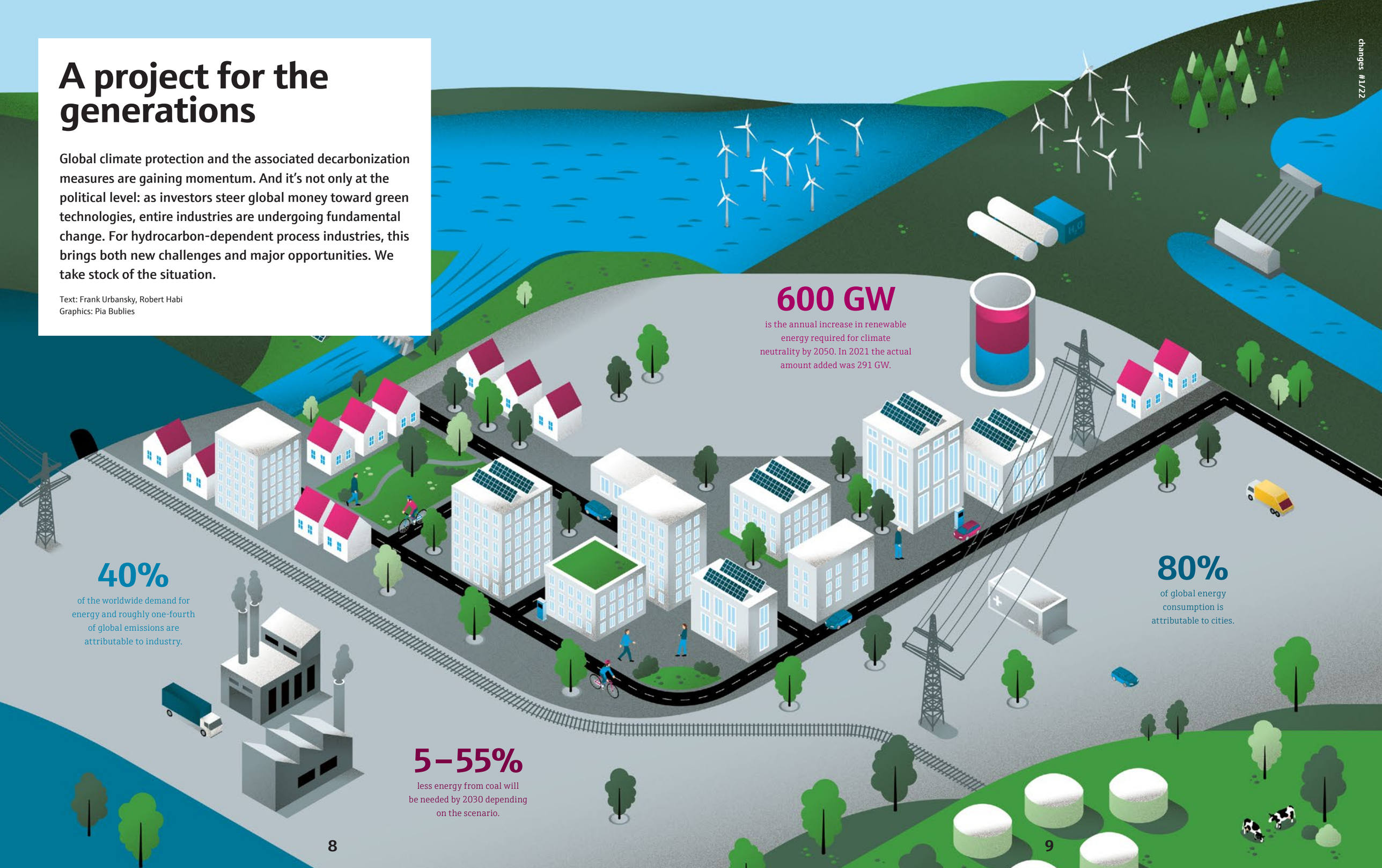
Powerful lightsabers, the good have

If people in a galaxy far, far away ever really encounter Master Yoda and his ilk, one question has already been answered: which lightsaber from Star Wars is the most powerful in terms of energy? A student at England's University of Leicester ran the numbers – and the results are reassuring. The red lightsabers wielded by the evil Star Wars characters are weaker than the green, blue or violet ones brandished by the good guys.

A project for the generations

Global climate protection and the associated decarbonization measures are gaining momentum. And it's not only at the political level: as investors steer global money toward green technologies, entire industries are undergoing fundamental change. For hydrocarbon-dependent process industries, this brings both new challenges and major opportunities. We take stock of the situation.

Text: Frank Urbansky, Robert Habi
Graphics: Pia Bublies



600 GW

is the annual increase in renewable energy required for climate neutrality by 2050. In 2021 the actual amount added was 291 GW.

40%

of the worldwide demand for energy and roughly one-fourth of global emissions are attributable to industry.

5–55%

less energy from coal will be needed by 2030 depending on the scenario.

80%

of global energy consumption is attributable to cities.

No one can doubt that achieving global climate neutrality is a Herculean task spanning generations. It's a task for humankind in general and industry in particular. Or as Larry Fink, head of BlackRock, the world's largest asset management corporation, put it: "The process of creating fuel, food and construction materials, with all the needs that we have as humanity, it all has to be reinvented." It's a project to which more than 150 countries have committed themselves through international agreements, albeit with varying objectives. The US and Europe want to achieve an overall balance of greenhouse emissions – otherwise known as net zero – by 2050. China is aiming for 2060 and India for 2070.

Whatever the political objectives, many industries are taking energy transition matters into their own hands: the shift to decarbonized processes, renewable energy sources and new business models is a complex undertaking, especially for energy-intensive industries. So what are the challenges facing sectors such as energy, chemicals, petrochemicals, gas, pharmaceuticals, steel and cement? And, just as importantly, what are their envisaged solutions?

THE NEW ENERGY LANDSCAPE

According to the International Energy Agency (IEA), roughly 40 percent of worldwide CO_2 emissions are attributable to energy production from oil, coal and gas. For energy producers, the transition to renewable energy sources will be a core task over the coming decades. Achieving net zero by 2050 means more than doubling the pace of expansion in renewables. The energy industry faces a highly complex balancing act of ensuring adequate supplies of electricity and heat while big, centralized power plants are being taken off the grid.

And talking of the grid, engineering preparations are necessary here to interconnect and control numerous decentralized producers that will form virtual power stations. In addition, the energy industry has to compensate for volatile grid inflows from wind and solar sources using either large intermediate storage systems or flexible solutions such as cogeneration power plants that can be started up or shut down on short notice. For storing green energy over longer periods, there are huge investments being planned, especially in Europe, for electrolyzers to produce green hydrogen. Economically speaking, North Africa lends itself particularly well to the production of this versatile gas.

In the area of conventional production, countries such as China also have modern coal- and gas-fired plants that will continue being part of the net zero timetable. Their climate compatibility could increase thanks to combined heat and power plants, as well as processes for capturing, utilizing and storing CO_2 from emissions that are still in the testing phase.

THE GLOBAL ENERGY TRANSITION IN NUMBERS

73%

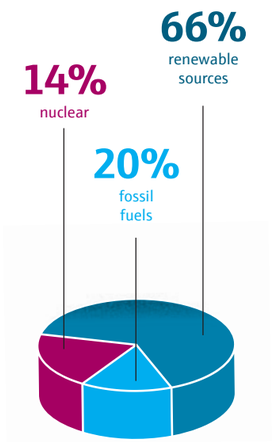
of all greenhouse gases stem from the production of energy. (Source: World Resources Institute)

24%

of direct CO_2 emissions, including process emissions, are caused by industry. (Source: International Energy Agency)

29%

of global electricity generation comes from renewable sources. (Source: International Energy Agency)



Energy mix for net zero CO_2 emissions in 2050 (Source: International Energy Agency)

2/5

of investment assets worldwide should flow exclusively into climate-friendly projects in the future. These financial resources are managed by the Glasgow Financial Alliance for Net Zero and its 450 members in the finance sector.

ENERGY LANDSCAPE OF THE FUTURE

What does the energy landscape of the future look like? How are cities changing, for example? Our poster included with the magazine visualizes this development.

TRANSITIONS WITHIN THE TRANSITION

Some companies in process industries can already minimize their CO_2 footprint by procuring energy from renewable resources. In sectors such as chemicals or the cement industry, where the raw materials and processes themselves release additional greenhouse gases, there will need to be multiple energy transitions within the value chain. The chemical industry is the world's largest user of oil and gas. Most of its end products, such as synthetics, are manufactured from ammonia, methanol, ethylene and propylene, and thus for the most part on the basis of hydrocarbons. Add to that the industry's position as the biggest user of electricity and you have enormous potential for defossilization.

If chemical companies shift to renewables and develop alternative hydrocarbon sources, this improves the climate footprint of the user industries as well. Green hydrogen could be used as a fuel by power plants to generate electricity and heat. Another possibility is to use green electricity for producing methanol from hydrogen electrolysis and CO_2. And new recycling methods for plastics reduce the need for fossil-based raw materials. The catch? All of these processes are not yet market-ready on a large scale.

HARD TIMES FOR THE CEMENT INDUSTRY

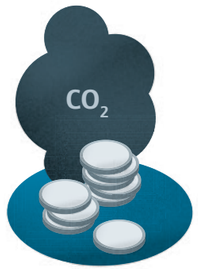
A similar situation exists in the energy-intensive cement industry, which the WWF says is responsible for around 8 percent of CO_2 emissions worldwide. Only about one-third is attributable to fuels that could be replaced with climate-neutral approaches. The vast majority of emissions escape from cement clinker when it is burned. According to the German Association of Cement Manufacturers, carbon dioxide capture, which to date has been tested primarily in the US, is the only serious alternative. In Germany, the lighthouse project Concrete Chemicals seeks to use captured CO_2 for making synthetic fuels.

LEGACY EXPERTISE, NOVEL APPLICATIONS

Expanding the use of renewables reduces demand for oil and gas. This development has set into motion a transformation of the industry's entire business model. The IEA views this as an opportunity for the established energy companies, with their expertise and resources in the fields of CO_2 capture and storage, hydrogen, bioenergy and offshore wind production. Shell has embarked on such a strategy with the aim of establishing itself as a leading provider of green hydrogen for industry and vehicle power trains. The company is currently investing in synthetic fuels and charging stations for electric vehicles (more about Shell on page 14).

FIRST STEP IS ENERGY EFFICIENCY

The dawn of a new era is within sight. But according to the IEA, of the 46 technologies needed across industry as a whole to achieve net zero by the year 2050, only two are mature. And because green energy will not be available in sufficient quantities for the foreseeable future, the focus on energy efficiency will be even more important in the coming years. After all, existing plants are where the necessary measures can mostly be implemented.



Blast furnaces and lime burners, for example, where much heat is still allowed to escape, offer great potential through thermal insulation. This waste heat can instead be recovered and used as process heat or in district heating systems. In the gas industry, reducing methane leaks and putting a stop to gas flaring is considered the most cost-efficient way to cut back emissions. And across all segments of industry, energy monitoring can facilitate more efficient operation of auxiliary systems for water, air, gas, electricity and steam.

CAPITAL MARKETS GO GREEN

One accelerator of decarbonization is large investors who are already steering the flow of global money toward climate-friendly companies and technologies. In his annual letter to CEOs in 2022, BlackRock CEO Larry Fink wrote: “Few things will impact capital allocation decisions – and thereby the long-term value of your company – more than how effectively you navigate the global energy transition in the years ahead.” Like 450 other financial institutions, BlackRock is a member of the Glasgow Financial Alliance for Net Zero. This initiative manages an astronomical sum of 130 trillion US dollars, which represents a good two-fifths of investment assets worldwide. The plan is for these financial resources to flow exclusively into climate-friendly projects and technologies in the future.

A PRICE SEEKS ITS VALUE

The question remains, how can decarbonization become economically comparable and globally attractive? To date the most practical answer has been to set a global price for each tonne of CO_2 emitted. Carbon prices, albeit at very different levels, are currently levied by 64 nations, including many EU countries and others such as Canada, Colombia and South Africa. China introduced a similar instrument for operators of gas- and coal-fired power plants. The US is relying on subsidies as a technology driver.

So while governments are still searching for the true value of CO_2 to the climate and the economy, industry is sending out clear signals. At the end of 2020, BP and other oil companies called for a significant increase in the price of carbon “in order to achieve a stable reduction of emissions generated by the use of energy”. And as we all know, this is a goal that everyone agrees on.

Taking off the blindfold

With its Green Deal, the EU seeks to move forward with reducing greenhouse gas emissions to zero by the year 2050. Is this goal achievable globally as well? Lino Guzzella believes this is unrealistic. While the professor of thermotronics is by no means expressing doubts about the available technologies, he questions whether we are properly assessing the economic and political constraints.

As told to Robert Habi

VIEWPOINT

Net zero. This is how the EU refers to its Green Deal, which aims to achieve a neutral balance of greenhouse gases by the year 2050. Anyone wanting to put this mammoth task into the proper context must look to where climate change is occurring – namely across the entire globe. In 2020 humanity’s primary energy sources were more than 80 percent coal, oil and gas. Solar energy and wind power still account for only a few percent globally. And in less than 30 years, we want to do without fossil-based sources for our energy needs, which have grown more than fivefold since 1950.

Of the nearly 8 billion people on the planet today, a good 3 billion are living in prosperity. The remaining population, plus the 2 billion that will be added by the year 2100, have a right to a life of prosperity as well – a point underscored by two of the 17 UN goals for sustainable development. But given that increased prosperity requires energy, which in the short term will lead to emissions rising yet higher, it won’t be possible to generate climate-neutral energy for all by the year 2050. To achieve this, we would have to downsize per capita and annual CO_2 emissions five times more than in the past 20 years, a feat that borders on magic. For this reason we need to make a clear statement: net zero will take longer and cost more than we currently think.

If we refrain from fixating on the year 2050, however, good news is on the horizon. Over the long term we can replace fossil-based sources with renewable energy, using it together with green hydrogen as a raw input to the steel industry, as a fuel for long-distance transportation routes or as storage. Technologies such as cogeneration and further increases in energy efficiency can also help. The technical solutions are available and they work.

TIME AND MONEY

The issue is that we need enormous amounts of renewable power in specific sectors such as industry, heating and transportation. Furthermore, the global energy and grid landscape must undergo massive expansion to ensure a stable energy supply. That won’t occur overnight; it takes time.

Added to that is the fact that the transformation must be affordable, otherwise it simply will not happen. According to estimates by Goldman Sachs, more than 60 percent of carbon dioxide emissions could be reduced at a cost of less than 100 US dollars per tonne of CO_2. This also includes approaches that are unpopular among climate activists, such as substituting efficient gas turbine plants for coal-fired power plants in the Asia-Pacific region, which quickly cuts their CO_2 emissions in half. Other measures that can be implemented relatively fast include insulating buildings and increasing energy efficiency through sensors, control system technology and automation, all of which happen to save money as well. We need to go down these paths first! In contrast, e-mobility or making industry climate neutral is many more times expensive.

Lino Guzzella (64) is a professor in the Department of Mechanical and Process Engineering at ETH Zurich. The Swiss-Italian mechanical engineer has for decades been conducting research into the optimization of energy conversion systems.

Moving faster and more cost-effectively in the direction of net zero requires us to adapt the strategy. That means taking off the blindfold, widening our view and pursuing the multitude of available technologies. It also means reducing emissions beyond the electricity industry. And possibilities such as storing or capturing CO_2 from the atmosphere must be vigorously explored and applied.

In my view, the most important task of government lies not in dictating technologies, but in negotiating a global price for greenhouse gases. After all, solving the global challenges of climate change calls for global solutions. Were Europe to press ahead unilaterally, that would put its industry at a competitive disadvantage and, ironically enough, punish precisely those companies that are doing so much for climate protection. We will find a fair and effective global solution only if all of the economic heavyweights do their equal share. By remaining open to technologies and weighing costs versus benefits, we can keep climate change in check. But that means having the courage to face a number of uncomfortable truths.

“The transformation must be affordable, otherwise it simply will not happen.”

Endress+Hauser has been a major and key supplier of process measurement engineering to Shell for more than a decade. Why are enduring partnerships especially important in times of fundamental change? An interview with Harry Brekelmans, member of the Executive Committee at Shell, and Endress+Hauser CEO Matthias Altendorf.

Questions: Laurin Paschek and Martin Raab
Photography: Christoph Fein

Partners in change

Mr Brekelmans, Shell aims to become an industry trailblazer by achieving a neutral CO_2 balance by the year 2050. Why this radical change in strategy?

Brekelmans: I've been working at Shell for more than 30 years and during this time I've experienced the company as highly dynamic. Change is nothing new for Shell. Time and again, we have turned to new fields of business and developed new technologies – and ensured their financial viability, such as with the introduction of biofuels and the exploration of hydrogen power. This attitude has made us one of the world's leading energy companies. The transition to a neutral CO_2 balance by the year 2050 is nevertheless a very big task. We're taking on this transition because it is what society, our stakeholders and our customers want. And we will shape it in constant dialog with these same interest groups.

What is the biggest challenge with this transition?

Brekelmans: There are a number of challenges here. One key question is certainly timing. If the company changes too quickly, on the one hand it could put us at an economic disadvantage with respect to our competitors and we then fall behind the global competition. In the end, perhaps we would lack the stamina to bring the transition to a successful conclusion. On the other hand, if we act too slowly, it could potentially jeopardize the actual goal. Such are the tensions under which we operate, and that's precisely why we want to press ahead with the transformation in line with the expectations of society and our stakeholders.

Mr Altendorf, in considering the magnitude of this task, have you ever experienced a comparable transformation?

Altendorf: Personally, I can recall the introduction of catalytic converters for automobiles in the 70s and 80s as a way to combat acid rain. In this case lawmakers led an entire industry to change based on available technologies. The Endress+Hauser Group has also undergone change, time and again. A good example is the transition from simple electric devices to electronic microprocessor-driven measurement technology, and onward to purely digital, software-based solutions. We were able to shape this transformation all on our own, so there is no comparison to the challenges of the energy transition.

1.7

gigatonnes of CO_2e = Shell's present carbon footprint, which the company aims to reduce to net zero by the year 2050.

The digitalization that you speak of can certainly be viewed as a major transformation. How do you go about mobilizing the necessary willingness to change?

Altendorf: First off, employees of large companies need a shared understanding of what the future could look like. And then, everyone has to tackle this envisioned future together. To do that, management must allocate resources to tasks that don't benefit the company in the here and now, such as developing and validating future scenarios. Once a company knows more, it can go a step further, but with a continued footing in the current business model so as not to endanger its future. People need a sense of security and dependability in times of change. They need to know that they are part of the journey to the future.

How did Shell convince its shareholders and the workforce of the new strategy?

Brekelmans: I believe this comes down to having a very logical and easy to understand approach. We have always tried to understand the world around us by listening to our stakeholders, writing scenarios and carrying out studies. Based on this, the Board of Directors and the Executive Committee develop the frame of reference. An important aspect is that when defining the future energy world, we have to think backwards in terms of what the customers need, rather than extrapolate forward based on assumptions about the available resources. We also have to ask

Partners in dialog: Harry Brekelmans and Matthias Altendorf at Shell in The Hague.

ourselves what forms of energy our customers will in future prefer if they want to see more climate protection at the same time. Another important aspect is the realization that while we need more and cleaner energy, global energy demand will continue to grow.

What technologies are the major actors in your strategy?

Brekelmans: Innovative technologies such as biofuels, hydrogen and atmospheric CO_2 capture feature large in most scenarios. But at this point in time, I would not emphasize any single technology. What's decisive is not the technology itself, but its scalability. With existing technologies we can make considerable progress toward our net-zero goal. Yet all that depends on leveraging the necessary economies of scale. This is where Shell has always performed well, and we must continue to work on that.

How can business partners such as Endress+Hauser best support you?

Brekelmans: Our partners can give support by developing the innovative components that we need for the transition and integrating them into novel, complex systems. Endress+Hauser has extensive experience in this area and a very good understanding of Shell's business as a long-standing supplier. In addition, our corporate cultures are very similar in a way that they both highly value technology and innovation, quality and reliability. That's why we view Endress+Hauser as a really important partner in our forthcoming transformation process.

Altendorf: Take the aviation industry as an example. A Shell pilot plant recently provided synthetic kerosene made from renewable energy sources that powered a flight from Amsterdam to Madrid, and will in the long term enable carbon-neutral aircraft fuel. Producing this climate-friendly kerosene as efficiently and cost-effectively as possible requires reliable and precise measurement technology. We can supply this technology today and advance it together with Shell as part of a further scaling effort. Sharing information directly between the two companies is of central importance to innovation development.

"Our corporate cultures are very similar in a way that they both highly value technology and innovation, quality and reliability."

Harry Brekelmans,
Projects & Technology Director, Shell

SUSTAINABILITY MISSION

Harry Brekelmans (born in 1965) is Projects & Technology Director at Shell and a member of the Executive Committee under CEO Ben van Beurden. In this role he has held responsibility since 2014 for implementing the company's major oil and gas projects, driving technology and commercial innovations and overseeing the areas of technology, contracts and procurement, IT, security and the environment. He joined Shell in 1990 after graduating from Delft Technical University. In describing himself, Harry Brekelmans says: "I'm fully aware of how important it is for industry, governments and society to optimally utilize the world's resources in a sustainable manner."

Conversely, could Endress+Hauser also use Shell products in its decarbonization strategy?

Altendorf: I can well imagine Shell one day providing our company with green energy, even though we don't have extraordinarily high demand in our production. But of course there is demand in our office buildings and our supply chain. At some locations we are currently producing the energy we need on our own, with the help of natural gas. We could eventually convert these cogeneration units over to synthetic, climate-neutral natural gas or green hydrogen from Shell.

A personal question before we wrap up: how do you make a commitment to more climate protection in your private life?

Brekelmans: My family understands the special responsibility my job carries. I have frequent conversations with both my children and my wife about the energy transition and climate protection. We try to create as few greenhouse gases as possible, even though we still drive a combustion engine vehicle from time to time privately. We use electricity from renewable sources and keep a conscious eye on the climate impact of the food we eat. We have set ourselves a goal of being CO_2-negative within the coming years.

Altendorf: I often have these kinds of conversations with my 24-year-old son. I currently drive a hybrid vehicle, which can operate fully electric on the commute to work, and I frequently take the train for medium-distance travel. Furthermore, the roof on our house is decked out with solar panels. In terms of my overall balance, I have the advantage of owning a few hectares of woodland, which I tend to and maintain myself. I enjoy working there. That's my personal carbon capture strategy. Ultimately, forests are the most natural way to draw CO_2 out of the atmosphere.

ENERGY GIANT

Shell is a global energy company with expertise in the exploration, production, refining and selling of oil and natural gas, as well as chemical manufacturing and sales. The company, which is based in London, United Kingdom, generated sales exceeding 180 billion US dollars in 2020 and employs a global workforce of 87,000 people.

Climate strategy

Shell aims to be emissions-free by the year 2050. The energy company wants to reduce its carbon footprint from 1.7 gigatonnes of CO_2e annually to net zero, which includes reducing its customers' emissions that stem from Shell products (Scope 3). Shell's energy transition strategy rests on three pillars:

- **Avoid:** Shell wants to provide, invest in and scale up low-carbon energy solutions for customers.
- **Reduce:** The company wants to limit emissions as much as possible today.
- **Mitigate:** Shell wants to capture or offset any remaining emissions.

Milestones
These are the goals that Shell has established for 2030:

Operational efficiency	– Eliminate routine flaring of fossil fuels – Maintain methane emissions intensity under 0.2% by 2025
Renewable energy	– Double sales of electricity – Supply over 50 million households – Build 2.5 million electric vehicle charging points
CO_2 capture and storage	– Target 25 megatonnes annually by 2035
Natural gas	– Reduce oil production by 1–2% a year – Grow gas share to 55% of hydrocarbon production – Refrain from new frontier exploration projects after 2025
Biofuels and hydrogen	– Increase production of low-carbon fuels eightfold – Increase the share of low-carbon fuels to more than 10% of transport fuels
Natural carbon offset	– Create 120 megatonnes of capacity a year – Give backing to high-quality compensation projects only

Hitting the gas for hydrogen

Green hydrogen has the potential to decarbonize entire industries. But as a fuel for the new zero-emissions energy era, it would need producing in huge amounts, a feat that requires enormous effort. Companies and researchers are working together to bring industry closer to the goal of CO_2 neutrality.

Text: Christine Böhringer
Photography: H-Tec-Systems, ZSW
Graphics: 3st

In some places the future is already here. Take the northern coast of Germany, for example, where the land is flat and the horizon wide. Meadows alternate with fields, and wind turbines and solar modules generate renewable energy. Over the last two years, this region has seen the addition of five white containers that hold electrolyzers from H-Tec Systems. These use locally generated electricity to split water into hydrogen and oxygen. The hydrogen goes on to further use.

While it may sound simple, there is a whole lot more behind it, because here is a piece of the global energy revolution puzzle. Hydrogen produced with wind, water and solar energy is CO_2-free – also known as ‘green’. “Green hydrogen could be one of the keys to the energy transition and help industry achieve a breakthrough in decarbonization,” says Uwe Wagner, Global Industry Manager for Power & Energy at Endress+Hauser.

This emissions-free gas has numerous uses in many sectors. It makes excess production of green energy storable. It can be fed into the gas grid. And it can be converted to electricity and heat in fuel cells. In the chemical industry, it serves as a feedstock for producing ammonia and methanol. In the oil industry it’s used in the refining process. Combined with CO_2, it makes synthetic methane and synthetic fuels. “And in the steel industry, green hydrogen can replace coal as a reducing agent in blast furnaces that manufacture pig iron,” says Jens Hundrieser, European Industry Manager for Energy at Endress+Hauser.

To date the global demand for hydrogen, currently at 90 million tonnes annually, has been met almost entirely with inexpensive gray hydrogen produced by steam reforming of fossil fuels. Electrolysis currently generates just 0.03 percent. Still, more than 30 countries have adopted or are planning a national H_2 strategy. In the EU alone, the goal is to increase production of renewable hydrogen to 10 million tonnes per year over the period 2024 to 2030. Alliances are driving the project forward.

FROM NICHE APPLICATION TO THE HEART OF INDUSTRY

"Industry and science are working together to make green hydrogen a competitive product. Work is underway on industrial-scale production, as well as on use in a wide range of applications," reports Jens Hundrieser. Technological trailblazers in the manufacture of green hydrogen in Germany include H-Tec Systems, a manufacturer of PEM electrolyzers and electrolysis stacks based in Augsburg, as well as the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW).

For more than 10 years, ZSW has been developing electrolyzers and components on its own initiative and on behalf of customers. The center also plans and sets up test systems and builds demonstration systems. "At the beginning we were guided by the then novel power-to-gas concept as a way to store renewable energy whose production inherently fluctuates, rather than being steadily generated to meet consumer demand. Hydrogen with its high energy density makes the ideal storage medium," says Andreas Brinner, Head of Electrolysis and Location Support. "For this reason we wanted to develop an alkaline electrolyzer that would operate efficiently and at low cost – in other words, a system that is an effective energy converter, with a long service life, able to start up quickly, endure downtime and require little auxiliary energy."

These are also the features of another major process that H-Tec Systems is focusing on: proton exchange membrane electrolysis, or PEM for short. In contrast to alkaline electrolyzers, the PEM process dispenses with potassium hydroxide as an electrolyte. Instead, it utilizes a semipermeable membrane that allows the passage of protons. "PEM electrolyzers have the advantage of continuing to operate efficiently under rather less than full load, so they do a great job on fluctuating renewable energy," explains Emily Pröll, Marketing Manager at H-Tec Systems.

Since this is a relatively new technology compared to alkaline electrolysis, its use to date has been only on a small scale and in niche applications. "PEM electrolysis still has a lot of development potential. In the years to date our primary goal has been to design an efficient, scalable technology that customers can use to produce industrial quantities of high-quality hydrogen at the lowest possible cost."

HIGH DEMANDS ON THE MEASUREMENT TECHNOLOGY

There are plenty of challenges in hydrogen production. "Electrolysis relies on lots of auxiliary systems coupled together and decked out with measuring points for all kinds of parameters that require continuous monitoring. Hence the need for a considerable amount of reliable and precise measurement instrumentation," explains Andreas Brinner. Then there is the fact that H_2 is the lightest of all gases, with extremely small molecules. "Hydrogen

"Industry and science are working together to make green hydrogen a competitive product."

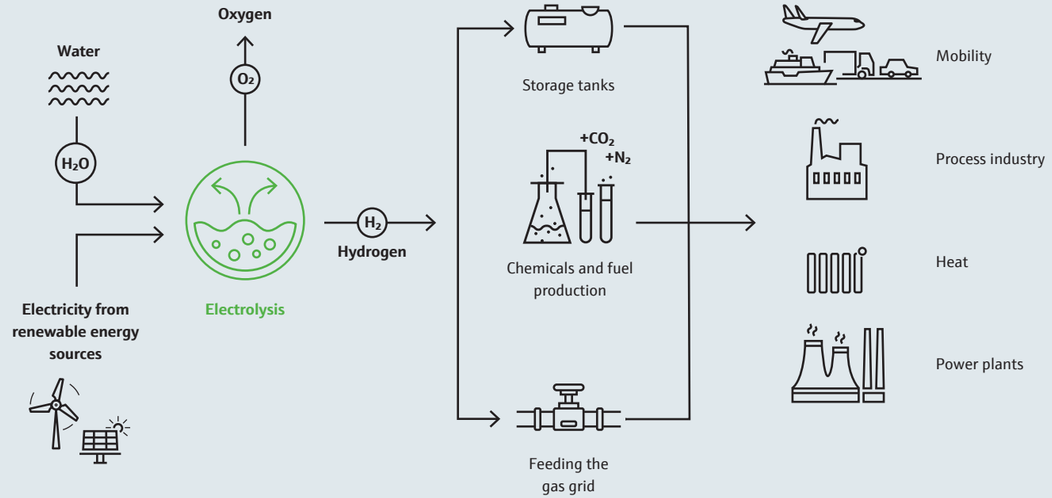
Jens Hundrieser,
European Industry Manager for Energy
at Endress+Hauser

H-TEC SYSTEMS

With two locations in Germany, H-Tec Systems develops and produces innovative electrolyzers and electrolyzer stacks in the megawatt range based on a proton exchange membrane process. The company boasts more than 20 years of research and development experience in the field of hydrogen technology, which it employs in various sectors and industries. H-Tec Systems has been part of MAN Energy Solutions since 2021.

Multitalented

Green hydrogen holds potential across a wide range of sectors. It can be converted to electricity and heat in fuel cells, fed into the gas grid or used in gas turbines. In the chemical industry, it serves as a feedstock for producing ammonia and methanol. In the oil industry it's used in the refining process. Combined with CO_2, it makes synthetic methane and synthetic fuels. In the steel industry, green hydrogen can replace coal as a reducing agent in blast furnaces that manufacture pig iron.



900

million tonnes of CO_2 are emitted each year in the course of producing hydrogen from primarily fossil sources.

easily diffuses through lots of materials and can cause metals to become brittle," says Prasanth Sreekumar, Global Industry Development Manager for Gas at Endress+Hauser. "This calls for careful selection of materials, instruments and seals."

Like many other electrolysis specialists, both H-Tec Systems and ZSW put trust in instrumentation from Endress+Hauser. "We have long relied on measurement technology from Endress+Hauser and value its quality, reliability, precision, media resistance and versatility. The large portfolio gives us many options," says Andreas Brinner. Other pluses include the instruments' compliance with functional safety (SIL) and explosion protection requirements. This in turn guarantees a high degree of plant safety. "We can cover a wide range of measurement tasks in our process with the sensors from Endress+Hauser," confirms Martin Linder, Development Engineer at H-Tec Systems. "What's also important for us is their straightforward installation and commissioning."

The electrolyzers from H-Tec Systems have a compact design.
PEM stacks built inside mobile containers produce hydrogen efficiently.

Endress+Hauser has benefited as well from its early involvement in green hydrogen. “This allows us to learn together with our customers and expand the breadth of products and solutions for the hydrogen sector,” emphasizes Prasanth Sreekumar. The market requires not only instruments that can withstand pressures of up to 1,000 bar and beyond, but also solutions suited to extremely low temperatures. “Innovation is in our DNA. Today Endress+Hauser boasts a broad portfolio of solutions for critical measuring points in the hydrogen value chain,” adds Prasanth Sreekumar.

The portfolio includes gas analyzers that use laser-based technologies such as TDLAS to reliably and precisely determine the quality, concentration and composition of gases, all with minimal maintenance effort. Added to that are solutions along the value chain, such as flow measurements in pipelines or level measurements in tanks storing liquid hydrogen. Customers furthermore profit from Endress+Hauser’s expertise in the field of gas applications. “We have acquired valuable process and industry knowledge over the years, from both gray and blue hydrogen applications, as well as from CO_2 capture,” reports Prasanth Sreekumar. “That makes it easier to jointly develop standards for new applications.”

H-Tec Systems has demonstrated many times that PEM technology is helping to spur the energy transition. At E-Farm, for instance, Germany’s largest hydrogen mobility project, the locally produced H_2 is transported to hydrogen filling stations. In other projects, green hydrogen is fed into the gas grid or used in gas turbines. “We are swamped with inquiries. There is also interest from industrial sectors in addition to mobility applications,” explains Emily Pröll. Andreas Brinner from ZSW can confirm this trend: “We have a lot to do.”

46

million tonnes of H_2 were used by the chemical industry in 2020, three-fourths for ammonia production and one-fourth for methanol production. Around 40 million tonnes went into oil refining.

ZSW

The Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), with headquarters in Stuttgart, Germany and roughly 280 employees, is one of the leading energy research institutes in Europe. In the area of electrolysis, the center has used its engineering and systems knowledge to build various systems with capacities going into the megawatt range. ZSW also advises customers on everything from design planning to the commissioning of commercial systems and their subsequent technology monitoring.

THE COLORS OF HYDROGEN

Green hydrogen is produced from renewable energies and is thus free of CO_2 emissions. The process uses electrolyzers powered by renewable energy from wind, solar and hydroelectric sources that split water (H_2O) into its constituent parts of hydrogen (H_2) and oxygen (O_2).

Gray hydrogen is produced from fossil fuels and normally involves thermal processes to convert natural gas into hydrogen and CO_2. The CO_2 is then released into the atmosphere. Producing one tonne of H_2 creates around 10 tonnes of CO_2.

Blue hydrogen uses the gray hydrogen process but captures the CO_2 for use or storage. Blue hydrogen is considered CO_2-neutral and hence a bridge technology on the way to all-green production, as well as a means to meet increasing H_2 demand.

ON THE PATH TO MASS PRODUCTION

Both ZSW and H-Tec Systems are currently focused on reducing the cost for green hydrogen in order to make it more competitive. To do that, data is being used to optimize the electrolysis process and increase the power rating of the individual modules comprising the systems. “At the moment we’re making inroads into increasingly larger areas,” reports Emily Pröll. “That means more and more systems in the double-digit megawatt range.”

Another goal is to enable the series production of electrolyzers. This is where H-Tec is working with industry and research partners, within the framework of the German government-funded flagship project H_2Giga, to develop new production processes for PEM electrolysis stacks and electrolyzers. ZSW is also addressing the question of how electrolyzer technologies can be scaled further. “We’re conducting research into materials and manufacturing technologies that will allow implementation on an industrial scale,” says Andreas Brinner. The scientists are also developing a concept for large-scale manufacturing of electrolyzer blocks.

The market is already demonstrating how progress is being made with green hydrogen. Shell has been operating Europe’s largest PEM electrolyzer featuring 10 megawatts of capacity since 2021. And in 2022, industrial gas manufacturer Linde will bring online the world’s largest PEM electrolyzer, rated at 24 megawatts. Several 100-megawatt projects across the globe are also planned. The focus is primarily on regions that have an abundance of renewable resources for electrolysis: inexpensive energy from solar, wind or hydropower plants, as well as seawater that can be desalinated.

It seems the future is picking up even more steam. Whether the impetus is sufficient depends on more than just investments, new technologies and industry’s willingness to change. “The political frameworks must be right as well,” emphasizes Jens Hundrieser, who recently started representing Endress+Hauser in the European Clean Hydrogen Alliance. Above all, that means one thing: “A global carbon pricing mechanism has to be established. Only then will the energy transition be successful. Only then will the hydrogen economy prevail. And only then can the global climate goals be achieved.”

Reliable, precise and robust: the Center for Solar Energy and Hydrogen Research Baden-Württemberg relies on instruments from Endress+Hauser to monitor the electrolysis process.

It's time to pull together!

The energy transition is a collective undertaking that depends on companies pooling their know-how. Endress+Hauser is among those making a contribution to finding the right answers for the future.

Ahead of their time

Although gas-fired power plants are considered a bridge technology in the energy transition, they still have to be efficient, flexible and cost-effective. The plants operated by German regional energy provider KMW achieve this with innovative ideas, intelligent systems and advanced technology.

Text: Christine Böhringer
Photography: Christoph Papsch, KMW

TRANSFORMATION

The only reminder of the coal era at the Kraftwerke Mainz-Wiesbaden AG (KMW) facility is a wooden sculpture of Saint Barbara. The patron saint of coal miners stands in the control center of the German regional energy provider, watching over the machinery's performance and the employees' fates and fortunes. "The statuette is a remnant from the demolition of our three coal-fired plants," says Thomas Zimmerer, who works on electrical and control technology in KMW's engineering business area. Since switching to gas in the year 2000, the company has relied on highly efficient plants and flexibility to hold its own in an electricity market made increasingly volatile by renewable energy sources.

PATENTED HOT STANDBY METHOD

Starting right at the fuel changeover, the focus was on cost-effectiveness and sustainability. At a single stroke, the then newly built 400-megawatt gas turbine combined cycle power plant (GTCC) reduced CO_2 emissions by 1.4 million tonnes per year and even today remains one of the most efficient in the world. Net efficiency is 58.4 percent, which can be increased to 80 percent by decoupling the process steam and district heating. In addition, steam from the company's adjacent waste incineration plant is used to generate electricity and keep the machinery warm. "That means the cogeneration plant can be ramped up within a half hour, even after two days of downtime," reports Thomas Zimmer.

All of that notwithstanding, several years ago KMW was facing new challenges and once again instigated a power plant plan. For one thing, German gas power plants are putting in fewer operating hours because of the increase in renewable energy resources and declining commodity exchange prices for electricity. Second is rising demand for district heating in the region. "The issue is that the GTCC plant can only be operated in a reasonably economic manner when its operating hours track the electricity market, rather than district heating needs," explains Thomas Zimmerer.

QUICKLY RAMPING UP TO FULL POWER

The solution was a €115 million cogeneration power plant (CPP), brought on line in 2021. Ten identical gas engines with electrical and thermal output totaling 100 and 90 megawatts respectively can be started up and shut down in 150 seconds. The engines make very efficient use of the natural gas energy – over 85 percent. "When there is less sun or wind, meaning that electricity prices are good, the CPP starts up quickly. The heat is decoupled and, in situations of low demand, temporarily held in three new heat storage units with a total capacity of 12,000 cubic meters," says Thomas Zimmerer. Together they can buffer up to 750 megawatts of thermal power for later release.

The plant includes technology from Finnish general contractor Wärtsilä Energy Solutions – and know-how from Endress+Hauser, the main instrumentation supplier. More than 300 instruments monitor the processes for water used in cooling and heating, and the auxiliary systems. In addition, KMW directly commissioned Endress+Hauser to supply instrumentation for the heat storage systems: more than 120 temperature sensors record their heat profile; feed water is analyzed as well. At the input end of the CPP, Coriolis flowmeters measure the precise volume of incoming gas. Many of the measurement points are designed along the 'two out of three' principle: three sensors measure independently of each other so that should one malfunction, two values remain available.

NON-CONTACT MEASUREMENTS

It's no coincidence that Endress+Hauser was awarded the contract. "We always rely on our experience with the measurement technology in question when making our buying decisions," says Thomas Zimmerer. Among the things he values are the clamp-on ultrasonic sensors. "We're highly satisfied with these products' safety, measurement stability and precision." Other plus factors for Zimmerer are the simple operation of all instruments, as well as Endress+Hauser's capability to offer the complete installation, including pipework and commissioning. The people aspect is a good fit, too: "We enjoy working together with KMW," says Endress+Hauser employee Horst Theobald, who handles field support for the company. "And that's also because we can sense a lot of innovative spirit here!"

1

2

3

1
The new cogeneration plant can start up or shut down in just 150 seconds.

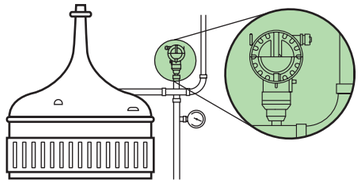
2
Endress+Hauser Cerabar S pressure transmitters monitor plant functioning.

3
Clamp-on ultrasound sensors are deployed all around the plant.

KMW

KMW is a German municipal energy provider with more than 450 employees. The company generates electricity, steam and district heating from conventional systems at its location in Ingelheimer Aue. The portfolio also includes wind and solar farms, plus a power-to-heat and power-to-gas plant.

ENERGY MONITORING
IN THE BREWERY



1

Flowmeters and pressure and temperature sensors monitor the consumption of steam, compressed air and water in the brew house and in the steam boiler and water house.

2

Memograph M data managers collect the data via 4–20 mA or impulse signals.

3

Measurement values from the sensors are then forwarded via Profinet to the process control system. Heat quantities are directly calculated and sent to a software platform across an Ethernet TCP/IP connection.

4

The Field Xpert industrial tablet provides WLAN or Bluetooth access to all Endress+Hauser instruments and thus to the current energy consumption levels.

CO_2 belongs only in the glass

Numerous actions taken by Hofbräu München have already resulted in a 70 percent reduction in CO_2 emissions per hectoliter of beer brewed. Now the plan is to realize even more reduction potential with the help of a solution from Endress+Hauser: the most advanced energy monitoring system installed at any brewery worldwide.

Text: Christine Böhringer
Graphics: 3st

ENERGY EFFICIENCY

Drink Hofbräu München beer and you can be sure of one thing: every sip contains only water, malt, hops and yeast, exactly as stipulated by the German purity law. And, of course, carbon dioxide, which forms during fermentation. Dissolved in water, the CO_2 forms carbonic acid that gives the beer its tangy taste.

Outside the glass, though, Hofbräu makes sure that it discharges as little CO_2 as possible. “We began systematic environmental management as far back as 1998 with the main goal being climate protection,” explains Sebastian Utz, Environmental Officer and Deputy Technical Manager at the brewery.

There is an impressive outcome to show for the numerous actions taken to date: within 20 years, the brewery was able to reduce by 70 percent the CO_2 emissions per unit volume brewed, to 5.2 kilograms per hectoliter of beer. Major steps included the switch to green energy and LEDs, conversion of a steam boiler from oil to gas and a redesign of the brew house, where boiling the wort now requires less energy.

“Now it’s time for the detailed work,” says Sebastian Utz. “Endress+Hauser has supplied us with the most advanced energy monitoring system ever installed at any brewery worldwide. Soon we want to track the energy efficiency of every process in the brew house.” More than 50 sensors have already been installed for monitoring the consumption of steam, compressed air and water in every area of the brewery. This information is forwarded to a platform via a data manager. “Our aim is to use these results for honing processes, thus saving even more gas energy and hence reducing our CO_2 emissions,” explains Sebastian Utz.

The goal, however, is not zero CO_2 emissions but climate neutrality – by the year 2025. “Wherever we are unable to avoid or reduce emissions, we will compensate for them,” says Sebastian Utz. Hofbräu goes all-out on transparency here as well by investing regionally in renaturation of moorland and accumulation of humus soils, both of which can potentially bind thousands of tonnes of carbon dioxide over the long term.

Energy shapes both the private and professional life of Endress+Hauser project manager Peter Gibas.

Full of energy

As a project manager at Endress+Hauser, Peter Gibas helps customers find better ways to generate energy and use it more efficiently. But in his private life too, every watt counts. Here he explains why.

As told to Christine Böhringer
Photography: Enno Kapitza

COMMITMENT

For me, energy is life. And my life continues to be shaped by energy. As an electrical engineer, I was responsible for energy supply systems at an automobile factory. I later went to work at a nuclear power plant, first as a reactor operator and then as a shift electrical foreman. I’ve been a field engineer at Endress+Hauser for 28 years, where among other things I manage energy projects. My current responsibilities mainly involve helping customers make green hydrogen marketable, or achieve higher turbine and engine efficiency – in other words, better utilization of energy.

This includes keeping an eye out for new technologies with the potential to make a real difference. I then work together with our partners to develop the measurement solutions needed to advance such technologies. The goal is to have reference systems so that people in the industry, including Endress+Hauser, can see that the technology works. My basic attitude is that if you want to change something, you have to set an example!

I follow this motto in my private life as well. Twenty-five years ago, when oil was still cheap and global warming was an issue that few were aware of, I installed a wood heating system with buffer storage in our home. The wood comes from my own patch of forest, which I keep reforesting – just recently we planted 640 trees. After that came a solar heating system that covers one-third of our heating needs. And three years ago, we put in a photovoltaic system for generating electricity.

Just like I do with my customers, at home I look to see how the energy is flowing, where it’s being wasted and how it can be better utilized. To cite a few examples: the house walls are especially thick so that very little heat escapes; the sunroom on the south side of the house is heated by solar power; our low-temperature underfloor heating system requires only minimal flow temperatures. We do our laundry when the sun is shining, to make immediate use of its converted electrical energy. And most recently, we stopped using energy guzzlers like halogen bulbs.

I’m pleased to see how, in recent years, energy has become the most important factor in industry. There is a lot of work being done on how best to convert energy and create less CO_2. And green products are in demand. I hope this trend soon broadens across society as a whole. Because it’s important that we act now – and not just when we personally begin to feel the effects of atmospheric warming.

INNOVATIONS

The future – we have lift-off!

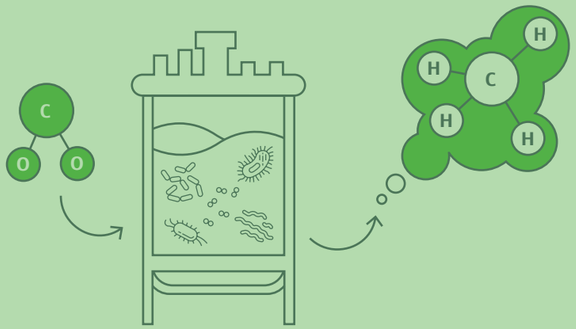
The energy transition raises countless questions, which in turn are catalyzing an abundance of bright ideas. Wherever you look, there are companies creating solutions with the 'eureka effect' – like these ones…

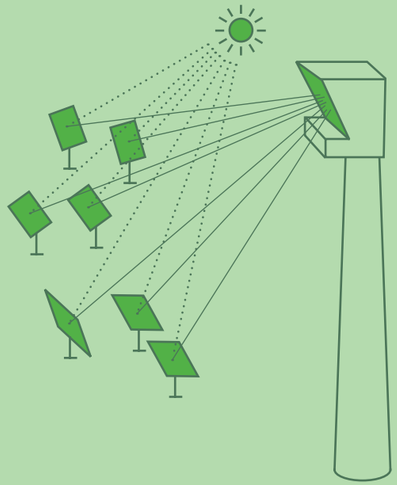
Text: Christine Böhringer
Graphics: 3st

1

MICROORGANISMS CHOW DOWN ON CO_2

The cement industry faces significant challenges because of the energy transition. This sector is responsible for 8 percent of CO_2 emissions worldwide. Two-thirds of those are process related and hence unavoidable, just like in the lime industry. That's why these industries are currently exploring numerous avenues for capturing CO_2, which in turn raises the obvious question of what to do with the resulting huge quantities of this greenhouse gas. One novel solution uses bioreactors, inside which rapid-acting microorganisms convert the CO_2 mixed with green hydrogen into biomethane for feeding directly into the natural gas grid. The advantage is that the CO_2 does not require pre-treatment: the bugs do a great job on impure gas as well. The technology was recently tested in a research project in Switzerland. Endress+Hauser participated by supplying pressure and temperature instrumentation, in addition to flowmeters for the hydrogen and biomethane. The technology will now be scaled up to commercial plant operation, with a pilot project at a lime manufacturer in Belgium scheduled to launch soon. The goal is to recycle up to 90,000 tonnes of carbon dioxide annually and supply the biomethane product to as many as 15,000 households.





2

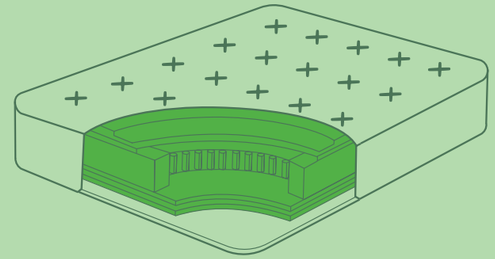
MORE POWER FOR THE TOWER

Solar tower plants comprise hundreds of mirrors that reflect sunlight to a receiver at the top of a tower, where heat from the concentrated rays is transferred to a carrier medium – usually liquid sodium and potassium nitrate, which can absorb especially high temperatures. Energy in this form can be cost-effectively stored in tanks and piped to a steam generator to produce electricity, even when the sun is not shining. To date, the operating temperature of such power plants has maxed out at 565 degrees Celsius, but the Institute for Solar Research at the German Aerospace Center (DLR) wants to change that. In a project funded by the German Federal Ministry for Economic Affairs and Energy, a consortium of industry and research partners led by the DLR developed a receiver that enables temperatures of up to 600 degrees Celsius. The next step is to adapt power plant circulatory systems to such temperatures. "The challenges with this application are density fluctuations in the liquid salts, the chemical resistance of materials employed for containment and the extremely high temperatures," says Markus Schmitz, initiator of the project at Endress+Hauser. For precise flow monitoring between the two storage tanks, Endress+Hauser recommended the use of differential pressure measurement technology. The sensors are now undergoing tests in circulating liquid salts. "If the diaphragm seals meet those demanding requirements, then we have found the solution for this difficult new application," adds Markus Schmitz.

3

SLEEP WELL WITH CARBON DIOXIDE TECHNOLOGY

Covestro is one of the world's largest polymer manufacturers. As a pioneer in the plastics industry, the company has fully committed itself to the circular economy; its endeavors include replacing raw materials such as crude oil with alternative sources. CO_2 plays a central role in the strategy because it too contains that essential element, carbon. Covestro collaborated with partners to develop a groundbreaking process in which up to 20 percent CO_2 is integrated into a chemical building block for plastics, thus conserving a corresponding amount of crude oil. To date the product has been used mainly to manufacture soft foam materials, such as for mattresses. What sounds simple is in fact complicated. "Carbon by itself does not readily bond with chemical compounds," explains Jörn Matthies, Global Strategic Account Manager at Endress+Hauser. "But special catalyzers from Covestro and the Catalytic Center in Aachen are helping to make this difficult reaction possible at last." Covestro manufactures its novel material in Dormagen. The requisite CO_2 comes from exhaust outflows of nearby chemical plants. Instruments from Endress+Hauser monitor the process. Covestro relies on its instrumentation partner's know-how at other locations as well. "We're the primary global supplier of flow, level, temperature and analysis instrumentation," explains Jörn Matthies.



1
The Hellisheiði geothermal plant supplies the green energy needed for the capture process.

2
Carbfix mixes the CO_2 with water and pumps it underground, where it mineralizes.

3
Orca, the direct air capture plant from Climeworks, captures up to 4,000 tonnes of CO_2 from the air annually.

Growing together

The systems of Swiss company Climeworks remove carbon dioxide from the air. They are becoming more powerful and cost-effective thanks to highly precise process data.

Text: Christine Böhringer
Photography: Benjamin Hardman, Climeworks

PARTNERSHIP

It was clear to Katrín Jakobsdóttir: “This is a milestone in the fight against climate change.” In the fall of 2021, Jakobsdóttir, the Prime Minister of Iceland, opened what is currently the world’s largest direct air capture and CO_2 storage plant. Called Orca, it’s situated in Hellisheiði, a plateau east of Reykjavík.

Both the plant and its underlying direct air capture technology were developed by Swiss company Climeworks. The system consists of stackable, shipping container-sized collector units equipped with fans to draw in the surrounding air. Filter material inside the collectors captures CO_2 on its surface. When the filters are saturated, they are heated to about 100 degrees Celsius to release the CO_2 molecules, which are then removed from the collectors under negative pressure. The green energy used for the process comes from a geothermal plant in the vicinity. Local Icelandic company Carbfix mixes the greenhouse gas with water and pumps it some 1,000 meters underground, where it mineralizes in less than two years.

Orca captures up to 4,000 tonnes of CO_2 annually, an extremely small amount when compared with the 35 billion tonnes being emitted into the atmosphere worldwide. The Intergovernmental Panel on Climate Change nevertheless says that limiting global warming to 1.5 degrees is possible only through negative emissions; in other words, constantly removing CO_2 from the atmosphere. “The climate objectives cannot be achieved without capturing, utilizing and storing this gas,” emphasizes Arjan van Ginkel, Industry Manager for Oil, Gas and Chemicals at Endress+Hauser Netherlands.

INSTRUMENTS FOR EVERY REQUIREMENT

Climeworks has quickly enhanced its technology over recent years. The first large-scale plant, which has been operating in Switzerland since 2017, captures only 900 tonnes a year. One reason the company has been able to refine the process so rapidly is Endress+Hauser. “Our technology is installed not only in Climeworks’ 15 worldwide direct air capture plants but in the test facilities as well,” says Francesco Cali, sales engineer at Endress+Hauser. Climeworks benefits from Endress+Hauser’s extensive portfolio. “Gaining a better understanding of the processes and increasing effectiveness calls for extremely precise measurements. And in the plants themselves, it’s essential to have robust instruments that can also withstand extreme and heavily fluctuating weather conditions. We can meet any customer requirement with our products and grow together,” says Francesco Cali.

RAPIDLY SCALABLE

Climeworks is planning the next large-scale project with support from Endress+Hauser once again. The company also wants to significantly reduce the price per tonne of CO_2 captured. That price is still relatively high because the concentration of CO_2 in the atmosphere is much smaller than in flue gases, for example. Hence the capture process is more costly and energy intensive. Climeworks is still optimistic though. The price per tonne is expected to be between 100 and 200 US dollars by the year 2040. And companies such as Boston Consulting Group, Square and Microsoft are already relying on agreements with Climeworks to achieve their climate objectives in future.

3

The industry manager for oil, gas and chemicals in the Netherlands is an expert in the capture, utilization and storage of carbon dioxide.

3 questions for Arjan van Ginkel

What is the role of carbon capture, utilization and storage – CCUS for short – in attaining worldwide climate objectives?

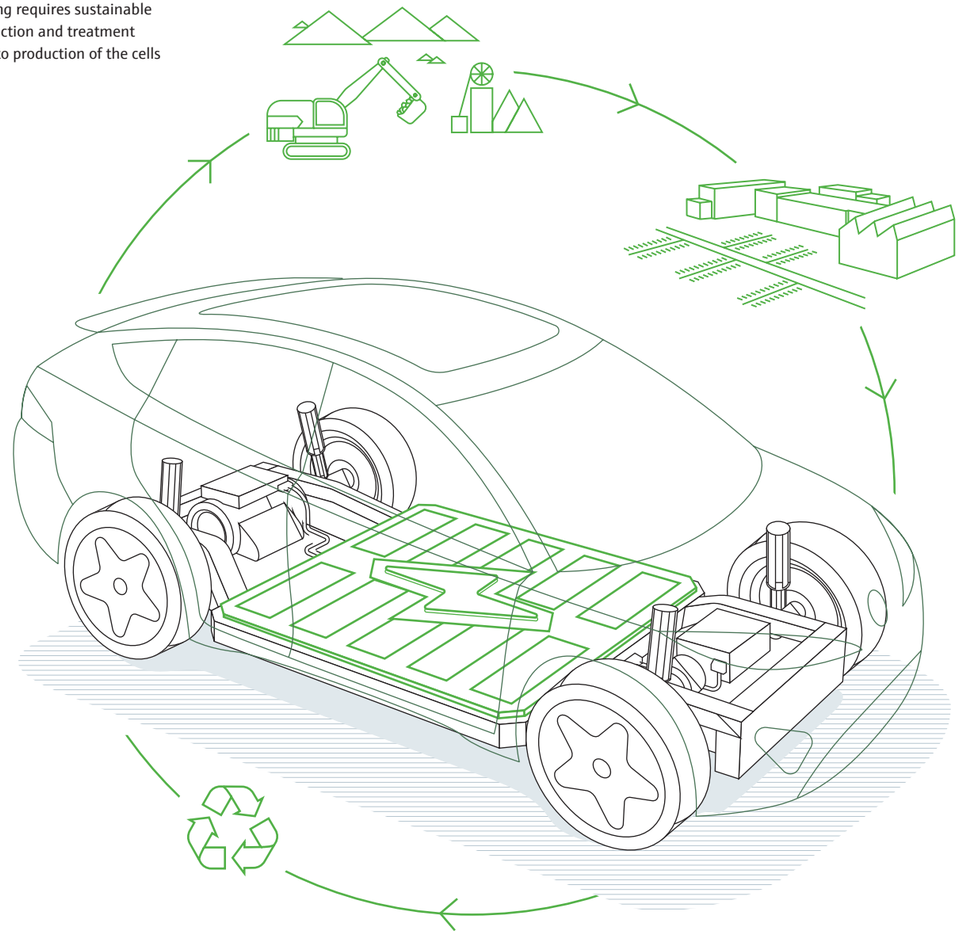
It plays a major role, because CCUS can be used in the short term and at a relatively low cost to prevent large quantities of CO_2 from entering the atmosphere in the first place. The process involves capturing carbon dioxide from exhaust streams, for example. This is an option for heavy industry in particular – with its hard-to-avoid emissions – especially since existing plants can be retrofitted. Or you remove the CO_2 from hydrogen production with steam reforming. This helps to rapidly expand the production of so-called blue hydrogen, which is low emission. It’s also possible to remove CO_2 directly from the air.

What kind of experience does Endress+Hauser bring to the table with this technology?

This is not uncharted territory for us. CCUS has been around for more than 40 years. Back then, CO_2 was captured for the first time in the US in order to stimulate natural gas and crude oil fields. We have since implemented commercial CCUS projects in many industries and we also supply our instruments for research and pilot projects. This topic is gaining momentum like never before. More than 100 new CCUS facilities have been announced in 2021 alone.

What benefits does Endress+Hauser offer customers?

We use our industry know-how and extensive portfolio to support customers along the entire CCUS chain. As a main supplier of the measurement technology, we cover all instrumentation needs, including gas analysis. Our instruments are employed in the separation of CO_2 from gas mixtures, in skids for measuring CO_2 gas flows, for compression and leakage detection in pipelines, and in storage units. We also cover all applications when it comes to CO_2 utilization in industry. And with our engineering tools and services such as remote commissioning, plants can be brought online much faster!



Battery manufacturing requires sustainable processes, from extraction and treatment of the raw materials to production of the cells and their recycling.

An electrifying market

Electromobility is an indispensable building block of the energy transition. So it's no surprise that the lithium-ion battery market is booming. But with this come myriad challenges all along the value chain.

Text: Frank Jablonski
Graphics: 3st

BATTERY MANUFACTURE

With electromobility booming across Europe, Asia and America, it's not just battery manufacturers and automobile companies looking to seize an opportunity. Companies including BASF, Umicore and Johnson Matthey are also striving for market share while investing billions in battery manufacturing. Analysts predict that electromobility could be one of the biggest growth drivers for the chemical industry in the coming years.

As this change plays out, global markets are also on the move. Government subsidies, Asian investors and fast-growing startups are right now laying the foundation for activities that could help Europe establish itself as the world's number two manufacturing region for batteries in less than 10 years. Nevertheless, old and new players alike face major challenges. Compliance with environmental, social and corporate governance standards is a key factor for industry to pave the way for tomorrow's mobility.

EFFICIENT RAW MATERIALS EXTRACTION

Lithium compounds are at present extracted from high-yield brine lakes or a seldom-occurring pyroxene mineral called spodumene (lithium aluminum inosilicate), primarily in South America, Australia and China. Sufficient quantities of this key battery element can still be found today: estimated lithium resources stand at around 40 million tonnes, which equates to more than 210 million tonnes of lithium carbonate equivalent. Experts nevertheless anticipate a shortage no later than 2025, considering the complexity and high cost of extracting this raw material. With brine lake groundwater, for example, the lithium-rich brine has to be pumped into evaporation basins, concentrated and then cleaned. The evaporation process increases the lithium concentration from 2,000 ppm or so to as much as 6 percent in the end brine. It's then processed further at chemical plants into lithium carbonate with 99.9 percent purity. "Advanced process solutions for flow, level, pressure and temperature measurement help at every step to efficiently extract battery-grade raw material," says Andrew Reese, Global Mining, Minerals & Metals Industry Manager at Endress+Hauser.

QUALITY IN THE RIGHT MIXTURE

Raw material purity and composition are critical in battery manufacturing. The main requirement for the cathode and anode material is to be as free from water as possible. With the other constituents the requirements vary, because different lithium compounds impart different characteristics to the end product. In the tradeoff between power density, energy density, safety and service life, as well as availability and costs, there are compounds with strengths in certain departments but weaknesses elsewhere. This is why the industry utilizes so-called NMC mixed oxides – blends of nickel, manganese and cobalt oxides – which count among the top materials used to store electricity in lithium-ion batteries for e-bikes and e-vehicles.

150

million e-vehicles are expected globally by 2030.

For a battery to have particular properties, the NMC composition must be precisely known. Then there is the fact that the materials pass through numerous process steps on their journey from extraction to end product. Every transfer requires checks on the state of the material. "It takes advanced analysis instruments to satisfactorily resolve these challenges," says Philipp Conen, Global Industry Manager for Chemicals at Endress+Hauser. Raman analyzers supply all of the real-time, inline measurements needed to guarantee the properties and quality of lithium-ion batteries.

CLOSING THE LOOP

The accelerating proliferation of e-vehicles will also rapidly grow the stockpile of exhausted batteries. So companies will increasingly turn to recycling as a way of recovering raw materials from battery cells to address growing demand, conserve resources and make e-mobility more sustainable.

There are currently two primary recycling methods. One is cryogenic cleavage, which involves cooling the aged cells to minus 196 degrees Celsius with liquid nitrogen and then crushing them. Following that, a reaction with sodium hydroxide releases hydrogen that is burned off in a controlled manner. Plastics, metals and lithium salts can then be separated out for further processing. Hydrometallurgical methods employ wet chemical processes to separate out the metals. "Endress+Hauser instruments ensure safe battery recycling processes and help make them sustainable. Our analysis measurement technology is also at work here treating the wastewater," says Philipp Conen.

Autonomous measuring

Not everywhere in the world has access to a power grid when there is a need to measure how much water is flowing through a pipeline. For such situations Endress+Hauser has developed the battery-powered Promag W 800 flowmeter, for autonomous operation even at inaccessible locations.

Text: Richard Backhaus
Graphics: 3st

Whether for humans, our fellow animals or plants, there is no life without water. In order to reach the consumer, this precious substance must sometimes travel great distances through long pipelines and be accurately monitored and measured. But the more remote corners of our planet in particular often lack the external power sources that the measurement instruments need to do their job, not to mention cables for transmitting the measurement values.

Added to that is the challenge of transmitting those measurement values over long distances. “We developed a completely wireless measurement instrument specifically for these application scenarios,” explains Matthias Reist, product manager at Endress+Hauser. “Thanks to the battery, the Promag W 800 enables flexible and autonomous operation even in off-grid locations, because it requires no external power source and has a maintenance-free service life of up to 15 years.”

In order to reliably transmit the measurement data, and conversely receive other data, the instrument also features an integrated mobile communications module. “This gives the water provider remote access to the measurement values from anywhere in the world, regardless of how distant the measuring point is from the control center,” reports Matthias Reist.

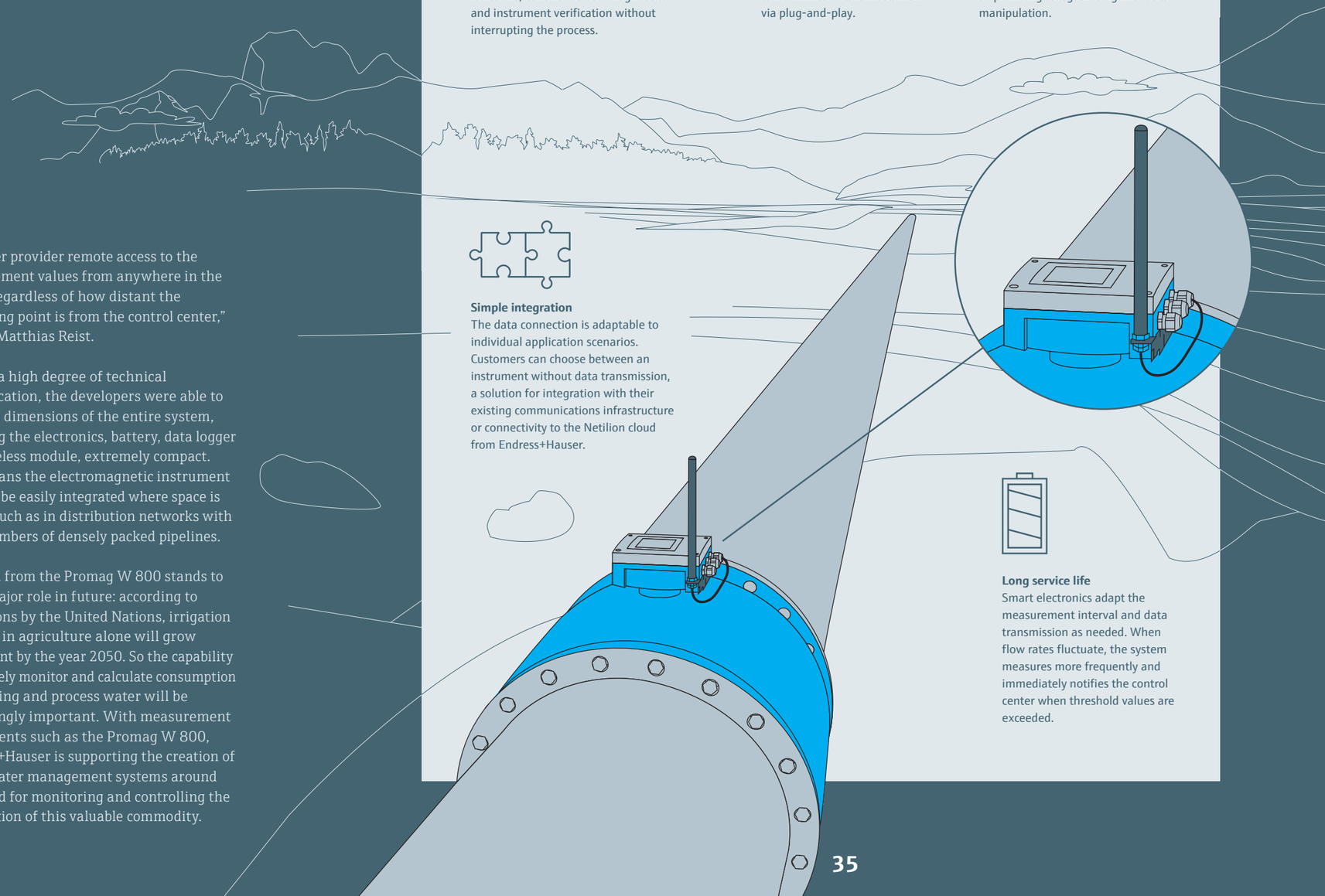
Despite a high degree of technical sophistication, the developers were able to keep the dimensions of the entire system, including the electronics, battery, data logger and wireless module, extremely compact. That means the electromagnetic instrument can also be easily integrated where space is scarce, such as in distribution networks with large numbers of densely packed pipelines.

Key data from the Promag W 800 stands to play a major role in future: according to projections by the United Nations, irrigation demand in agriculture alone will grow 50 percent by the year 2050. So the capability to precisely monitor and calculate consumption of drinking and process water will be increasingly important. With measurement instruments such as the Promag W 800, Endress+Hauser is supporting the creation of active water management systems around the world for monitoring and controlling the distribution of this valuable commodity.

Comprehensive diagnostics
Endress+Hauser Heartbeat technology handles diagnosis, monitoring and verification of the Promag W 800. This facilitates legally required test functions, continuous self-diagnostics and instrument verification without interrupting the process.

Operation
With the SmartBlue app for smartphones and tablets, all communication parameters are preconfigured so that users can commission the instrument via plug-and-play.

Data security
End-to-end encryption in accordance with current technical standards protects the Promag W 800 data during transmission and cloud storage, so providing safeguards against data manipulation.



Simple integration
The data connection is adaptable to individual application scenarios. Customers can choose between an instrument without data transmission, a solution for integration with their existing communications infrastructure or connectivity to the Netilion cloud from Endress+Hauser.

Long service life
Smart electronics adapt the measurement interval and data transmission as needed. When flow rates fluctuate, the system measures more frequently and immediately notifies the control center when threshold values are exceeded.

A clear sense of direction

Endress+Hauser pursues long-term goals for corporate development, with strong values as the foundation. This pays dividends – for people, for the environment and for the company.

Text: Martin Raab
Photography and graphics: Endress+Hauser, Christoph Fein, Thomas Frank, Shutterstock, 3st

91.2%

of all deliveries were received on time by Endress+Hauser customers in Europe during 2021.

112,000

account-holding customers used functions of the endress.com website in 2021.

2.6

million sensors were manufactured and delivered by Endress+Hauser last year.

Vote of confidence

Which companies enjoy the highest levels of trust? To find the answer, German business magazine Focus-Money launched a study that evaluated 21,000 companies and brands across more than 200 industries. In the measurement technology category, Endress+Hauser topped the list. Although the study result is a snapshot of feeling, it does raise the question of what this trust is based on, especially now after two years of the coronavirus pandemic.

1

Endress+Hauser could always deliver during the pandemic. Supply and logistics chains held up despite being under strain. Considerable effort went into safeguarding the availability of materials for production; long-term supplier relationships also helped here. In the area of transportation logistics, specialists managed to secure the required capacity despite frequent interruptions to the chain. “We fought for every shipment,” reports Oliver Blum, Corporate Director of Supply Chain. The on-time delivery rate exceeded 90 percent, an excellent figure even in normal times.

2

Endress+Hauser was always available during the pandemic. A key factor here was digitalization: salespeople were able to consult with customers while working from home and service technicians provided remote support. The endress.com website has long offered not just information but a wide range of services. Customers value closely interlocking physical and virtual worlds. Digital business may still represent a small share of overall global activities, but the online sales channel is up and coming, emphasizes Nikolaus Krüger, Chief Sales Officer: “In Brazil, a fifth of sales volume is online, and six out of every seven customers are digitally active.”

3

Endress+Hauser was always reliable during the pandemic, including for its employees. From the outset, the Group announced that it would do everything possible to retain people and avoid short-time working. Sales and production were ready for when business picked up again, and the workforce demonstrated its full commitment. “Trust in the Endress+Hauser brand rests on the people in the company,” stresses CEO Matthias Altendorf. “They live up to our values and deliver on our brand promises.”

Next generation

The next generation of the shareholder family is in the ascendant. Sandra Genge, granddaughter of company founder Georg H Endress, is the newest member of the Endress+Hauser Supervisory Board. She succeeds Hans-Peter Endress (75), who is stepping down upon reaching the age limit. Sandra Genge, born in 1977, is a self-employed communications consultant and a mother of three. She has represented the younger generation of the shareholder family on the Family Council since 2006.

“The company is demonstrating how proven measurement technologies can be steadily advanced. That puts Endress+Hauser in our top 10.”

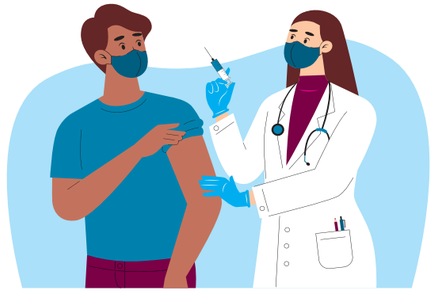
Swiss business magazine Bilanz on Endress+Hauser achieving seventh place in the 2022 ranking of Switzerland’s most innovative companies.

Ideas in action

Have you already acted on your New Year's resolutions? Dozens of Endress+Hauser employees are setting a good example. CEO Matthias Altendorf got the ball rolling with his support for the Endress+Hauser Water Challenge. This involves employees around the world taking part in charity runs to raise money for projects that provide access to clean water. The Group doubles each donation. Given that Covid has impeded communal endeavors, now anyone can become active on their own as long as the chosen goal is tied to a physical activity. The Group's CEO has set his own objective of splitting 10 cubic meters of logs from his own patch of forest. Around the globe, 120 employees have signed up to participate as joggers, skiers or swimmers for this good cause. Campaign proceeds flow into new water projects in the Philippines and India.

Innovation incubator

Polluted water, tainted foodstuffs, contaminated milk: rapid molecular analyses will one day enable on-site detection of contaminants in even the tiniest amounts. Endress+Hauser and Hahn-Schickard, a German non-profit research association, have created a joint venture – Endress+Hauser BioSense – tasked with developing the methods and instruments needed for in-process and laboratory applications. Like other innovative Endress+Hauser units involved in novel sensor technologies, biosensors and solutions for Industry 4.0, the new startup is based on the campus of the University of Freiburg, Germany.



Life-saving jabs

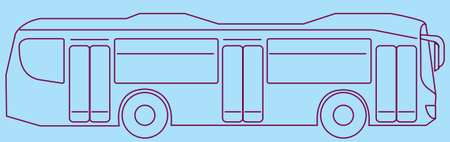
Vaccination against the coronavirus reduces infection risk and is effective at preventing serious illness. That's why many Endress+Hauser locations made it possible for employees, their family members and even people in nearby companies to receive a jab. One especially significant initiative took place at the production facility in Aurangabad in western India. With support from CII, an industry association, and Bajaj, a multinational conglomerate, Endress+Hauser erected a vaccination center on the Group's campus. Employees of micro, small and mid-sized companies across the region, and not least residents of surrounding villages, came in droves to be vaccinated at no cost. More than 50,000 doses have been administered to date.

Training initiative

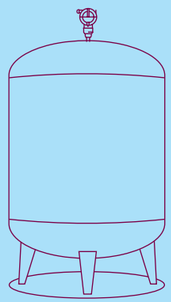
Well-trained specialists count among the keys to success for Endress+Hauser. Commitment to training young people is also an expression of social responsibility. With this in mind, Endress+Hauser plans to more than double the training rate over the long term, with five percent of all positions set aside for interns, apprentices, trainees and students.

Signs of transition

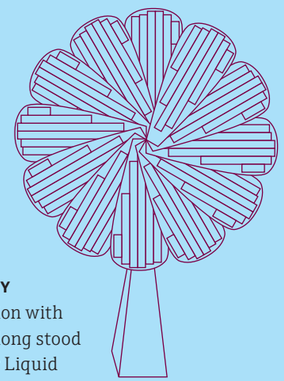
The energy transition is taking clearer shape at Endress+Hauser too, producing some noteworthy results.



GREEN COMMUTING
Around 250 people produce measurement technology for Endress+Hauser in Aurangabad, India. They are bused in from the surrounding area and brought back home in the evening. Two electric buses manufactured by Tata Motors recently went into operation, each nine meters long and carrying up to 34 passengers. As photovoltaic systems on the roof of the Aurangabad plant generate green energy, the electric buses are not only free of emissions while on the road but can also be charged in a climate-friendly way.



HEAT ON TAP
More than 25,000 square meters of new buildings at the flow measurement technology plant in Reinach, Switzerland, are climate neutral. Photovoltaic systems are part of the location's energy concept, with supplementary solar panels boosting the installed capacity to one megawatt peak. Another key to energy efficiency is a 57,000-liter heat storage vessel that accumulates operational waste heat and releases it as needed for heating the premises and producing warm water.



BLOOMING SUSTAINABILITY
A wind tree – a metal construction with miniature wind turbines – has long stood in front of the Endress+Hauser Liquid Analysis facilities in Gerlingen, Germany. Now a sunflower has also sprouted up there. The Smart Flower has photovoltaic modules on its petals, which unfurl and follow the sun's course throughout the day. At nearly five meters in diameter, the solar flower is visible evidence of the location's sustainable energy concept, producing power of up to 4.5 kilowatts.

3,000,000

electromagnetic flowmeters have been sold by Endress+Hauser since 1977. This technology can be used to measure electrically conductive media such as water, milk and beverages, in addition to slurries, acids and alkalis, in pipes with diameters ranging from a tiny 2 millimeters to a massive 3 meters.

2021

The financial year at a glance

> Sales growth was dynamic in Asia and the Americas and solid in Europe. In the Middle East, however, business shrank due to the disproportionate weighting of the oil & gas industry.

Net sales

€2.88 bil.

(+11.7%)

Sales by region

Europe
€1,257 mil.
(+7.2%)

Americas
€624 mil.
(+16.8%)

Africa, Middle East
€102 mil.
(–4.6%)

Asia-Pacific
€896 mil.
(+17.4%)

Return on sales

16.1%

(2020: 13.1%)

> Operating expenses grew slower than sales, while financial investments yielded a solid return. Both developments boosted profitability.

Investments

€193 mil.

(2020: €206 mil.)

Net income

€357 mil.

(+40.0%)

> We retained our employees during the pandemic in 2020. We were thus in a position to immediately support our customers when business picked up in 2021. To meet demand, we created new jobs, particularly in production.

Employees

15,117

(+663)

EcoVadis rating: Platinum status

76/100 points

(2020: 72 points)

> We once again improved our score in the independent EcoVadis sustainability rating, placing in the top group for the fifth consecutive year. This puts Endress+Hauser in the top percentile of the companies in the comparison group.

R&D ratio

7.4%

(2020: 7.6%)

> While we vigorously increased spending for research and development (+9.4%), sales grew at an even faster pace.

Patent filings

258

(2020: 276)

> How did Endress+Hauser perform in the past year?

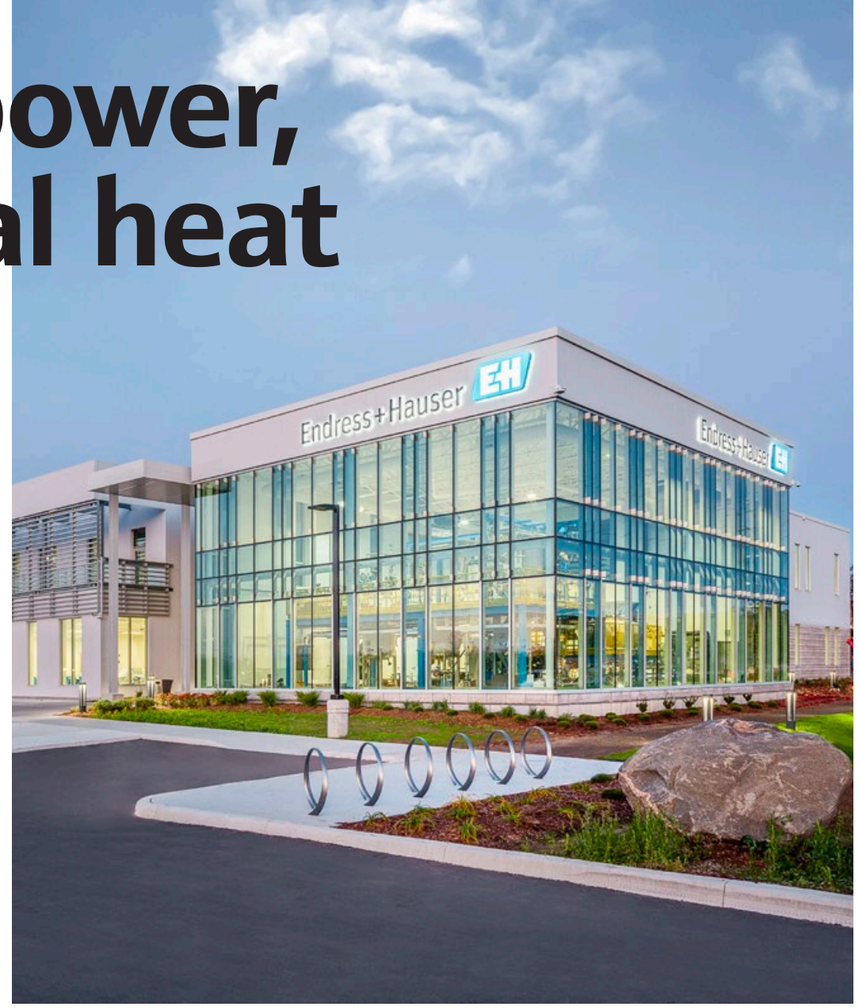
Robust surge in growth

Endress+Hauser returned to the growth path in 2021. Business got off to an excellent start, continuously picking up speed as the year progressed. The result was an increase in net sales of nearly 12 percent, with orders on hand growing even more strongly. We thus not only improved over the prior year, but significantly exceeded the comparative figures for 2019. We did not anticipate such a dynamic development. All of our strategic industries, led by life sciences, chemical and food & beverage, contributed to the strong growth. Given that profit and headcount are also higher than ever before, we can proudly look back on a 'best ever' year for Endress+Hauser!

DR LUC SCHULTHEISS, CFO

Solar power, thermal heat

1



2

3

Endress+Hauser Canada involved employees in the planning of its new Customer Experience Center in Burlington, Ontario. The result is a wealth of good ideas for one of the greenest buildings in the country, which generates more renewable energy than it consumes – and more than compensates for the small indulgence of a traditional barbecue.

Text: Laurin Paschek
Photography: Philip Castleton

4

Snow-covered pine forests and sweeping winter landscapes. When talk turns to Canada, many people think of the cold season. But in truth, this is a land of extremes. Winter temperatures in the densely populated regions of southern Canada on the Great Lakes can drop to minus 30 degrees Celsius or lower. But in summer, these same areas experience a humid climate, with occasional hot spells when temperatures may rise as high as 35 degrees Celsius.

That's why many buildings in Canada need both heating and cooling. While electric air-conditioning systems keep things cool, heat still comes primarily from fossil-based natural gas. All the same, hydroelectric power is traditionally a major component of Canada's energy mix: the second largest country on earth in terms of land area already sources two-thirds of its electricity needs from renewables.

THREE CERTIFICATIONS AT ONCE

In late 2018, sustainable energy was a hot topic at Endress+Hauser's Canadian sales center. "A desire to invest in green technologies quickly became clear from discussions with employees and management about our new Customer Experience Center in Burlington," says Anthony Varga, Managing Director of Endress+Hauser Canada. "The result was that we became a pioneer in Canada." That's because Endress+Hauser is the first private company to strive for all three certifications bestowed by the Canada Green Building Council: Net Zero Energy, Zero Carbon Building Standards, and gold-level Leadership in Energy and Environmental Design (LEED).

After the go-ahead, Project Manager Eliza Vrbanac and her team developed a total operating concept for the office building, which also serves as a Customer Experience Center. The ground floor houses a process training unit (PTU) that includes a pilot system where customers can test Endress+Hauser applications under wide-ranging process conditions, a calibration lab, a repair shop and a training center. The floor above provides flexible workspaces for up to 120 employees. "We also installed south-facing windows in order to let abundant sunlight into the building," says Eliza Vrbanac. "And as a further example, the atrium has a four-meter-high fig tree that improves air quality in its own natural way."

1
Endress+Hauser Project Manager Eliza Vrbanac: "We can even feed power back into the grid."

2
The Customer Experience Center is aiming for three certifications from the Canada Green Building Council.

3
A broad set of windows lets as much sunlight into the building as possible.

4
Customers can test measurement technology under a wide range of conditions in the Customer Service Center.

775 SOLAR PANELS AND 24 DEEP BOREHOLES

At the heart of the concept are two components: a solar energy system on the roof and a geothermal heat pump system that it powers. The 775 solar panels can produce a theoretical 408,000 kilowatt-hours per year. "Compare that number to our average annual consumption of roughly 350,000 kilowatt-hours. Generating capacity exceeds in-house demand, which means we can even feed power back into the grid," the project manager calculates.

The geothermal system draws heat from 24 boreholes under the employee parking lot that go down to a depth of 180 meters. "We laid nearly 9 kilometers of pipes for the geothermal system," explains Eliza Vrbanac. "180 meters down, the year-round temperature at our location is a constant 12 degrees Celsius. This gets absorbed by a glycol-water mix that circulates through the underground geothermal loops and back into the building, where it feeds the heat pumps and only has to be warmed by about 10 degrees." Best of all, the 130 heat pumps send warm air at 20 degrees directly into various areas of the building. So they act as an all-in-one heating and air-conditioning system, depending on outdoor temperature.

NATURAL GAS IS RESERVED FOR THE BARBECUE

"All of the features were based on an employee survey," emphasizes Anthony Varga. "We were able to fulfill a considerable number of wishes, from an exercise room, shower and changing rooms, to a multifaith prayer room." The most important leisure amenity, though, is the gas grill on the roof patio. "Barbecuing is a big thing in Canada," explains the managing director, tongue in cheek. "So we are still connected to natural gas – although it only gets used for firing up the grill."

Strong relationship

How does a company gain customers' trust? Klaus Endress and Matthias Altendorf know the answer: good business relationships have to grow, but what it really comes down to is people.

Questions: Martin Raab
Photography: Andreas Mader

"No one would have dared to hope at the beginning of 2021 that we would be in such a good position by the end of the year."

Klaus Endress,
Supervisory Board President
of the Endress+Hauser Group

Mr Altendorf, Mr Endress, the Group can look back on an excellent year. Was that anticipated?

Altendorf: It's not quite what we expected. Wave after wave of the pandemic made us cautious. Our goal for 2021 was to even out the dent made by Covid. At least in the first half of the year, we could not have anticipated significantly exceeding 2019 levels.

Endress: No one would have dared to hope at the beginning of 2021 that we would be in such a good position by the end of the year. By our definition, it was a 'best ever' 12 months. Incoming orders, sales, profit and headcount all reached record highs.

Are the family and the Supervisory Board also satisfied with the business year?

Endress: I'm never satisfied… you can always do better. But I'm pleased and happy with these results – and I'm proud of the company and our people!

What were the pivotal factors behind this solid development?

Altendorf: China, an economic powerhouse, performed well. The US was also quick to emerge from the crisis – and hence Europe, as a significant exporter to both regions. A good half of this growth is probably attributable to catch-up effects. But the global drivers also had an impact: health, energy, food. We saw considerable investment in pharmaceutical plants, as well as electromobility and the energy transition. Cyclical and non-cyclical alike, all our strategic industries performed well.

Endress+Hauser outperformed the market. Where does this success spring from?

Altendorf: Customer intimacy is one important factor. Innovation is another. Our customers must be able to recognize that we can help them become better. Then there is the fact that at Endress+Hauser we don't focus on short-term results but rather the long-term goal. Temporary headwinds won't blow us off course. Above all, though, we put people first. The main drivers of our success are our employees who make it all happen!

Endress: Everyone worked very hard. We stand by our employees and they stand by us. At the beginning of the pandemic we made clear our objective to keep everyone on board, avoid short-time working and continue investing. And of course that creates a special relationship. We are all working toward a common goal. Great things always come out of such joint efforts.

A German study found Endress+Hauser to be the most trusted brand in measurement instrumentation. Where do you think this trust stems from?

Altendorf: It doesn't happen overnight. This is trust that has been cultivated over decades. And we have to keep earning it, time and again.

Did this trust grow during the pandemic?

Altendorf: Challenging times always reveal how resilient a relationship is. That also holds true in business – and Endress+Hauser proved reliable, even in an extreme situation.

Endress: We delivered during the pandemic. We met more than 90 percent of our delivery commitments in the past year. And this at a time of interrupted supply chains and parts shortages. What's more, we didn't take advantage of the situation. The foundation of trust is respect. Customers have a keen sense of how they are being treated. This is something they never forget.

Altendorf: The market's trust in us comes down to the people in the company. Endress+Hauser employees, management and shareholders share a set of values including responsibility, trust and commitment. We endeavor to practice these values in our daily activities. It reminds me of Alfred Herrhausen, a German banker, who once said: "We must say what we think. We must do what we say. And we must be what we do."

The corporate culture is heavily influenced by the shareholder family. What are the main topics of discussion when you get together?

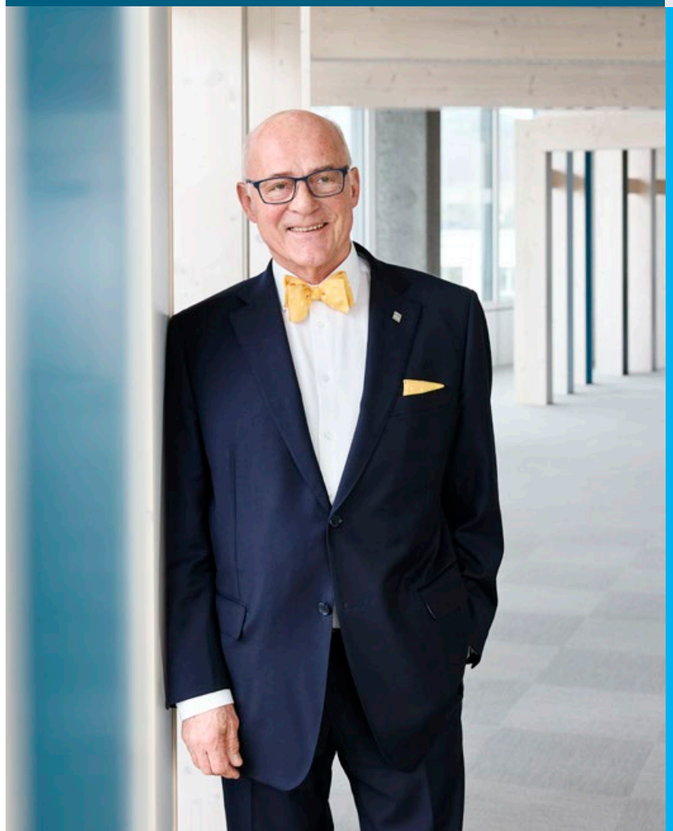
Endress: For one thing, the question of successors. We have on our boards an age limit of 75, so my elder brother Hans-Peter Endress retired from the Supervisory Board this year. The succession issue was settled years in advance and announced a while back: my niece, Sandra Genge, succeeded Hans-Peter. She has been a guest during the meetings and events of the Supervisory Board for the past two years and thoroughly prepared herself for this responsibility; she has now officially taken her place on the board. My succession is likewise settled, another process that spanned years. And it all works smoothly because we take a lot of time and put in a lot of effort. That's something you can do in a family company.

FAMILY TIES

Klaus Endress (born in 1948) obtained a degree in industrial engineering from the Technical University Berlin. He joined his father's company in 1979, took over the reins of the Group in 1995 as CEO and moved to the Supervisory Board in 2014 as president. Klaus Endress is married and the father of two grown children. A passionate horse rider and mountain biker, whenever possible he heads outdoors and into nature, accompanied frequently by Maya, the family dog.

"Challenging times always reveal how resilient a relationship is – and Endress+Hauser proved reliable."

Matthias Altendorf,
CEO of the Endress+Hauser Group



"We are all working toward a common goal. Great things always come out of such joint efforts."

Klaus Endress,
Supervisory Board President of the Endress+Hauser Group

Also important for the future is the Group's new Strategy 2027+. What are its focal points?

Altendorf: We are basically updating our previous strategy. The digitalization issue has grown more concrete; we've seen where we still have things to do. Developing our business in Asia and the Americas, where our market share is still smaller than in Europe, is a long-haul effort. Environmental protection, climate protection and the energy transition are a preoccupation of our customers and society as a whole. Here we can make a solid contribution to addressing these challenges. In terms of people, digitalization is changing the work environment. We need to find a way for our corporate culture to operate effectively in these digital and global work environments, so that we don't lose our customer intimacy and cohesiveness.

What do you see as the hallmarks of Strategy 2027+, Mr Endress?

Endress: What I find special is the goal of acting and being perceived as one company. We have a tried-and-true structure with sales centers, product centers, holding and support entities. That structure drives a particular logic in these units. Nevertheless, we have to think about things from the customer perspective. And this we aim to accomplish with Group-wide business processes, stretching from the customer to ourselves and back.

One topic in the strategy is the energy transition. Does Endress+Hauser have to fear losing established business?

Altendorf: No, I don't believe that business is in jeopardy. First, our share of the oil & gas market is very small; we're not a major player here. Second, the oil will not disappear overnight but rather over decades. New energy sources such as green hydrogen and synthetic fuels are emerging to replace fossil sources such as coal and oil. That means different or adapted processes. But these applications too need measurement so that you can control the plant.

Let's talk about the outlook. What are your expectations for the current year?

Altendorf: Politically speaking, the known troubles such as the Russia-Ukraine conflict are a cause for concern. In terms of the economy, inflation is creating uncertainty. The biggest economic risk I see is in countries pursuing a 'zero Covid' strategy. Of course we hope the pandemic will now downshift to endemic status. When things have opened up and people are on the move again, that will spur the global economy. That's why we expect to see growth in 2022. Whether it's single- or double-digit is unimportant. We will grow and develop and do everything possible to make our customers happy.

Your thoughts, Mr Endress?

Endress: Our world has seen fragility for over a decade. And in a fragile world, a company's only chance is to focus on the customers. They are all we can rely on over time. We will support our customers wherever we can, and to the best of our ability. We have great products. Measurement technology always means efficiency, quality, protecting the environment – and they have all of that packed inside them. We can't go wrong here. If we do it right, we'll still have plenty of work a hundred years from now!

"We will grow and develop and do everything possible to make our customers happy."

Matthias Altendorf,
CEO of the Endress+Hauser Group

ROOTS IN THE COMPANY

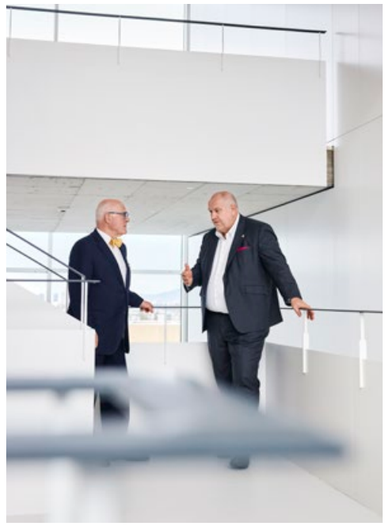
Matthias Altendorf (born in 1967) began his Endress+Hauser career with a mechanic apprenticeship, followed by studies, stays abroad and further education. He was appointed to the Executive Board in 2009 and became the Group's CEO in 2014. He balances his work life by sailing, playing chess, riding his motorcycle and spending time working in the woods. Travel, the arts and reading round out his hobbies. Matthias Altendorf is married and the father of a grown son.

One last personal question: what would make 2022 a really good year or even a 'record year' for you?

Altendorf: If we overcome the pandemic, regain substantial freedom of movement and are able to reliably plan our lives again. That translates to a happy and satisfied life!

Endress: If the world stabilizes politically and the community of nations addresses climate change. That would be the best of all for me!

1



1
Long-term outlook: Endress+Hauser implemented all of its major investment projects in 2021 as planned.

2
Collaboration based on trust: Matthias Altendorf (right) and Klaus Endress in discussion.

2

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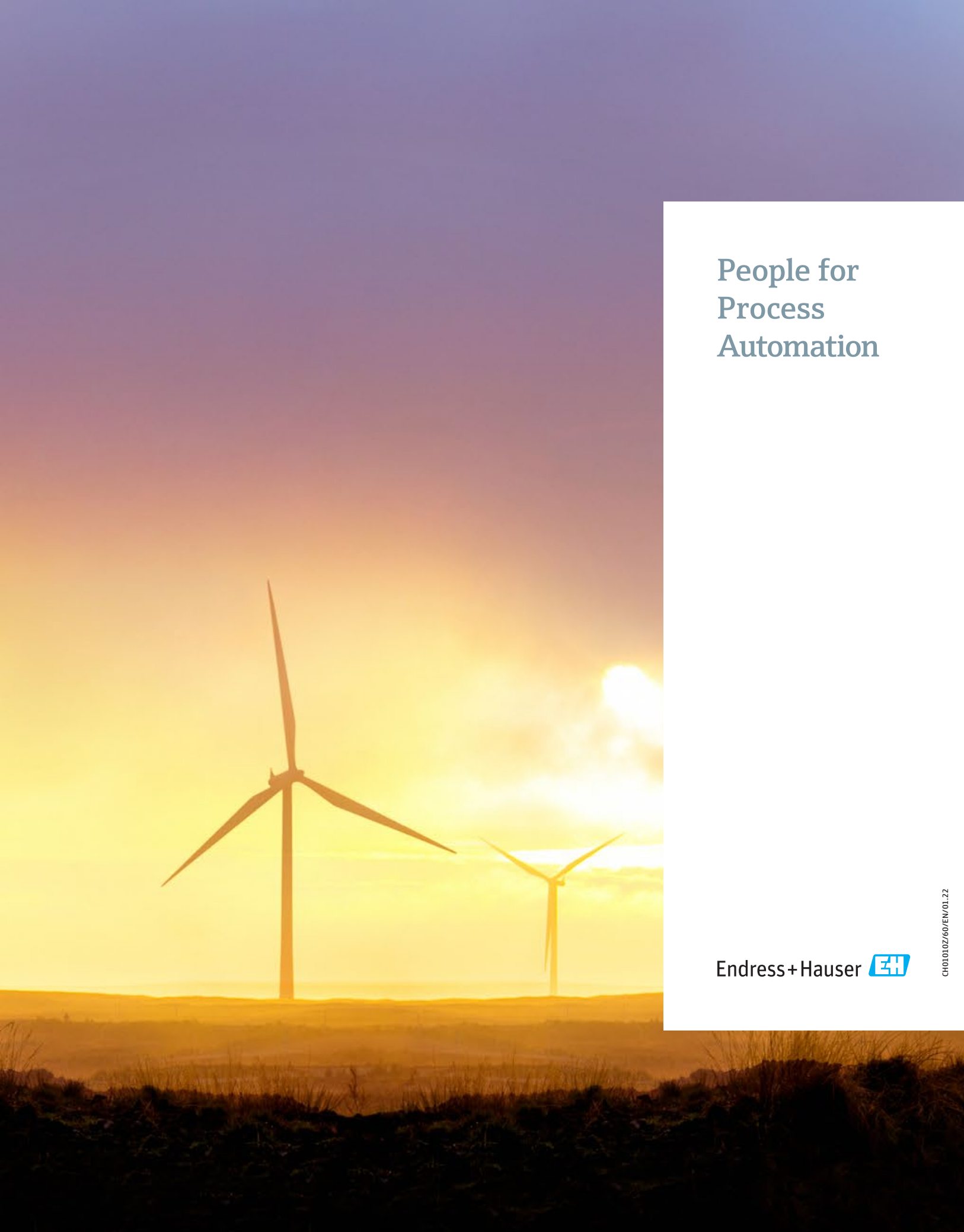

People for Process Automation

Endress+Hauser

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