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# ESSENTIAL

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FREUDENBERG SEALING TECHNOLOGIES  
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## RETHINKING

On the added value of looking at things differently – to tackle the challenges of the future.

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### TERRY TAMMINEN

The climate activist explains why it pays to bet on sustainability.

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### ENERGY MANAGEMENT

How smart monitoring systems are helping to generate more electricity – and to reduce consumption.

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### CHINA

The Asian powerhouse is moving away from coal and into renewables. Its investments are massive.



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# RETHINKING

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“Doing a headstand promotes blood flow in your brain,” according to the old saying. So the position would inevitably be beneficial for your thinking, right? Unfortunately, things aren’t that simple – the systems supplying our brains with nourishment are much too complex for that. But if you stand on your head, one thing is certain: Your perspective will change.

Suddenly things look totally different.

A headstand or handstand is not the easiest thing in the world to do. But the reason is not the lack of strength in your arms, as many believe. Your arms only contribute in small measure to the effort. Instead the exercise requires balance, body tension and an equilibrium of forces. It takes your full attention and your entire body to turn things upside down. It is not something that you do casually.


Rethinking: The term mostly comes up again and again in connection with environmental issues and the problems of the future. “This won’t work anymore. We need to rethink what we are doing,” people are saying. But what does rethinking actually mean? Aren’t our thoughts free? Aren’t they constantly wandering and swirling in every possible direction? Isn’t that what sets humanity apart: fantasy, dreams and visions of the future?



THE MAGAZINE online:  
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A silhouette of a boat is visible on the left side of the page, floating on a calm sea. The sky is filled with soft, white clouds, and the overall color palette is a mix of blues and greys, creating a serene and contemplative atmosphere.

As human beings, we are not as inclined to think as multilaterally as we believe. Much of what we invent is based on experience and influences. Our thinking can be very firmly rooted. That can be an advantage since our experience is often a good guide. If you really want to rethink things, you'll hear people tell you, "I can't imagine that." Isn't that a crazy thing to say when our brain is capable of imagining the most insane things?

In the course of human history, there were often times when people doubted that something could ever work totally differently. "How is a ship supposed to sail against the wind?" Napoleon is said to have asked. There is an endless list of such outdated prognoses. It is a source of amusement – but it really shouldn't be. When it comes to most visions of the future today, we are just as skeptical as the people who dismissed the telephone, television and the Internet as useless gimmicks.

This is also known as "tunnel vision." This is an interesting image from a number of perspectives: It is as though you are looking off into the distance and perhaps you even see the light at the end of the tunnel – but you're actually only looking in a single, very limited direction. Another example involves the images in which optical illusions are hidden. You have surely experienced how difficult it can be to see the other design. But once you discover it and rethink it, the design is literally imprinted in your mind. Suddenly you find it hard to call up the original image. Rethinking means staying flexible mentally. That's always a good thing.

The trick with Columbus's egg famously involved turning something upside down. Legend has it

that Columbus challenged his sceptics and detractors to place an egg vertically on the table. (They had been asserting that his expedition had been easy). In the end, Columbus managed the feat with the egg by slightly indenting its underside. The message: The most important groundbreaking innovations and inventions start out with a great idea – and with a belief in it. The implementation is easy by comparison. Which means you may have already won the race with the very act of rethinking.

You have to force yourself a bit to rethink things. Rethinking is uncomfortable, and you have to do it again and again. It is not enough to do it just once because habituation quickly sets in. Psychologist George Stratton demonstrated this back in 1896 with his inverting glasses – a set of glasses that tricked the eye and the brain and turned the world upside down. He proceeded from the knowledge that the image on our retinas are already upside down and that it is the brain that turns the image around. Since then, numerous other scientists performed Stratton's test on people wearing the inverting glasses and determined that, despite the inversion, people in every case properly turned the images around in their head after about six days. At any time, we have an astonishing capacity to adapt to the oddest changes and become comfortable with them.

If we want to turn things upside down, we have to do more than stand on your head. If we want to tackle the challenges of the future, we have to challenge ourselves – again and again. Our current edition shows a few ways to do that. ©

THE MOST IMPORTANT  
GROUNDBREAKING INNOVATIONS  
AND INVENTIONS START OUT  
WITH A GREAT IDEA – AND WITH  
A BELIEF IN IT.





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## PARAGONS OF VIRTUE

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It was a major accomplishment for Britons Bob and Barney Swan: The father and son reached the South Pole without leaving a CO<sub>2</sub> footprint behind, aided by special equipment during the journey. For example, they used solar cells on their sleds to generate heat and energy to prepare their food, dry their laundry and melt snow. During their South Pole Energy Challenge (SPEC), they also used a biofuel developed from residual waste. After 57 days, with the support of two companions, the Britons reached the South Pole. They proved that it is possible to survive with renewable energy sources even in the land of eternal ice. They are offsetting the CO<sub>2</sub> emissions caused by the transportation of materials in the Antarctic in part by sponsoring reforestation projects.





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# NATURE'S POWER STATION

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While many countries are trying to improve their CO<sub>2</sub> balance sheets, the conditions in Iceland come close to ideal. This island nation in the North Atlantic has geothermal energy and hydropower in abundance. The country draws three-quarters of its green energy from geothermal sources and one-quarter from hydropower. In 2015, Iceland was able to cover nearly 85 percent of its gross domestic energy consumption with these two energy sources. Those figures are still a distant dream for the EU states, the U.S. and China. The Icelanders have now set their sights on supercritical water vapor, which can be found miles below the surface in the stone above magma fields. It could have ten times the yield of normal geothermal energy due to its special consistency, heat and enormous pressure.







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## SUCCESS FACTOR

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The FIFA World Cup 2018 is starting out in Russia in June, and Germany is the defending champion. Its clear semifinal victory against host Brazil was a sensation in 2014. But not all its performances on the way to the title were as brilliant. The fact that the team was yet successful can be traced not least of all to a change in mindset. For many years, German coach Joachim Löw had wanted the team to score goals thanks to playful superiority. But in the preparations for the World Cup, he was persuaded that set pieces might be an useful alternative. With success. Thomas Müller began the goal fest against Brazil after a corner kick. Against Portugal, the preliminary 2:0 score came after a corner, as did the 2:2 final score against Ghana. The winning goal shown here in the quarterfinals against France resulted from a free kick.



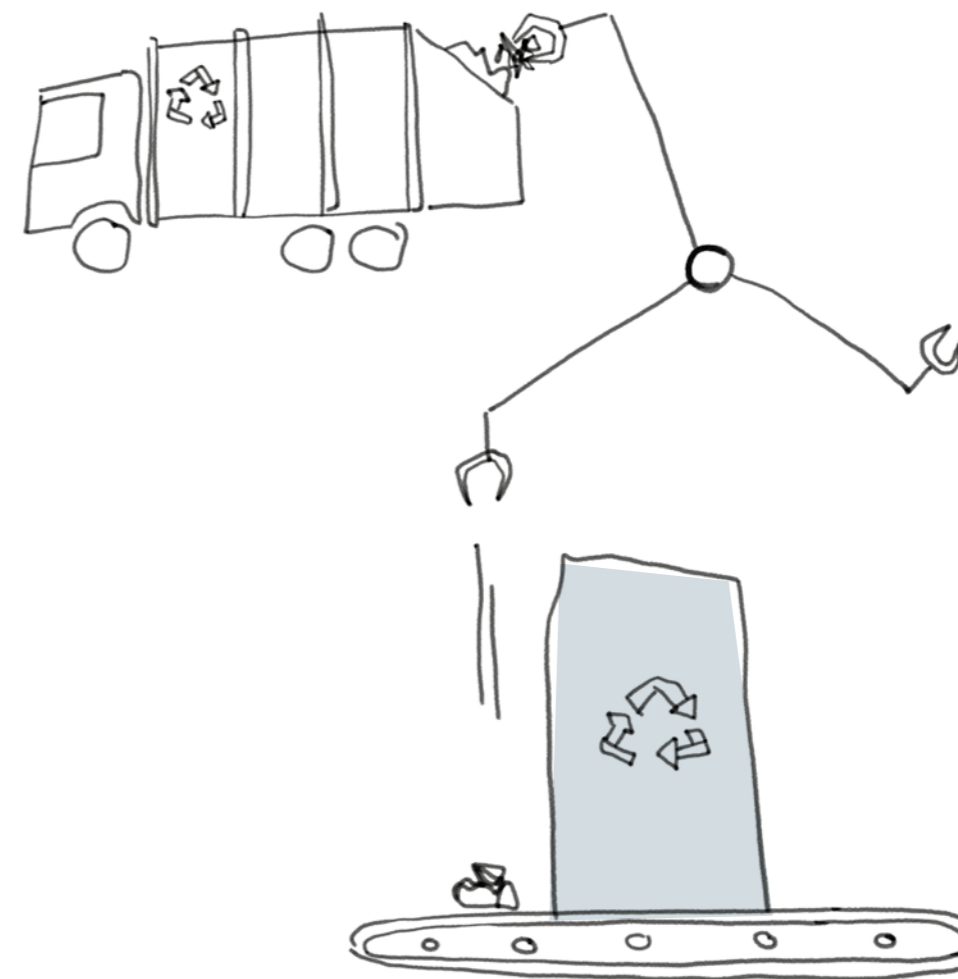


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## “WASTE IS A MINE PACKED WITH RAW MATERIALS”

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Over 40 years ago, Terry Tamminen committed himself to environmental and climate protection at one of the defining moments of his life. The American activist was the driving force behind Arnold Schwarzenegger’s environmental agenda and is now CEO of the Leonardo diCaprio Foundation. He talks about hydrogen propulsion, China’s role in environmental protection and why there is a payoff for energy-efficient manufacturing.







**MR. TAMMINEN, ACCORDING TO THE GUARDIAN, YOU HEAD THE LIST OF THE “TOP 50 PEOPLE WHO CAN SAVE THE PLANET.” HOW DOES IT FEEL TO BE ONE OF EARTH’S SAVIORS?**

It was very nice to be included on this list. But the planet does not need saving. The real issue is life on earth. A full 99 percent of animals and plants were gone before the Industrial Revolution due to the normal extinction process. Yet nowadays the process is a thousand times faster than before due to mankind. If we don’t change our behavior, it won’t be long before it will be our turn.

**WHAT DO WE HAVE TO CHANGE?**

We need to think long-term and plan ahead. As soon as our thoughts turn to protecting the environment, we mostly address the issue with short-term thinking.

**YOU ARE KNOWN FOR PLANNING LONG-TERM. WAS THERE A DEFINING MOMENT THAT LED TO YOUR COMMITMENT TO THE ENVIRONMENT AND EFFORTS TO COMBAT CLIMATE CHANGE?**

There were two defining moments. I was born in 1952 and I started scuba diving in LA when I was twelve. I was intrigued and inspired by the ocean with its animals and plants. Then we moved to Australia, and when I came back ten years later, pollution had destroyed the flora and fauna of my diving area. I was shocked. It opened my eyes to how quickly pollution could have an effect. The second moment was when I met Arnold Schwarzenegger and got to know him as an earnest environmentalist. When he took over as governor of California, the seventh largest economy in the world, he seized the opportunity to do something to help the environment and fight climate change.



**HE APPOINTED YOU AS HIS ADVISOR ON ENVIRONMENTAL ISSUES. WHAT WERE THE LEVERS THAT YOU COULD APPLY?**

Thanks to our legislation, we had the chance to act as a separate country. We passed numerous laws, first and foremost the *Global Warming Solutions Act*. It allowed us to set up a wide-ranging program to tackle reductions in greenhouse gases with determination. We promoted the installation of solar cells with our *Million Solar Roofs Initiative*. We also created a network of hydrogen filling stations to promote electric mobility. California became a pioneer in environmental protection.

**HOW HAVE MEASURES TO PROTECT THE ENVIRONMENT EVOLVED IN CALIFORNIA SINCE THEN? IS THERE A SUSTAINABLE PROCESS?**

Very much so. The laws and initiatives have continued to exist right down to the present, and the current governor, Jerry Brown, is moving ahead with energy-efficiency measures. He has accelerated and expanded some aspects. He has even explained his policies abroad, calling for people to take the same course and not let up. That is very good.

**YOU HAVE MEANWHILE BECOME CEO OF THE LEONARDO DICAPRIO FOUNDATION, WHICH IS STRONGLY COMMITTED TO ENVIRONMENTAL CONCERNS, AMONG OTHER ISSUES. WHAT SETS DICAPRIO AND SCHWARZENEGGER APART?**

Leonardo is passionate spokesperson for efforts to protect the environment and combat climate change. He deals with these issues vigorously and travels around the world to gain first-hand impressions on site. He and Arnold know what they are talking about. Arnold used his position as governor to advance environmental issues. He first sensitized people to them and, like Leonardo, continues to do so today.

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## LEONARDO DICAPRIO FOUNDATION

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Actor Leonardo DiCaprio formed this foundation in 1998. It supports innovative projects throughout the world with cooperative programs. The projects include protecting endangered wildlife and reestablishing the equilibrium of threatened ecosystems. It also promotes the best solutions for managing the climate crisis and supports a complete transition to renewable energy.



**WITH YOUR R20 INITIATIVE, YOU ARE STRENGTHENING EFFORTS TO PROTECT THE ENVIRONMENT ON A REGIONAL BASIS. DO YOU THINK IT IS MORE PROMISING TO TACKLE ENVIRONMENTAL ISSUES ON A SMALLER SCALE THAN WITH NATIONAL OR INTERNATIONAL AGENDAS?**

Both approaches are important. Our policies in California were based on the Kyoto Protocol of 1997 with its legal climate protection objectives. If there had not been that international element, we couldn't have done it that forcefully. This was the only way that we could become a driver. And we still are despite the policies of the current U.S. administration. But its actions have had positive effects as well. They made many Americans aware of the Paris Agreement. Many realized there was still much to do to protect the environment and were mobilized. Companies also see that they can profit from measures to protect the environment.

#### **IN WHAT WAY?**

Companies recognize that they can cut costs with more energy-efficient manufacturing. With the emissions trading, as companies move from coal and oil to renewable energy, fuel switching saves money. That's why I really think measuring carbon emissions offers possibilities. Environmentally conscious companies benefit from the trade in emissions. With emissions trading, even if companies have not come very far, they can still do their part for environmental protection and can be motivated to invest in it.

**DO PEOPLE NEED TO ACKNOWLEDGE THAT MONEY CAN BE MADE OR SAVED WITH ENVIRONMENTAL MEASURES, IN ORDER TO PLAY A ROLE IN THIS?**

This may not be the only aspect. But it affects everyone. In the U.S., we could be much further along, even with the positive side effects. If we were to replace the 26 million streetlights that still use old technology with energy-saving LED lamps, the investment would be amortized within five years. It would also be a kind of stimulus program since it would create jobs.

**IN YOUR OPINION, WHAT INNOVATIONS HAVE THE POTENTIAL TO ADVANCE EFFORTS TO FIGHT CLIMATE CHANGE DECISIVELY?**

First and foremost, hydrogen fuel cells. If the hydrogen is collected through electrolysis drawing on wind or solar energy, it is a completely emission-free resource. It can also be easily stored and is available as an energy supply when needed. Many automakers are offering fuel cell models and are thinking more in this direction.

I also consider smart grids to be a major achievement. You can be at the other end of the world and still regulate the thermostat in your house using a smartphone. This allows you to easily control energy consumption in your own home and save money.



**CHINA IS SETTING NEW PRIORITIES FOR ENVIRONMENTAL PROTECTION AND EFFORTS TO DEAL WITH CLIMATE CHANGE? DO YOU CONSIDER CHINA TO BE THE WORLD'S NEW HOPE ON THESE ISSUES?**

China's role as world's great hope is not that new. But perhaps we are only recognizing a longer-term trend. China has now surpassed the U.S. in wind power. China has long been the largest manufacturer of solar cells, and in recent years the United States has benefited as a buyer of its affordable products. And with its new coal-fired power plants, China is significantly cleaner and more advanced than the United States. Their carbon trade system is like the Californian system. They have been leading by example for a long time.

**CHINA IS A FORCEFUL ADVOCATE FOR ELECTRIC MOBILITY. IS ELECTRIC MOBILITY ONE OF THE MAIN WAYS TO REDUCE CO<sub>2</sub> EMISSIONS APPRECIABLY AND EFFICIENTLY?**

Absolutely. Oil products are not merely environmental polluters. You need to drill deeper and deeper, at ever higher risk, for oil. Furthermore, oil has to travel enormous distances to reach its target markets. Electric mobility is a fantastic alternative by comparison. Gasoline just fizzles out and then it is gone. Electric motors continually score points for their innovations and improved recycling methods. Even the rare earths that they require are now used significantly less than just a few years ago.

**YOU DRIVE A HYDROGEN-FUELED CAR. IN YOUR OPINION, WHAT ADVANTAGES DOES A FUEL CELL OFFER COMPARED TO A BATTERY-POWERED CAR?**

I am a big fan of hydrogen propulsion. It may have a bad reputation because many people think that hydrogen is burned in the fuel cell. But that is wrong, of course. It is converted into electricity. The advantage of hydrogen vehicles is that they closely match the habits of consumers today. You fill up your car as you would with an internal combustion engine, and five to ten minutes later you are on your way again. That makes it attractive.

**ESPECIALLY IN WESTERN COUNTRIES, THE ENORMOUS AMOUNT OF WASTE THAT HUMAN SOCIETY PRODUCES IS A HUGE PROBLEM. YOU ENVISION MINING RAW MATERIALS FROM LANDFILLS. HOW WOULD THAT WORK?**

I am really excited about this. In five or ten years, we are going to mine our landfills. The way many countries have dealt with trash until now is totally incomprehensible. It offers so many opportunities at their doorstep. It's insane that we only use objects briefly and then throw them away, only to extract the raw materials used in them at great effort from somewhere else. Recovering raw materials from landfills offers enormous potential for savings and creates jobs locally. Countries, regions and communities must understand this. Waste should not be seen as a liability but rather as a source of raw materials.





**DO THE INCREASING DIGITALIZATION AND AUTOMATION OF INDUSTRY AND SOCIETY ALLAY ANY OF YOUR CONCERNS ABOUT CLIMATE CHANGE?**

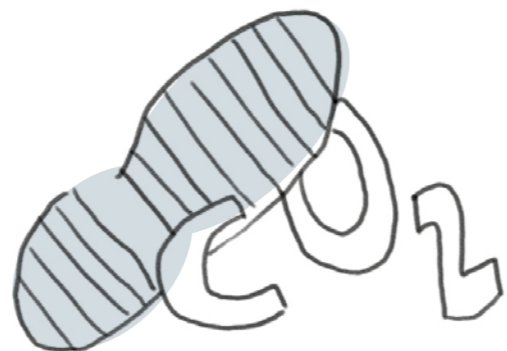
Yes. I do think they can be a solution. They make things more efficient. Package shippers in the U.S. use them to help drivers navigate and take the best possible routes. The company saves time and customers receive their goods more quickly, and it all reduces fuel consumption. Walmart is so well networked that it can avoid sending empty trucks onto the road as much as possible. And California has equipped its trash cans with sensors that tell the waste collectors which cans need to be emptied. Efficiency of this kind is not something to be dismissed.

**LET'S LOOK AHEAD TO THE YEAR 2050: HOW WILL CLIMATE MEASURES, POPULATION GROWTH AND ECONOMIC GROWTH INTERACT WITH ONE ANOTHER?**

If our attitude continues to be "business as usual," we are not going to be able to sustain 10 billion people until 2050. We are going to see diseases and storms made worse by climate change. In the United States, we can provide real help to casualties of severe weather, but not in Bangladesh. No one comes to their assistance. So it must be clear that we can't waste anything. It is incredible how much food we produce and then throw away. We have to change our habits of consumption and work to reduce our waste. Farm production also needs to get more efficient, and we may have to deal with the reality that people in drought regions cannot survive any longer.

**SO IT IS TIME TO SEE THE CURRENT SITUATION FOR WHAT IT IS.**

Absolutely. To me, it is important to recognize the seriousness of the situation. We've known about climate change for years. We have perhaps three to five years to respond effectively. People must be aware that they have to change some aspect of their attitudes. That also applies to governments and companies. Don't look for new sources of raw materials. Comb through your landfills. Deal with your ecological footprint. Make sure that you get the CO<sub>2</sub> out of your products. I describe how this works in my book, *Cracking the Carbon Code*. I think it is essential to rethink these things. The payoff will take two forms: financial and ecological. ©




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**TERRY TAMMINEN**

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Born in 1952, Tamminen is an American who spent part of his childhood in Australia where his family ran a breeding station for tropical fish. During his professional life, he devoted himself to the nonprofit sector, especially in environmental protection. While he was governor of California, Arnold Schwarzenegger appointed Tamminen as his environmental advisor. In 2010, he cofounded the R20 initiative, which promotes climate protection at the regional and local levels. He has been the CEO of the Leonardo DiCaprio Foundation since 2016.





## NEW DIRECTIONS

People who have achieved great fame and reached the pinnacle of their profession have nothing more to prove. Yet there are figures who more or less reinvent themselves and then stand out in an entirely different field.

### ARNOLD SCHWARZENEGGER

#### From Icon ...

Austrian native Arnold Schwarzenegger became a sensation as a bodybuilder in the 1960s and 1970s. After his emigration to the United States, he set new standards with multiple Mr. Universe and Mr. Olympia titles. During this period, he began an acting career that made him a familiar figure to international audiences by the 1980s.

#### ... to the Environmental Governor

In a surprise move in 2003, Schwarzenegger announced his candidacy for the governor of California. After a successful electoral campaign, he governed the country's most populous state until 2011. Throughout this period, he devoted himself to environmental protection and initiated many groundbreaking measures. Even after his term in office, he remained loyal to the cause and has been a strong international advocate for the environment down to the present. ©



### ALFRED NOBEL

#### From Inventor ...

The Swedish chemist Alfred Nobel not only achieved fame by inventing dynamite – he became enormously rich as well. Patented in 1867, the explosive could be transported, stored and used more safely than the nitroglycerin that it was based on. Dynamite made innumerable construction projects possible, including the Gotthard tunnel and the Corinth canal. Its value for military purposes was also recognized.

#### ... to Philanthropist

At the end of the 19th century, Nobel faced criticism from peace advocates and in the media due to the use of dynamite in wars and assassinations. The response was likely one of the reasons that he endowed a foundation with most of his wealth. The interest earned on his fortune was to be paid to award-winners who “benefited humanity the most over the past year.” Bestowed since 1901, the world's most famous scientific prize was named for him. ©

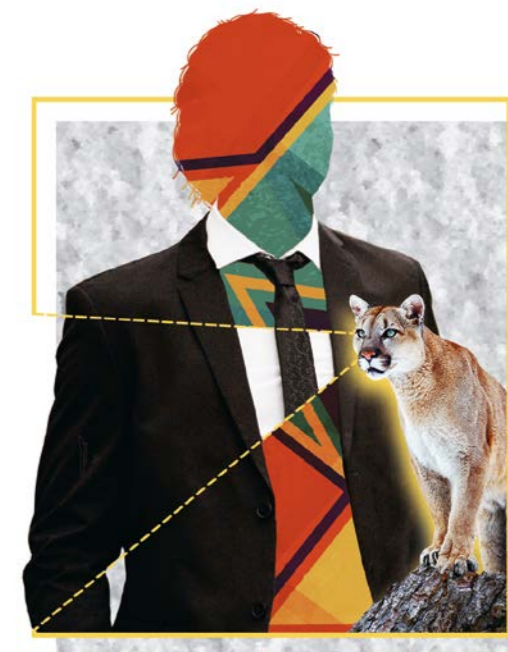
### JOCHEN ZEITZ

#### From Successful CEO ...

In 1993, Puma appointed Jochen Zeitz, then just 30 years old, as its chief executive. The sporting goods company was in a critical condition at this time. There was a real possibility that the venerable company might not survive. Zeitz radically changed its brand image, combined sportiness with fashion, and generated consistently high growth rates. During his tenure, Puma became the world's third largest manufacturer of sporting goods.

#### ... to Sustainability Champion

Zeitz left the job of CEO in 2011. Under his leadership, Puma became the first company in Germany to create an ecological balance sheet and introduce a sustainability program. After leaving Puma, he devoted himself more extensively to these issues. He is convinced that only sustainable businesses can be profitable in the long run. He now teaches his philosophy to companies around the world, aided by a so-called “B Team” of well-known business leaders. He also created a climate-neutral luxury eco-resort in Kenya. In Cape Town, he founded the Zeitz Museum of Contemporary Art Africa (MOCAA), the first museum of its kind on the continent. ©







Traffic jams are strangling inner cities around the world, drivers are in despair, and transportation planners are looking for a way out. Can we learn something from cities whose transportation is mainly the two-wheel, motorized variety? Yes, if you think ahead into the future – and rethink the way things are done now.

It is a seething mass, alternately swarming and scattering, almost impossible to disentangle, complete with the endless blaring of horns. Analogies from the animal world spontaneously occur to anyone observing traffic in Hanoi, the capital of Vietnam. Ants and swarms of fish come to mind. The streams separate, follow curves, turn corners, and move along in utter confusion. It is an extraordinary form of swarm intelligence, with a dynamic that is completely different from what happens in most other cities in the world – where cars inch forward in stop-and-go traffic.

The usual term for these metropolises in the transportation literature is “motorcycle-dependent cities.” There are a number of them, especially in Asia: the major cities in Vietnam, along with Taipei, the



©

## TWO-WHEEL TRANSPORTATION



Taiwanese capital, plus, to a lesser extent, cities such as Bangkok in Thailand and Surabaya in Indonesia. For various historical reasons, transportation is heavily dependent on motorized two-wheelers in the cities. There is also a larger share of motor scooters in Tokyo, Singapore and Hong Kong than in comparable cities in Europe or the Americas. “The textbooks on urban transportation in Western countries don’t even mention motor scooters,” wrote researcher Khuat Viet Hùng in his dissertation on the subject. He defines a city as motorcycle-dependent when the number of scooters reaches more than 350 per 1,000 inhabitants and the two-wheelers represent more than half of the traffic elements. The situation is often accompanied by a rather weak public transportation infrastructure.

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### THREE-QUARTERS OF ALL TRAVEL WITH SCOOTERS

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In Ho Chi Minh City, the South Vietnamese metropolis, there are 700 motor scooters per 1,000 inhabitants – and only about 30 cars. About three-quarters of all daily trips are taken with motor scooters. The use of pedestrian walkways plays a marginal role at just 7 percent. Cars come in even lower, at 4 percent. If you are traveling to work, for shopping or just to see “friends in the neighborhood” for a moment, you use a scooter. And even though the number of cars has grown in recent years, a range of factors are working against them: side streets are rather narrow and hard to access, and parking spots are scarce commodities. Concerned about gridlock, the Vietnamese government imposes high vehicle taxes.

But the huge swarm of scooters has its pitfalls: They are loud and their gasoline two-stroke engines poison the environment just as four-wheel vehicles do. The scooters also score comparatively low on safety. There are 24 traffic deaths per 100,000 inhabitants



75%

of all trips taken by residents of Ho Chi Minh City employ motor-scooters



102

hours — that’s the amount of time that Los Angeles drivers spend in traffic jams. The figure is 64 for Bangkok and 44 for Berlin



5.12 mph

is the average speed by car during rush hour in New York

annually in Vietnam: The figure for Germany is just four. Furthermore, the scooters’ agility leads to situations where drivers snake through the smallest gaps, creating traffic jams and chaos in their own right. The alternative is even gloomier: If you were to replace scooters with cars, the traffic in these cities would grind to a halt. Even side streets and fairly small alleys like those in Hanoi’s old city are surprisingly easy to reach with scooters, and this accessibility promotes local economic development. Restaurants and shops have to be accessible.

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### HOW CAN HUMANITY ESCAPE MEGA CONGESTION?

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From this perspective, the motor-scooter cities are superior to automotive metropolises in a number of ways. And they could be an answer to the questions that have concerned researchers around the world for some time: How can cities get along with fewer cars? How can cities in developing and emerging countries be prevented from falling one by one into the same trap of relying on cars for transportation, with all the accompanying woes such as traffic jams and pollution? The average resident of Los Angeles spends more than 100 hours a year in traffic jams, according to the latest study by Inrix, a transportation analytics firm. The figures for cities such as São Paulo, Bogotá and London aren’t much better. By comparison, the motor scooter-dominated cities fare far better. Even during rush hour, the average speed in Hanoi is 20 kilometers per hour (12 miles per hour), statistics show. That is more than twice the figure for some American cities.

Around the world, cities have become increasingly motorized in recent years, including those that had comparatively poor populations and bad roads not so long ago – two factors that discouraged car purchases. But when growing numbers of vehicles are on the road, public transportation



options run into problems. In São Paulo, the number of miles traveled by bus per capita has decreased since the 1990s. Are smaller vehicles like motor scooters a possible way out?

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### NETWORKED AND FAST – THE “SMART SCOOTER”

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Taiwan is an interesting starting point. Its 23 million inhabitants own 14 million motor scooters. The electric scooter got its start here back in 2008, but its success was only moderate for a number of years. Even in 2015, sales of electric motorcycles were barely 4,000 units a year. Surveys showed that the problem was less the price difference than weaknesses in their performance: long charging times, short ranges and difficulties with steep inclines. But now a new generation of “smart scooters” – from companies such as Taiwan’s Gogoro – wants to change all that. Aside from improved performance and a winning idea – just exchanging batteries rather than charging them – these motor scooters are luring customers with modern networking technology. A variety of functions can be handled by smartphone apps, such as locating the next station for a battery replacement, adjusting the

volume of the motor noise, or even controlling the scooter’s speed. These features not only make the vehicle more environmentally friendly – but modern and appealing to young buyers as well.

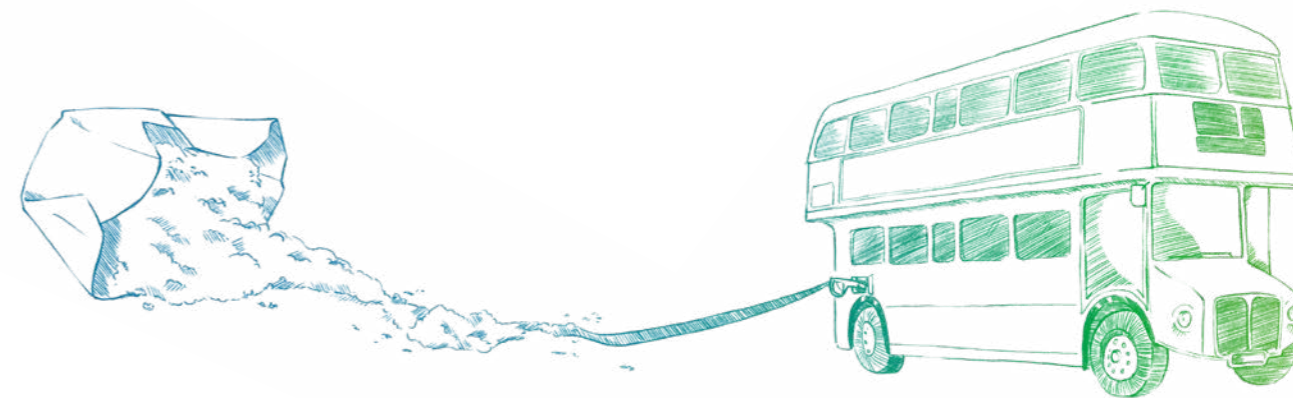
So what solution would provide clean air and flowing traffic? There would ultimately be a mixture of solutions: In his dissertation back in 2006, transportation scientist Khuat Viet Hùng was already making the case for better public transportation in Vietnam’s cities. The idea is to retain motor scooters’ advantages while limiting their disadvantages. And then there are the new opportunities offered by Big Data, transportation analysis and traffic management apps, along with self-driving taxis and car-sharing. If you add a growing share of environmentally friendly electric bikes and smart scooters, the result is a surprisingly sustainable vision of the future. In any case, visionaries are needed to do the transportation planning of the future along these lines. The old visions – where more transportation simply takes up more space – led to six-lane roads clogged with traffic jams, like those in America, or to the inextricable tangle of two- and four-wheel vehicles found in many Asian cities. A rethinking is needed. And why not keep the motor scooter, which has been such a rarity in western cities, in mind? @





## FROM OLD TO EXTRAORDINARY

Recycling has long been part of everyday life. Everyone knows about newspapers and notepads made of waste paper. But it's also possible to give aging products and materials a completely new life. This is called upcycling, and it puts objects manufactured for industrial purposes in a completely new light.



The recycling can take many forms. Instead of leaving old products to their fate in a landfill, they can be given a new, altogether fashionable life. Shoulder bags made from [truck tarpaulins](#) are a familiar example.

A Portuguese clothing company is benefiting from the use of automotive products as raw materials for its shoes. For example, it has used the nylon in [airbags](#) and recycles [plastic bottles](#) and tires on a separate PET line, engineering a somewhat unusual comeback for the products. An Ethiopian company manually produces shoes that are partly made from old [truck tires](#). These striking shoes are mainly exported abroad and have even made it as far as New York.

A very special kind of recycling has come into play in the production of fuel for buses. Since the end of 2017, some of the famous red London buses have been fueled with a biofuel mixture derived from [coffee grounds](#). A British company goes around the country collecting these remains from the coffee machines at cafés and cafeterias and then combines them with fats and oils to create an innovative biodiesel.

At some point, even airplanes could take flight with the help of a special biofuel. That is at least what an international team of researchers demonstrated in 2017. They started out with [sour whey](#), which is a waste product from the production of yoghurt and the acid-set cheese known as quark. Then they extracted a purely biological oil that can be further processed into fuel for aircraft. The process does without expensive chemicals. Bacteria cultures are merely added to the sour whey in two bioreactors heated to different temperatures, which makes it possible to recycle the substance into a valuable material.

Even scrapped [wind turbines](#) can end up in a completely new environment. Due to their very high carbon fiber content, the rotor blades are hard to recycle. A Dutch company came up with a different use for them in Rotterdam. Since 2012, they have been used as park benches and as futuristic climbing structures in a playground.

With its Freudenberg Performance Materials (FPM) unit, Freudenberg is doing its part to promote upcycling as well. FPM takes old [PET bottles](#) and uses them to manufacture small, interconnected fiber balls that are incorporated as padding in the ski clothing of a North German sportswear manufacturer. This sets the label apart as a seller of highly functional, sustainable and pollutant-free winter sports clothing. The examples show that upcycling not only helps companies produce new, modern products – it reduces waste as well. A new way of thinking can be a beautiful thing.





## OLD INPUT

People have been using wind power for centuries – most obviously at sea but on land as well. Windmills are a tremendous aid for work processes. With their help, fields can be drained, wood sawed, oil pressed, dyes extracted, and grain and plaster milled. Classic Dutch windmills began their ascent in the 16th century and fall into the best-known category of



wind power. Their structures could rise as high as 40 meters (130 feet). With a wingspan of more than 20 meters (65 feet), they were capable of generating up to 30 kilowatts. The influence of windmills waned with the arrival of industrialization, and they were increasingly abandoned during the 19th century.

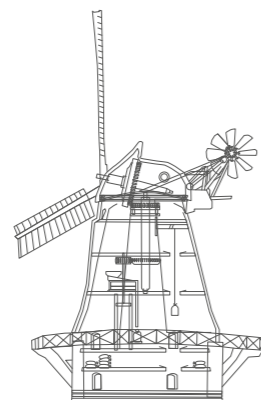


## NEW OUTPUT

In 1888, the first sign emerged that windmills could still be useful: American entrepreneur Charles F. Brush had the first fully automatic windmill for the production of electricity constructed. It was nearly 30 meters (100 feet) tall and generated 12 kilowatts. As the search for alternative energy resources picked up steam, wind energy began enjoying a renaissance in the 1980s. Technological

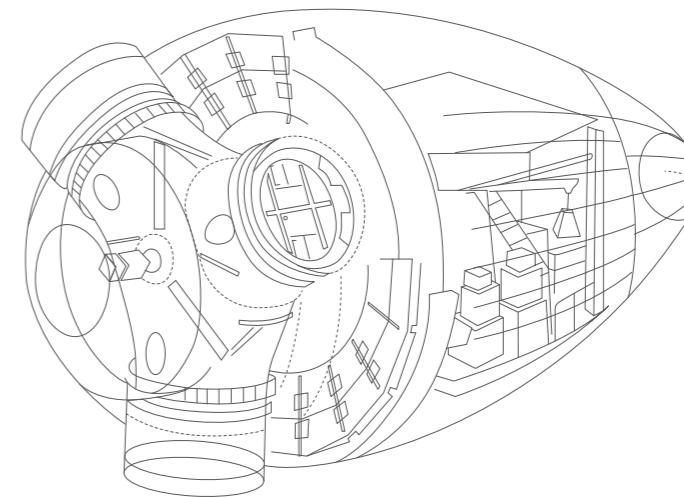
progress allowed larger and larger facilities to be built, and they produced more and more electricity. The highest performing facility today can produce 8 megawatts with a rotor diameter of 180 meters (590 feet). Soon wind turbines with a total height of more than 200 meters (650 feet) will be mainstream. An offshore facility generating 12 megawatts has been announced for 2021. ©





**CLASSIC  
DUTCH WINDMILL**

Height: up to 40 meters (130 feet)  
Wing diameter: up to 30 meters (100 feet)  
Output: up to 30 kilowatts  
Start of rotation: 5–6 m/s (16–20 ft/s)



**MODERN WIND ENERGY TURBINE (ENERCON E-126)**

Height: 135 meters (440 feet)  
Rotor diameter: 127 meters (420 feet)  
Output: 7.580 kilowatts  
Engagement speed: 3 m/s (10 ft/s)



#### WHITE GOLD

The Salar de Uyuni in Bolivia is the world's largest salt flat. It also contains enormous lithium reserves.



## A RECIPE FOR A BATTERY

Take 10 kilos (22 lbs) of lithium and 16 kilos (35 lbs) of cobalt, and stir thoroughly. And that gives you a driving range of 500 kilometers (310 miles)? Making a battery is not quite that easy – in part because the key materials could be in short supply.



The Industrial Revolution would have almost broken down. To be sure, at the start of the 18th century, England had already developed an advanced technological culture famous for its iron-working and shipbuilding. But its supply of its most important raw material – wood, and consequently the charcoal made from it – was running short. Charcoal had been essential for the operation of ironworks. Contemporaries spoke of a serious threat to civilization. Similar discussions about electric mobility are underway during the early years of the 21st century: At a time when the breakthrough seems within reach, critics are increasingly predicting a scarcity of crucial raw materials. That's because rare earth metals are needed for electric motors, as are some rare materials for lithium ion batteries – and not just the lithium. Many scientific studies have reached careful conclusions that, once summarized very briefly, can lead to alarming headlines.

### 10 KILOS OF LITHIUM IN A BATTERY

It is the on-board battery system that mainly seems seriously threatened by a raw materials shortage. The reason: Despite intensive research, only one approach seems suited to the application so far: the lithium ion battery whose technical foundations were laid during the 1980s. Lithium, which occupies the third position on the periodic table, is not just the most lightweight of all the solid elements – in ionized form, it has an extremely high electrical charge density, which is the ideal feature for use

in a mobile energy storage system. Lithium is in fact the active material in the battery, which is why it is needed in relatively large quantities. Depending on its composition, the cathode – the “garage” for the lithium ions – contains 111 to 139 grams (3.9 to 4.9 ounces) per kilowatt hour of battery capacity. If a battery with 75 kilowatt hours is taken as an example – an output suited for a large vehicle covering long distances – it will have more than 10 kilos (22 lbs) of lithium inside. Even the promising alternatives to today's design, the solid-state battery and the lithium sulfur battery, cannot manage without lithium. On the contrary, even more lithium would likely have to be used per kilowatt hour to achieve the same energy density.

But a meta-study published in the trade journal “Joule” last year found that there is probably no reason to fear a lithium shortage in the medium term. The study consolidated and evaluated the results of many other studies. Researchers at the Massachusetts Institute of Technology and three other American institutions looked at the demand for the material based on various market scenarios, even considering stationary energy storage units and drones in addition to cars. Their conclusion: In view of reserves of up to 40 million tons that can be extracted economically even today, it is unlikely that there would be a shortage. They point out that more deposits are continually being discovered and that it is theoretically possible to extract lithium from the sea. The authors describe the situation for cobalt as much more critical. “The supply of cobalt is potentially at risk,” the team led by Elsa Olivetti wrote.



**COBALT**  
A by-product of copper and nickel mining, cobalt plays an important role in the manufacture of battery cells.

This element is also used in battery cathodes to bond with the lithium ions parked there. Certainly, there is a lesser need for cobalt atoms than for lithium atoms in a functioning battery, but since cobalt has ten times the atomic weight of lithium, the quantity becomes substantial, reaching about 16 kilos (35 lbs) in a current 75-kilowatt battery.

Unlike lithium, cobalt has not been mined directly to date. It is normally a by-product of copper or nickel mining. The researchers are not too concerned about nickel mining as a way to obtain cobalt, but they see its extraction via copper mining as a potential problem: Nearly all the cobalt acquired in this way, currently about 50 percent of the global supply, comes from the Democratic Republic of the Congo. But even if this central African country, formerly known as Zaire, were to remain politically stable, there would still be risks. That's because the material has to be processed before it is used in a battery, and this mainly takes place in China. The supply chain is another concern for automakers. BMW and Volkswagen have announced that they want to guarantee a secure supply of cobalt with their own long-term supply contracts – otherwise they won't enter into battery cell production. Aside from a long-term supply, ethical standards would be part of the agreements, including the prohibition of child labor.

### VALUABLE RECYCLING

The recycling of used but still-operational batteries could reduce the demand for the raw material. The battery of an electric car is certainly not something that you discard. Even after 200,000 kilometers (124,000 miles), it should still have 75 to 80 percent of its original capacity left. In stationary applications, the batteries, if connected in a series, could store excess solar or wind energy – a business model that is still in the test phase. But the recycling of battery materials is already tried and tested, as the Belgian firm Umicore has shown at a demonstration facility in Antwerp. There are three steps in the process: The first is to dismantle the battery; large components, such as the steel or aluminum housing and the copper lines, are fed directly into material recycling. The cells, which had been bundled into modules, are melted in a smelting furnace. The recovery of the metals –

### “THE SUPPLY OF COBALT IS POTENTIALLY AT RISK.”

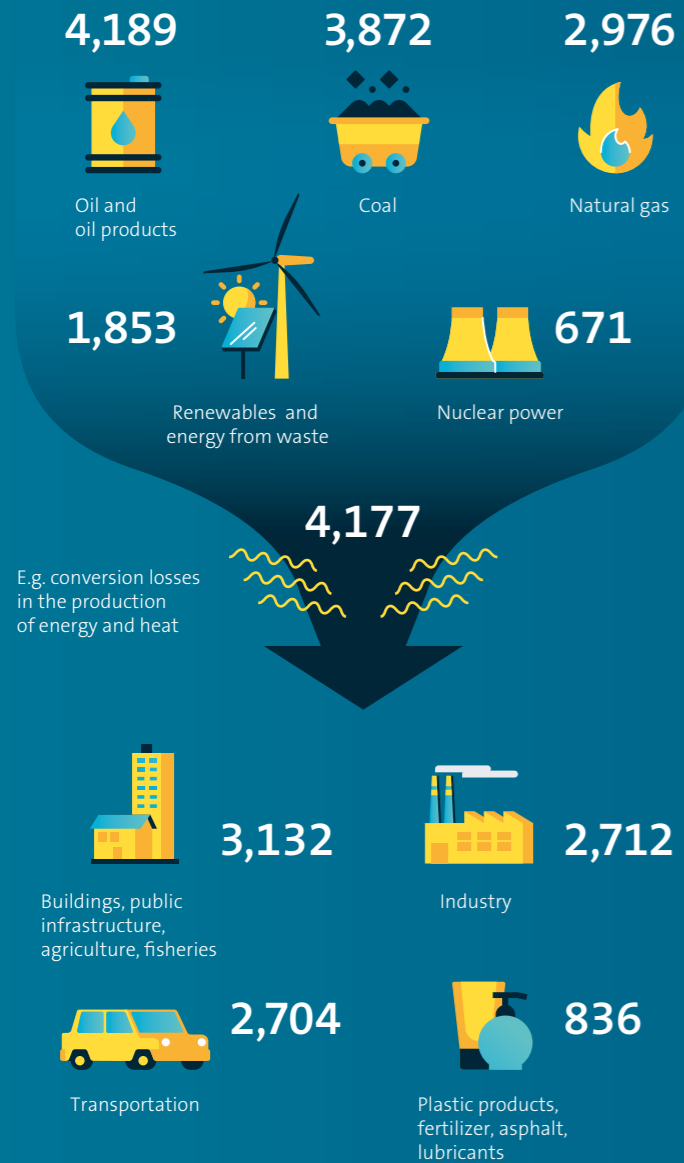
cobalt, copper and nickel – is relatively straightforward. Due to their different melting points and densities, the fluid metal phases are easy to separate. More than 95 percent of the cobalt contained in a battery can be recovered in this way, according to Umicore. Slag, largely consisting of lithium with aluminum and iron residue, is left behind. It goes through another step, mostly to recover the lithium. Even if high rates of recycling cannot eliminate short-term bottlenecks in the long run, they have another benefit. According to Umicore expert Christian Hagelüken, they reduce the energy expenditures for battery manufacturing by 50 percent. This is mainly relevant because battery production makes up about half of the total carbon footprint of an electric car, provided that it runs exclusively on green electricity.

Higher recycling rates or even completely cobalt-free batteries could be on the horizon: It is precisely the threat that some materials could be in short supply that offers opportunities to resourceful entrepreneurs. That was the case in 1730 when Abraham Darby took over his father's business and converted iron processing from charcoal to coke, which he obtained from bituminous coal using pyrolysis. This gave the Industrial Revolution a push, in part because steam engines were then sorely needed to pump groundwater out of coal mines. ©



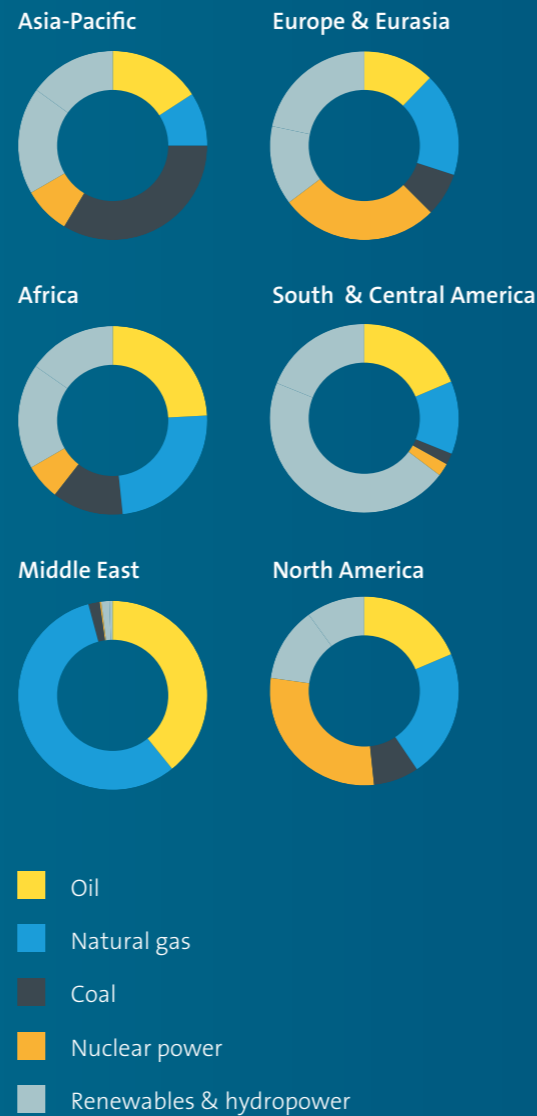
# ENERGY FACTS AND FIGURES

## COMPLETE OVERVIEW: HOW MUCH ENERGY DOES THE WORLD CONSUME – AND FOR WHAT PURPOSES? 2015, in millions of tons oil units



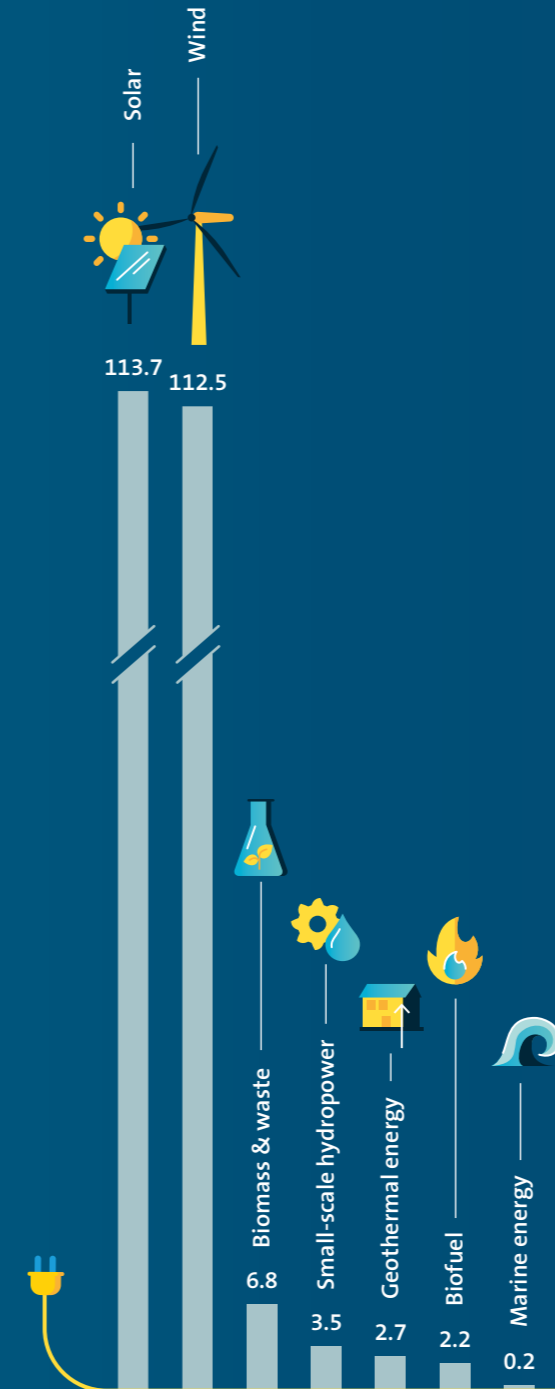
Source: International Energy Agency (IEA)

## WHICH GLOBAL REGION CONSUMES WHAT SOURCES OF ENERGY?



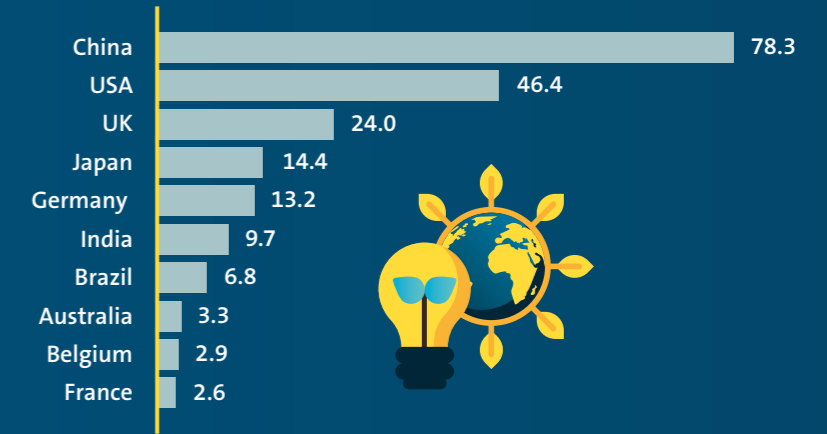
Source: BP Statistical Review of World Energy June 2017

## WHAT INVESTMENTS WERE MADE IN RENEWABLE ENERGY TECHNOLOGIES IN 2016? in billions of US dollars



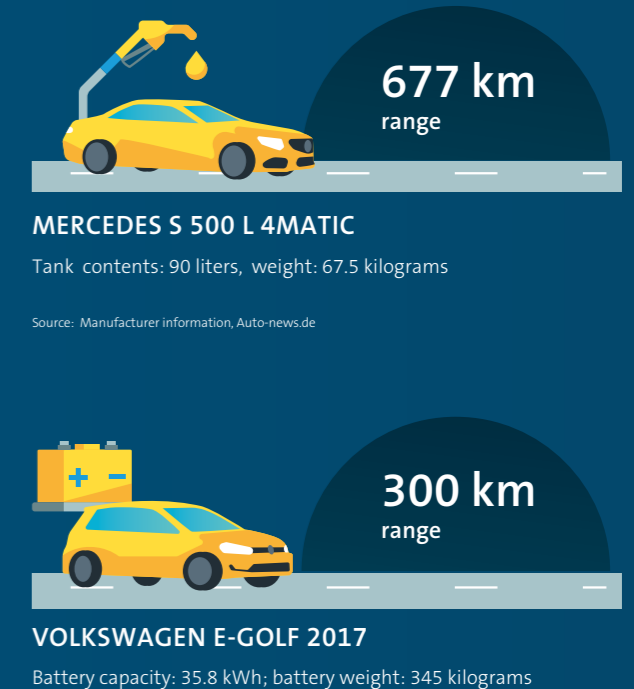
Source: Bloomberg New Energy Finance, via Statista

## WHAT COUNTRIES INVESTED THE MOST IN RENEWABLE ENERGY IN 2016? in billions of US dollars



Source: BP Statistical Review of World Energy June 2017

## COMPARISON OF THE ENERGY DENSITIES OF GASOLINE AND BATTERY POWER



Source: Manufacturer information





## AROUND THE CLOCK

Solar energy is booming. But photovoltaic systems are too dependent on the time of day and the weather to provide a constant energy supply. On the other hand, solar thermal power stations in desert regions provide electricity around the clock.

It usually happens in February in Lisbon, in March in Berlin and in April in Oslo. On the first beautiful day of spring, people rush out and sit down at hurriedly cleared tables in cafes. “The sun’s energy is finally back.” The very thought makes you happy – even if it is not true from the standpoint of physical science. The sun continually provides the same amount of energy. The solar constant is exactly 1,367 kilowatts per square meter – at every point in the earth’s atmosphere, in winter as well as summer. It is the duration of the solar radiation – that is, the length of the day – that changes with the time of year. So does the distance that solar radiation has to travel through the atmosphere to reach the earth’s surface. If the distance is long because the sun barely climbs above the horizon, some of the radiated energy is lost. Even when the sky is cloudless, molecules and suspended particles absorb and reflect some of the photons. And if thick clouds roll in, only a fraction of the energy arrives. The global daily average is 165 watts per square meter. But according to calculations made by the United Nations, even this remnant is 9,000 times humanity’s total energy needs.

Even back in 1905, Albert Einstein was predicting that electricity could be produced from light through the use of semiconductors. It was the theoretical birth of the photovoltaic cell. But suggestions that solar energy could have an economic use were long considered utopian. That changed with the rapid technological progress over the past twenty years and the collapse of solar cell prices. The International Energy Agency assumes that photovoltaic systems with a capacity of about 740 gigawatts will be installed worldwide by 2022. But a basic problem with photovoltaics remains: Only the solar energy that actually reaches the earth’s surface can be “harvested” – and it fluctuates with the time of day and the season of the year. An initial, relatively simple solution uses equipment that tracks the sun. That’s because the yield of a solar cell is typically the highest when sunlight hits the cell surface at a right angle – that is, at noon. To increase the yield in the morning and the afternoon, the entire solar module can follow the course of the sun using

a hydraulic linear track. But this type of power plant can only provide energy around the clock if it buffers the electricity generated during the day in very large and expensive battery storage units.

Back in the 1970s, it was mainly German and U.S. researchers who were working on an alternative to photovoltaics – solar thermal power stations. At their core, they were based on the same idea as the showers used in some garden plots that lack electricity. During the day, solar radiation lands on a container and heats the water inside. To produce electricity with a power station based on this principle, the approach has to be modified somewhat. Instead of a shower head, a steam turbine is used to drive a generator. And instead of water, oil with a high heat capacity is used. The oil passes the energy on using a heat exchanger. The sunlight has to be focused to bring the oil to a high temperature. This can take place in two ways: Either the light is directed by long parabolic mirrors, or numerous mirrors are set up in a large area to capture and reflect it at a single point. The oil flows through that spot. It must be elevated high off the ground in a specially constructed tower. Both types of facilities have been tested, and the parabolic mirror system is the more mature technology. The mirrors are always adjusted to achieve the maximum burning-lens effect. For example, the Spanish mechanical engineering company Hine Renovables provides hydraulics for this approach and has equipped 38 solar thermal power stations worldwide. The company has been one of Freudenberg Sealing Technologies’ customers since 2017.

Compared to photovoltaics, solar thermal power plants are still grappling with a small market. According to the “Ren 21” network, just 4.8 gigawatts had been installed by the end of 2016. “Still, there are great opportunities for this technology,” said Andoni Zozaya, who is in charge of Freudenberg Sealing Technologies sales in Spain, a hotbed of solar technology. “Due to their base load capability, more and more countries are promoting the construction of solar thermal power stations.” For example, the 580-megawatt Noor power plant is being built in Morocco. The first section of the facility – which ESSENTIAL will report on in its November edition – has been in operation since 2016. Its location at Ouarzazate, about 200 kilometers (125 miles) southeast of Marrakesh, was selected advisedly: With few exceptions, the sun shines 365 days a year there. ©

### ELECTRICITY FROM THE DESERT

In Ouarzazate, 200 kilometers (125 miles) from Marrakesh, the sun shines nearly 365 days a year.





# TRANSPORTING ELECTRICITY – THE ENVIRONMENTALLY- FRIENDLY WAY

In the future, massive quantities of electricity will have to be transported over long distances. But a gas 22,800 times as harmful to the climate as CO<sub>2</sub> is used as an insulator in the switching systems of local distributor and transformer stations. Now engineers are testing alternatives – using gases that put especially high demands on seals.

At first glance, the plan for a climate-neutral future seems simple. But electricity from wind turbines, solar facilities and hydropower cannot always be generated near consumers. So it is transported via high-performance grids and becomes an energy source for the transportation and heating sectors. To keep energy losses low, the electric current must flow through the grid at the highest possible voltage, which has to be transformed several times in the process. Electrical circuits in the switching system are switched on and off to control the grid.

## PROTECTIVE GAS PREVENTS FLASHOVERS

With the grid's expansion, the number of these facilities is growing in urban areas that have little space available. To make the switching systems in the local distributor and transformer stations as compact as possible, the switches for high and medium voltages are encapsulated in a gas-tight arrangement. When a switch opens up and the metal contacts move apart, a special gas inside the switch en-

sures that the charge separation occurs quickly and that there is no flashover in the form of an arc. And if a flashover were to occur, the gas would extinguish the arc so the switch could function safely. Sulfur hexafluoride (SF<sub>6</sub>) is one protective gas that meets these requirements well. It is fed into the switch at high pressure and features a very high dielectric strength when used as an insulation material – as a compressed gas, it can separate one electric charge from another reliably even under high voltage. It also extinguishes any potential electric

arc immediately. An SF<sub>6</sub>-molecule consists of one sulfur atom and six fluorine atoms and is relatively large. Even that is an advantage since the molecule is not inclined to migrate through rubber – and therefore through the O-rings and special seals that, for example, seal the passage of the power lines through a switch housing. Freudenberg Sealing Technologies has developed seals that coexist with the protective gas in switches for many years. It is only when the gas pressure in the switch falls below a certain level that the SF<sub>6</sub> has to be replenished during maintenance.

But this protective gas has a major disadvantage. It is more damaging to the climate than CO<sub>2</sub> by a factor of 22,800. Experts call this capacity to damage the environment the global warming potential (GWP). Even if the gas takes a while to migrate through the sealing material, it will arrive in the atmosphere sooner or later. In 2014, in legislation to reduce fluorinated greenhouse gases, the EU began gradually limiting the available quantities of gases such as SF<sub>6</sub>, encourag-

ing the search for alternatives. Meanwhile, a handful of potential materials have been identified that are all based on CO<sub>2</sub> and, in some cases, are enriched with other ingredients. They are far more climate-friendly but have a major disadvantage: They migrate much more easily through sealing materials. "It is like a balloon," said Dr. Robert Rotzoll, material developer at Freudenberg Sealing Technologies. "At first, it is filled to bursting, but over time the air or the helium escapes through the rubber surface."

## SEALS FACE NEW CHALLENGES

That defined the job for Freudenberg Sealing Technologies' material developers. "The trick was to design a material that did a balancing act among all the requirements," Rotzoll said. In this case, it mainly involved the least possible permeation within a maximum temperature window range, from -50 °C (-58 °F) to more than 100 °C (212 °F). That was because the

switching systems were supposed to be suited for cold regions such as Scandinavia and Siberia as well as warmer ones. In addition, the sealing material had to have a long lifespan and be resistant to aggressive media such as oxygen and ozone that act on the seal from its exterior.

After several years of development work, Rotzoll and his colleagues have now identified two materials that meet the higher standards for permeation, without having to accept declines in temperature resistance. One material was based on EPDM, and the second is synthetic rubber based on chlorobutyl (CIIR), which stands out for its low permeability to gases and liquids and is used in the tire industry and other sectors. "The development of the new O-rings for climate-friendly alternative gases is complete, and we have already installed seals based on chlorobutyl in prototype switches," Rotzoll said. "Now it is a matter of jointly testing them with our customers." If the tests succeed, it will be possible to transport electricity from renewable sources in an even more climate-friendly way. ©

## ELECTRICITY FROM RENEWABLE ENERGY

Has to flow under maximum voltage through a high-performance grid and must be transformed in electrical substations.







## MORE THAN HOT AIR

Natural gas is considered a climate-friendly alternative to coal as a fuel for power plants and a complement to renewable energy. Nonetheless, it still plays a secondary role in the energy mix. Why is this the case?



The feat was achieved on May 11, 2011: The Technical Inspection Association (TÜV) certified a world record for the newly constructed Block 4 of the Irsching natural gas power plant on the Danube. In combination with downstream steam turbines, its powerful gas turbine transformed more than 60 percent of its primary energy into electric current. It was state-of-the-art technology, ready for export to the world. Just a few years later, the operator – Uniper AG, a spinoff from the E.ON Group – was battling to shut down the entire power plant. Its turbines, which had been functioning flawlessly, were up and running, but millions in losses were piling up. But regulators refused to let the power plant be disconnected from the grid. As part of the so-called “cold reserve,” it is supposed to remain operational to ensure the stability of the grid when the last nuclear power plants are decommissioned in southern Germany at the start of the next decade. On the other hand, bituminous coal power plants continue to be connected to the grid and produce more than 22 percent of Germany’s electric power. And with every kilowatt hour, they produce twice the carbon dioxide of a natural gas power plant.

Even as Irsching was being expanded, the advanced thinkers of the energy transition were extolling natural gas as the ideal complement to energy generation based on unpredictable solar and wind power. In 2007, Peter Hennicke und Manfred Fishedick, the heads of the renowned Wuppertal Institute for Climate, Environment and Energy, submitted a simple master plan saying that Germany should trim its energy use by 15 percent while producing 50 percent of its electricity from renewable sources and 35 percent from natural gas. The plan was designed to reduce CO<sub>2</sub> emissions by 85 percent. In fact, the energy industry and especially the municipal plants put their faith in newly built natural gas power plants. In 2016, Düsseldorf beat Bavaria’s world record with its “Fortuna” block. Even on purely economic grounds, it seemed sensible to bet on natural gas. Gas turbines can react more flexibly to fluctuating demand than coal-burning facilities for a simple reason: A large portion of the energy driving the electric generators comes directly from combustion – and not from the lagging response of steam processes.

If you want to understand why coal generates three times as much electricity as natural gas, you have to look at who decides when and where electricity is generated in Germany in

the first place – and who has priority. This is mainly the four transmission system operators. They are responsible for maintaining a stable grid in their particular areas. That is no easy task since supply and demand must always be kept at the same level. Even slight deviations lead to changes in the frequency of the alternating current, which in Germany is 50 Hertz. If it stays out of balance, the entire grid crashes within seconds. Previously, when only a few power plants fed electric current into the network, it was easier to maintain the ideal frequency. But in 2017, 1 kilowatt hour in three was already coming from renewable sources. The transmission network operators see this as a disadvantage since green electricity always has priority on the grid, yet the amount of electricity actually produced depends heavily on the weather. Sophisticated predictive models are supposed to make the calculation easier. In the end, however, only continual corrections help.

### “MERIT ORDER” PUTS MODERN GAS POWER PLANTS AT A DISADVANTAGE

A legally defined process – the so-called “merit order” – determines the method of buying additional electricity that is not generated renewably. It basically says that the electricity is to be sourced from the providers that are the most economical. If several producers offer capacity, then each provider takes its turn starting with the least expensive offer. The process continues until the demand is completely met. Although this definitely benefits electric power consumers, the process puts state-of-the-art natural gas plants at a disadvantage. Their production costs are significantly higher than those at depreciated coal power plants.

Energy policy-makers had long thought the disadvantage could be offset with the trade in CO<sub>2</sub> emissions rights. Since the operators of fossil fuel power plants had to use up an allowance certificate or buy one on an exchange, the costs of climate change would be internalized. At least that was the thinking. But the European Union, which is responsible for allowance certificates, miscalculated. The great success of renewable energy led to a collapse in certificate prices – they fell to less than 5 euros for the right to emit 1 ton of CO<sub>2</sub>. The EU has meanwhile reformed the trading system and tightened the supply of certificates. Critics say that’s not enough. But at least the price on the exchange was back in the two-digit range as of early March. Experts now say that electricity from natural gas could exceed the output from bituminous coal for the first time in 2018. ©

STATE-OF-THE-ART TECHNOLOGY  
Powerful turbines transform primary  
energy into electricity.





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# THE POWER OF TIDES

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Today hydropower is more than just generating electricity at reservoirs or buffering electric energy in pumped storage plants. Tidal power stations are now on the way to commercialization as well. The current turbines on the seafloor exploit the power of tides by capturing the water's kinetic energy.

**HYDROPOWER**  
They look a bit like sea snakes. These structures, which can be up to 150 meters (490 feet) long, use the ocean's wave movements to generate energy.



The sun is almost always the source of our renewable energy. Silicon cells in photovoltaic facilities transform sunlight directly into electric current. Solar thermal processes use the energy of the sun to heat up water. Wind is generated by the sun as land masses and oceans warm unevenly and by the earth's rotation. Over the past few years, however, the moon has turned out to be a source of renewable energy as well. In fact, thanks to its gravitational pull, the moon is a main cause of tides — as is the sun. Tidal power stations use the kinetic energy of seawater captured with underwater rotors like those of a wind turbine, and transform the rotational movement into electric energy. Due to their regularity, tides are ideal for planning purposes — you can set your watch by their ebb and flow. That means electric power generation can be reliably forecast — unlike nearly all the other forms of renewable energy, which are heavily dependent on the weather.

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## RENEWABLE ENERGY ON SCHEDULE

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“The biggest advantage of tidal power stations is that we know precisely how much electric current they are producing at any given time,” said Hans van Breugel, CEO of the Dutch turbine manufacturer Tocado. They also provide a base load for electric power generation, which can be valuable to an energy supply system geared to renewables. Since 2008, Tocado has operated an endurance test facility for tidal turbines at Afsluitdijk, north of Amsterdam, Netherlands. It lies at a 32-kilometer-long (20-miles-long) dam that connects northern Holland and Friesland, separating the IJssel Sea from the North Sea. It is an ideal location for

the test, which is initially taking place in just one direction at low water. “Every day, the locks are opened twice so that water from the IJssel Sea can drain,” van Breugel said. Then the water flows at a speed of 3 to 4 meters per second (10 to 13 feet per second) through the turbines that Tocado has installed right at the lock. Tidal power stations manage extremely well at speeds that seem slow only at first glance, as the density of water is about 800 times that of air.

But tides do not flow at the required speed everywhere. As a result, tidal power station developers have to take a close look at the topography of the seafloor to find potential sites. Regional conservation measures must also be taken into account. In 2015, the French turbine manufacturer Sabella installed the country's first sea current turbine at a depth of 55 meters (180 feet) in a strait between two Breton islands. In Europe, about 48 terawatt hours could be generated annually in the short term — the equivalent of 15 typical blocks of a coal-burning power plant. By 2050, an association, “Ocean Energy Europe,” expects to see an installed capacity of 100 gigawatts, which it says could cover up to 10 percent of Europe's need for electricity. Tidal power stations also offer great potential at sites outside Europe, for example, off Canada's Atlantic coast, around the islands of Indonesia and the Philippines between the Atlantic and Indian oceans, and off the coast of China.

The world's largest tidal power station, the “MeyGen” project, is being developed between the Atlantic Ocean and the North Sea off the coast of northern Scotland. In 2017, the Scottish project developer and operator Atlantis Resources installed four tidal turbines on the sea-

floor in the strait known as the “Pentland Firth” between the Orkney Islands and the mainland as a first step. Each has an output of 1.5 megawatts. The roughly 11-meter-long (36-feet-long) gondolas stand on special tube foundations at a depth of 30 meters (98 feet) and are connected to three rotor blades at a hub. The blades have a diameter of 18 meters (59 feet) and rotate at a speed of 14 rpm. Since the tidal flow naturally switches directions, the angles of the individual rotor blades can be adjusted. The gondola can also be oriented to the flow. Freudenberg Sealing Technologies participated in the development of a special sealing system to seal off the individual mechanical elements from the aggressive saltwater — at a water pressure of about 3 bar at the height of the hub. Since its installation, the pilot facility has provided a wealth of technical data, and Atlantis Resources intends to develop four other turbines with increased performance. A third installation with 49 turbines is planned for 2019. By 2022, 269 turbines off the Scottish coast are expected to have a total capacity of about 400 megawatts and provide electricity to about 175,000 households.

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## RELIABLE COMPONENTS ARE INDISPENSABLE

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“Dependability is the most important aspect in the operation of tidal power stations, and it requires a technical solution that is as straightforward and well-engineered as possible,” said Fraser Johnson, who is in charge of operations and maintenance on the MeyGen project. The effort begins even before the deployment of the turbines. “The most attractive sites for tidal energy are those

with a strong tidal range,” Johnson said. “At these locations, the time frames for installation are accordingly short at low water.” Atlantis Resources recently succeeded in securely positioning its AR1500 model turbine on the seafloor in just 35 minutes. After the installations, Johnson and his team monitor the turbines' condition daily so they can detect any problems early. “We've also configured some of the systems redundantly if they are especially critical for operations,” he said. The next step is expected to be marketing the electricity — after all, Scotland wants to generate all its electricity from renewable sources by 2020. Electricity from tidal power stations is

not yet competitive. “The biggest challenge is for the electricity to find a sure path into the market,” Johnson said.

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## WAVE POWER STATIONS IN TESTING

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Wave power stations are even further away from commercialization. The prototypes tested so far don't use tidal flows — they depend on the continual rise and fall of waves to produce electrical energy. Wave power stations based on the principle of oscillating water columns use pneumatic chambers equipped with

tubes. The waves alternately compress or suck the air inside the system. The resulting stream of air drives a turbine that produces electricity with a generator. Snake-like floating elements with hydraulic cylinders in their joints offer another option. The movement of the waves forces the hydraulic fluid into a leveling cylinder, driving a turbine. A 150-meter-long (490-feet-long) structure dubbed “Pelamis” (Greek for sea snake), from a Scottish company of the same name, achieved a rated output of 750 kilowatts a few years ago. Unlike tidal power stations, there has been no breakthrough for the technology so far. It is never an easy matter to tap the energy of the ocean. ©

### TIDAL ENERGY

In the MeyGen project, tidal turbines each produce 1.5 megawatts at a depth of 30 meters (98 feet).







**SOLAR POWER**  
A solar power plant is being constructed in Datong, 300 kilometers (186 miles) west of Beijing. It has been set up in the shape of pandas.



# FAREWELL TO COAL

China has launched its energy transition – a Herculean task given the size of the country. But it has the political will to follow through. The first step is bidding farewell to coal and substituting alternatives such as natural gas. China is also investing billions to expand its wind, solar and hydropower sectors while spending heavily to promote electric mobility.



Dense air hangs over the city. In the neon-yellow West, police are stopping one small truck after another on the freeway. Beijing has invoked its second-highest alarm level – orange – which is why the police are carefully selecting who may enter the city. Delivery vehicles from online stores, moving vans and small open trucks are sitting forlorn on the shoulder. Construction work and painting are now prohibited. It is the first smog alert of the winter, even though it is already early March.

The air over the Chinese capital has definitely improved since the country began

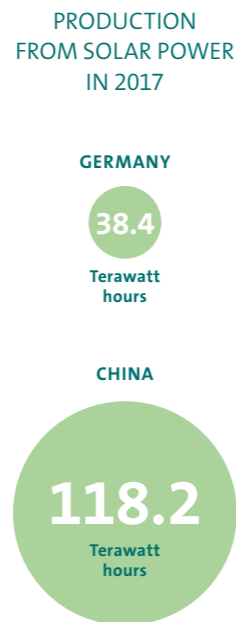
its comprehensive energy transition a few years ago. The air pollution in Beijing and many other metropolises was the main reason for the initiative. China is also feeling the effects of climate change. For example, the droughts in the country's arid north are becoming more frequent. China is indeed the world's top emitter of greenhouse gases and coal still dominates the energy and electric-power mix. But the country has meanwhile become the world's largest investor in renewable energy. In many cities, residents protested against the dirty air. But the government and other authorities mostly drove the change – with goals, rules and subsidies.

**2017**  
No country generated more solar energy than **CHINA** during that year.

In 2017, **CHINA** generated **1,7** BILLION KILOWATT HOURS of electricity from renewable sources.



China's installed renewable energy capacity stood at 650 gigawatts at the end of 2017, according to the National Energy Administration (NEA). For all of 2017, renewables generated 1.7 billion kilowatt hours of electricity, NEA Vice Director Liu Baohua said. Hydropower accounts for the lion's share of the electricity generated, but it has been controversial due to its effects on the environment along rivers. But wind power and solar facilities are catching up. In 2017, China was the top country for solar power generation with 118.2 terawatt hours. By comparison, Germany produced 38.4 terawatt hours with photovoltaic facilities during the same year.



### GLOBAL LEADER IN THE CONSTRUCTION OF FACILITIES

In 2014, China agreed to start reducing gases harmful to the climate by 2030 at the latest, clearing the way for the Paris climate accord. By 2020, the government intends to increase the share of non-fossil sources in its energy mix to 15 percent. In China, the non-fossil category includes nuclear power as well as renewables, although in absolute terms the role of nuclear energy is minor. By 2030, the figure should rise to 20 percent; it was already 13.3 percent at the end of 2016. The five-year plan ending in 2020 also calls for the energy intensity per unit of economic output to decline by 15 percent. These massive efforts now stand out at the global level. In 2016, China alone accounted for 40 percent of the world's growth in renewable energy, the International Energy Agency (IEA) said in its "Renewables 2017" report.



In early 2017, the NEA announced that China would invest another 2.5 trillion yuan (nearly 320 billion euros) by 2020. About 1 trillion yuan is intended for solar energy, with about 700 billion yuan for windfarms and 500 billion for hydropower. The NEA is also backing tidal power stations, geothermal projects and other new energy sources. In this way, the wind, solar and hydropower sectors are expected to cover about half of the country's generation of electricity in 2020, based on the government's plans. Greenpeace East Asia now puts the figure at 26 percent. In China, the environmental organization mainly has an advisory role and does research. "The goals for 2020 had already been achieved for solar and wind power, so the government has raised them," said Huang Wei, who handles coal and energy issues for Greenpeace in Beijing. He said the goals were increased from 110 to 213 gigawatts of installed capacity for solar facilities and from 210 to 264 gigawatts for wind energy.

### CONVERSION TO MODERN GAS HEATING

A shift away from coal is the core of the energy transition, even though the country is temporarily turning to other fossil fuels that damage the climate less. "Peak annual coal consumption was reached in 2013," Huang said. By 2020, its share in the energy mix should drop from 60 to less than 58 percent. So far, it is mainly the use of coal for heating purposes that has been reduced. North of the Yangtze River, the coal furnaces commonly used in many households are being converted to modern gas boilers. The conversion is already complete in Beijing, which had ranked among the country's cities with the worst smog. The scope of the initiative has now expanded. "This winter, coal furnaces were shut down everywhere," said Niu Haiyan, who

comes from a small town in Hebei province, which surrounds Beijing, and works in the capital. "All of a sudden, there were gas lines in every village. It happened unbelievably quickly." More than 3 million households near Beijing were converted this winter, Huang said. At the same time, difficulties with the gas supply developed, leaving some households temporarily without heat. But now there is a comprehensive plan for reorganizing north China's heating systems. "The initiatives include measures to improve building insulation and support individual solar heating systems," Huang said.

### GRIDS MOVE INTO SPOTLIGHT

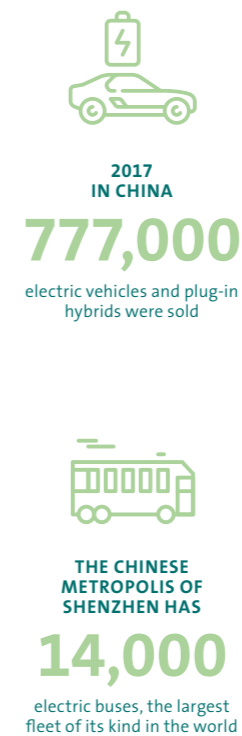
But if the energy mix for electricity is solely considered, the share of coal is still around 70 percent. But that is due to change. The NEA has canceled plans to construct 85 new coal-fueled power plants. Beijing has already shut down all four of its coal-burning plants in the urban district. With the energy transition, the grid is getting attention at just the right time. For example, renewable electricity is mainly being generated on the high plains of western China, but the demand is in the metropolitan areas on the coast. The renewables are competing with coal-generated electricity on China's grids. The result: The networks are distributing too little green electricity, and large portions of the electricity that can be generated remains unused. Up to 40 percent of the country's wind energy is produced in the autonomous region of Xinjiang in China's far west. "The government wants to scale this waste back to a reasonable level within three years," Liu Baohua of the NEA said. The more ecological the energy mix for electricity, the more electric mobility – which China has generously supported – improves its climate balance sheet. Electric cars are

### CHINA'S PLANNED INVESTMENTS IN RENEWABLE ENERGY



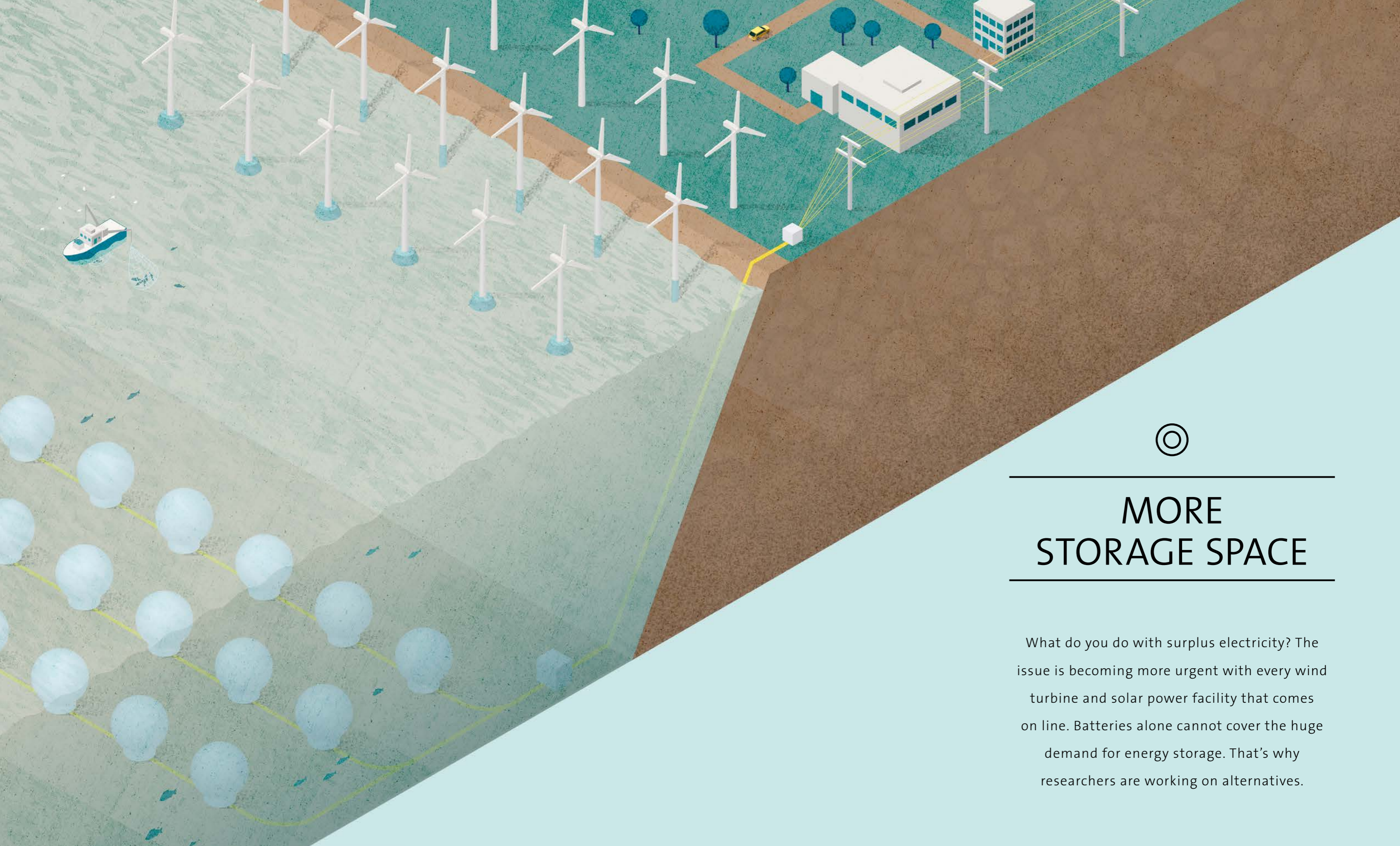
mainly supposed to alleviate the smog in the cities. But there are two other reasons why China is betting on electric mobility: The country needs much more oil than it can produce itself and it wants to reduce its dependence on oil imports. Beijing is also striving to give its companies a global technological edge in electric vehicles. Based on the government's plans, one out of every five cars in China should be an electric model by 2025. The government subsidizes the purchases of electric cars and has released them from the registration limitations in force in many large cities. Beginning in 2019, all automakers have to sell a minimum quota of electric vehicles: 10 percent of sales in 2019 and 12 percent starting in 2020. Thanks to these incentives and rules, China has already become the world's largest market for electric vehicles. In 2017, about 777,000 all-electric vehicles and plug-in hybrids were sold in the country. That was 53 percent more than during the previous year.

### BOOM OF "NEW ENERGY VEHICLES"



About 14,000 electric buses are among the so-called "new energy vehicles." The Chinese city of Shenzhen, a metropolis with 12.5 million people lying just north of Hong Kong, has been buying them over the past two years. By the end of 2017, the city had converted its entire bus fleet and now has the world's largest fleet of electric buses. That means the next smog alert will be a longer way off – and hopefully a thing of the past someday. ©





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## MORE STORAGE SPACE

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What do you do with surplus electricity? The issue is becoming more urgent with every wind turbine and solar power facility that comes on line. Batteries alone cannot cover the huge demand for energy storage. That's why researchers are working on alternatives.





The first salvage attempt went awry. The 20-ton concrete sphere was stuck in the muddy floor of Lake Constance, at a depth of 100 meters (328 feet). Researchers from the Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) had sunk the three-meter sphere (10 feet sphere) so they could test a new pump storage concept. The goal of the pilot project was to show whether electric energy could be stored underwater using hollow concrete objects. But the sphere apparently did not want to give up its secrets. The researchers' ship was not buoyant enough to raise the load. In fact, the concrete sphere threatened to drag the vessel down. "We had to cancel the maneuver," said Matthias Puchta, who heads the energy storage department at Fraunhofer IEE. Even though the effort was only a salvage operation, he sees it as validation of the project's value. "This is precisely why we need these kinds of projects. No matter how thoroughly you think things through at your desk, you still have to do real-life testing."

### PILOT TEST IN LAKE CONSTANCE

Three months later, in March 2017, the salvage operation succeeded – this time with a bigger ship. As part of the "Stored Energy in the Sea" project sponsored by the German Federal Ministry for Economic Affairs and Energy, researchers are investigating the feasibility of offshore pump storage systems that one day could temporarily store large quantities of wind energy. The first trials were designed for a lake on a 1:10 scale. The principle: A hollow concrete sphere is submerged to a great depth. This allows the sea to serve as an upper storage reservoir while the concrete sphere – initially filled with seawater – serves as a lower reservoir. If surplus wind energy is available, water is pumped out of the hollow body with the help of a pump turbine unit attached to the top of the sphere. If the sphere is empty, the energy storage system is considered fully charged from an energy standpoint. Conversely, if electricity is needed, a valve opens up and water streams back into the sphere, driving a turbine. It in turn drives a generator that produces electric current. The storage capacity increases as the water pressure rises, so the spheres should be placed at the greatest possible depth. "With the test, we were not only able to demonstrate the principle's feasibility – we were able to clarify whether a pressure compensation line would be needed." The use of a line would make the implementation at sea much more difficult: It would have to rise to the surface like a snorkel to feed or release air during the pumping. "But the

pump was able to get along fine with strictly defined pressure ratios," Puchta said. As a result, pressure compensation measures are not envisioned in the tests to come.

### POWER STATION MADE OF 120 SPHERES

The next step is a pilot test at a 1:3 scale, with a concrete sphere 10 meters (33 feet) in diameter. But the researchers are ultimately setting their sights on huge spherical storage systems 30 meters (98 feet) in diameter and weighing 20,000 tons. They would lie at a depth of 600 to 800 meters (1,970 to 2,620 feet). "That would give us a storage capacity of 20 megawatt hours per sphere and an output of 5 megawatts," Puchta said. A concrete sphere could temporarily store the energy from one of today's offshore wind turbines with an output of 6 megawatts operating at nearly full power for nearly four hours. The researchers are not planning to deploy individual spherical storage devices – they envision entire pump storage power plants in the ocean, with up to 120 separate spheres. They have identified potential sites near the coast and at ample depths, for example, off the coasts of Norway, Spain, Japan and the United States.

But it will be a while before the first storage plants of this type connect to the grid. Still, any energy concept completely based on renewables such as wind, solar and hydropower cannot do without storage – the supply of energy fluctuates too much. And the electrical storage devices that we mainly use today – rechargeable batteries – are pressing against their limits. There are certainly supply systems with wind turbines, solar power facilities and battery storage in use on a small scale today. For example, the system developer Younicos, based in Germany's capital city Berlin, has installed self-sufficient grids on Kodiak Island in Alaska and Graciosa in the Azores. But Graciosa has just 4,000 inhabitants, and the battery system housed in a medium-sized building has a storage capacity of just 3.2 megawatt hours, or only about one-sixth that of a concrete sphere. As a storage solution for electric grids, batteries are not scalable to the level of the global demand – apart from the fact that they are needed elsewhere, such as in cars.

But batteries still have a role in the energy supply systems of the future. "Batteries compensate for frequency fluctuations within milliseconds and help to maintain voltage," said Philip Hiersemenzel, an expert on energy storage at Younicos. "So, in combination with intelligent software, they are superbly suited to the task of keeping the network stable in a smart grid." That is the main purpose of battery storage power stations. There are already 300 of them in the U.S., and more than 40 in Germany. The world's largest battery storage system, which has 129 megawatt hours of capacity, was set up at Hornsdale, an Australian wind park. But it is primarily used to stabilize the network for a brown coal power plant in the neighboring state of Victoria.

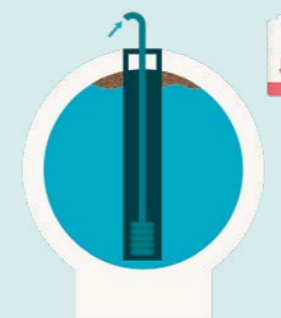
Alternatives are needed to store renewable energy in large quantities. One of them is the start-up Lumenion, which Hiersemenzel handles on the side. The idea is for surplus electricity to be used to heat huge steel elements to about 600 °C (1,112 °F). A dozen of these high-temperature storage modules forms a storage block, and ten storage blocks form a system with one gigawatt hour of capacity and an electric charging capacity of 100 megawatts. To release the energy, a block-type power station can be supplied with a thermal discharge capacity of 24 megawatts. The heat drives a steam turbine, converting the energy back into electric current: Temperature levels of 80 to 120 °C (176 to 248 °F) can also be used for hot water and heating.

"For the next heating season, we are launching a pilot product in Reinickendorf district of Germany's capital city Berlin," Hiersemenzel said. "An exciting aspect is that renewable energy can be moved into the storage modules very quickly and in large quantities." Based on his calculations, the costs are lower than those of a conventional battery by a factor of ten.

### SUBTERRANEAN SALT CAVERNS

There are many other approaches. For example, the Northern Germany based energy company EWE wants to use large underground salt caverns to store energy in so-called redox flow batteries – in electrolyte fluids consisting of saltwater and dissolved recyclable polymers. But that too is a long way off. But for the energy storage of the future to be ready at the right time, they have to be researched and tested now. ©

STORAGE FULL



STORAGE EMPTY



### WORLD IN REVERSE

When the pump storage is empty, it is loaded from an energy standpoint.

When it is opened, seawater rushes in and drives a turbine, producing electricity.





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# GIANTS ON THE HIGH SEAS

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Ever-larger wind power stations are being developed out on the ocean, with rotor diameters now reaching 167 meters (548 feet). There is a good reason for this trend: Larger facilities are more economical and less dependent on subsidies. But the enormous loads place tremendous demands on systems and their components.





The view from the gondola at the dizzying height of 120 meters (390 feet) extends far across the flat terrain, where coniferous forests alternate with snow-covered fields. Heavily layered clouds move rapidly along the horizon and highlight the most important feature that characterizes the small village of Østerild in north-western Denmark for many guests: Strong winds normally blow on this elongated peninsula between the North Sea and Limfjord – almost as much as on the open sea. That’s why the Department of Wind Energy at the Technical University of Denmark at Lyngby established the National Test Center for Large Wind Turbines six years ago. Since then, manufacturers such as GE Wind Energy, Vestas Wind Systems and Siemens Gamesa have been testing new offshore facilities here. From Østerild, engineers



With the extension of the rotor blades to **267 FEET** there is an increase of about **20%** in annual electricity production

and visitors can take a close look at a trend shaping the market for wind turbines: They are expanding in size to achieve greater energy yields and become more efficient for their operators.

The current record-holder at the test site is a system from Siemens Gamesa with a rated capacity of 8 megawatts. It succeeds an earlier 7-megawatt prototype with a rotor diameter of 154 meters (505 feet). By extending the new facility’s individual

rotor blades to 81.4 meters (267 feet), the designers increased their coated rotor surface – and thus the annual production of electricity – by about 20 percent. The rotor blades, which are attached to the hub of a direct-drive, gearless turbine, create a rotor with a total diameter of 167 meters (548 feet). “Larger turbines and larger wind parks allow greater efficiency for operators,” said Stephan Buller, Portfolio Manager for Offshore Turbines at Siemens Gamesa. “This is because components can be better utilized in relation to energy inputs or eliminated in many instances – for example, fewer foundations, fewer towers and less infrastructure such as connecting cables.” The costs of service and maintenance are



Offshore wind power generation grew considerably through the end of 2017, reaching nearly **16,000 MW** An increase of 25 percent over the previous year.

also lower for larger systems in terms of the kilowatt hours produced. Another advantage is that tried-and-tested technology from 6-megawatt facilities is largely used in the new systems. Components such as rotors, inverters and bearings are certainly larger, but the facility’s basic architecture is unchanged. Greater efficiency is the top priority in the wind energy market since public subsidies are being scaled back in many countries and the facilities increasingly have to support themselves. For example, fixed subsidies, which differentiated between onshore and offshore facilities, were paid out in Germany until the end of 2016. The initial payments for offshore facilities were 15.4 cents per kilowatt hour. But under the last amendment to the country’s Renewable Energy Law (EEG 2017), offshore projects going into operation in 2021 or later must apply for a subsidy in a bid process. In an auction in April 2017, the bidders were given the green light if they asked for subsidies between zero and 6 cents. The average bid amount was just 0.44 cents per kilowatt hour.

On one hand, the operators of offshore wind parks can offset the lower subsidy levels with the economies of scale from larger turbines and systems. They are also betting that the technology – which is now produced in high volumes – has survived its growing pains.

For example, in Europe alone in 2017, Siemens Gamesa installed about 450 offshore wind power facilities with a total output of 2400 megawatts. About ten years ago, the German-Spanish manufacturer turned to permanently excited synchronous generators. Instead of conventional drivetrains with a gearbox, they have a direct-driven generator mounted behind the rotor. The generator’s outer ring, which is equipped with permanent magnets, rotates at the speed of the rotor around the inner ring, which functions as a stator. This makes it possible to do without a conventional shaft and gearbox. The transformer can thus be housed right in the gondola instead of the tower base, which enables pretests of the entire system in port.

### COSTS FOR OPERATORS DECLINE

The declining cost of installation and maintenance is a key reason why offshore wind energy is seeing high growth rates. Installed capacity in Europe – where about 90 percent of the global offshore wind power is generated – grew strongly in 2017 and reached nearly 16,000 megawatts – a respectable 25 percent increase over the previous year. On the high seas, there are especially good conditions for high energy yields. “For one thing, there is enough space available,” Buller said. “For another, the wind often blows evenly from one direction for several hours, so it often reaches the ideal speed of 10 meters per second (32 feet per second) or more for electricity production.” The expansion will continue in

coming years. For example, Vattenfall has just ordered 72 8-megawatt systems from Siemens Gamesa for Denmark’s Kriegers Flak offshore project. Its installation is due to begin in February 2021. With a total output of about 600 megawatts, it will be the largest offshore wind power facility in the Baltic Sea. Another 41 systems of the same design are due to be built off Denmark’s western coast in the North Sea in 2020 and provide an additional 350 megawatts.

That is 950 megawatts in all, which is enough to power nearly a million households. One 8-megawatt facility alone will cover about 8,000 households. But despite the economies of scale, offshore wind power facilities are not likely to keep growing skyward indefinitely. In March 2018, GE Wind Energy indeed announced a turbine that is expected to have a capacity of 12 megawatts in combination with a direct-drive generator. But the demands on systems and components grow tremendously at the same time. “There is an optimal size for a wind turbine technologically, even if we cannot determine that point with certainty today,” Buller said. “The energy that can be produced with the turbine certainly rises with the increase in rotor surface. But the loads that are exerted on components such as the main bearing or the bearings for the rotor blades grow even more.” The result: At some point, the engineers will have to incorporate a disproportionate amount of material to handle the loads – which would make the system too heavy and too expensive.

### FLYING HIGH

The gondolas of modern wind turbines are positioned significantly higher than 100 meters (330 feet).





The systems in the 8-megawatt class that are now installed put huge demands on individual components such as seals. The job of the seal rings is to keep the lubricant in the main bearing and dirt particles, saltwater and rain out of the interior of the mechanical elements to be protected. “But with the increasing diameters of the torque bearings, the design principle of earlier shaft seal rings is pushing against the limits of scalability,” said Jens Kuhnert, Business Development Manager and wind power expert at Freudenberg Sealing Technologies. In direct-drive wind turbines, like those that Siemens Gamesa has developed, the seals are attached to the outer ring of the main bearing. It in turn rotates around the stator as a rotor along with the seal and the seal lip. Here the sheer size of the seal rings with a diameter of more than 3.5 meters (11.5 feet) is a challenge for the manufacturing process, which uses huge vulcanization presses. Increases in bearing diameters are certain to lead to a flattening of the radial curvature. Since the spring at the seal lip acts radially toward the interior, the contact pressure — which makes it possible for the seal to perform its task reliably — declines as the curve flattens.



the exterior. This gives the developers of wind turbines and their components new freedom of design.

### REMOTE DIAGNOSIS OF WIND PARKS

Furthermore, longevity is an important requirement for all the components of a wind turbine. That’s because operators rely on operating periods of 25 years in their calculations. Based on capital costs, operating costs and the desired rate of return, they compute the so-called levelized cost of electricity, or LCOE, which they compare to the expected yield of electricity. The remote diagnosis of entire wind parks offers still other ways to keep operating costs under control. In these systems, individual wind turbines are equipped with numerous sensors at important points such as bearings or housings; they measure vibrations, temperatures or torque and report the data to a control point on land. For example, Siemens Gamesa operates a remote diagnostic center at its main Danish location in Brande, where the data lines from all the wind turbines come ashore. Conspicuous data patterns are reported to the operators in real time so any forthcoming repairs or maintenance can be planned early. That means it is not just size that makes the giants of the high seas more efficient. ©

“That’s why we’ve developed a new seal ring that contains a meander spring instead of the worm spring used to this point,” Kuhnert said. With this seal — which is called the Seventomatic — a slender, elongated seal lip creates a V-shape with the carrier body. A curved, vulcanized-in profile strip strengthens the seal lip and the body. This makes it possible for the seal to act as a pressure spring. It “presses” onto the running surface on its own, replacing the customary worm spring. In this way, the linear force no longer depends on the curvature, and the seal can do its job extremely well even at higher loads. In addition, the direction of the seal’s force can be varied at will, depending on the design of the turbine. Its spring force can act toward the interior as well as

**GOOD CONDITIONS**  
Out in the ocean, the wind often blows constantly from one direction for several hours, enabling high electricity generation.



Sealing rings with a diameter of more than

**11.5 FEET**

pose a challenge.



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### WELL-SUITED FOR FARM MACHINERY

**With its low-friction sealing products, Freudenberg Sealing Technologies has the right solutions for agriculture, just as it does for other sectors. They help to save fuel, reduce emissions and extend the lifespan of powertrain systems.**

Manufacturers of mobile agricultural equipment increasingly have to cope with demanding environmental regulations, rising fuel prices and long maintenance intervals. These demands can be met with innovative sealing technologies — not least of all because seals in today’s automatic transmissions are responsible for nearly one-quarter of the equipment’s total loss of mechanical energy. The task at hand is to reduce the system friction in the transmissions. Freudenberg Sealing Technologies has the right products — Levitas and Levitorq — to do this. The transmission seal Levitas takes a fundamentally new approach: During operation, it floats on a hydrodynamic oil film that it creates on its own. The film prevents physical contact between the shaft and the seal ring, which reduces friction by up to 70 percent. Levitorq thrust washers also function with a hydrodynamic oil film. A bearing can run or a load can be applied on its surface. Freudenberg Sealing Technologies has developed thermoplastic and thermoset materials for these thrust washers. They replace heavy, torque-reducing thrust washers made of metal, reducing have friction and the weight of the components while improving flatness control. ©



### RESISTANT TO ACTIVE OXYGEN

**A new generation of washing machines is relying on active oxygen to help clean clothing. The advantage: Active oxygen makes it possible to run the machines at a lower temperature, sparing the clothing and the environment.**

The disadvantage: Conventional seals are not resistant to the active oxygen, which is produced by generators within the machine. Within just a few hours, it attacks conventional seals made of nitrile rubber (NBR) so aggressively that cracks form and the seals no longer work. The main seal, which seals the driveshaft at the housing, is especially affected.

Freudenberg Sealing Technologies has developed a sealing material made of fluoro rubber (FKM) that works in harmony with detergents and the lubricants employed so far, and with active oxygen. The new FKM mixture stands out for its improved wear behavior over its entire lifespan. Freudenberg has increased the resistance of the FKM material to the hot water-detergent mixture in the washing drum so it does not swell in water vapor. The geometry of the seal lip was ultimately adjusted so the seals made of the new material would exhibit the same mechanical characteristics as before, for example, when compressed or exposed to radial forces. Freudenberg Sealing Technologies is now preparing for the series production of the main seals in washing machines that use active oxygen. They are a robust solution that requires no additional installation space. ©





## SUPPLY AND DEMAND



GÜNTER KAISER  
Operating technician, Freudenberg Sealing Technologies

Production and consumption must be equalized within seconds on the grid. That's why the demand for electricity needs to become more flexible as variable energy sources such as solar and wind power become more widespread. This flexibility has already arrived at Freudenberg Sealing Technologies' Oberwihl plant in Germany.

The red digits are changing quickly. The operator, Günter Kaiser, takes a close look at the digital dial. The figure is fluctuating between 1,500 and 1,700 kilowatts. "This way, we're on the safe side," he said. He only uses four figures to manage the supply of electricity to Freudenberg Sealing Technologies' Oberwihl plant. It helps to know that electric power consumption in a manufacturing plant normally varies widely, depending on what machines are in operation. If consumption rises suddenly, the energy supplier must generate more electricity on short notice – supply and demand must always be in equilibrium on the grid. Electricity is considerably cheaper if it can be purchased long-term. With all this in mind, Freudenberg Sealing Technologies reached an agreement with the local energy utility: The Oberwihl plant made the commitment to use no more than an average of 1850 kilowatts of electric power per quarter hour. In return, it gets a discount on its electricity. "Over the last two years, we have not exceeded the limit even once, despite the fact that the factory has expanded and production volumes have significantly increased," said Roland Damrath, who is in charge of energy management at Oberwihl.

GOOD BALANCE SHEET  
30 percent more O-rings, 20 percent less electric power consumption.



In 2017, about 830 million O-ring seals were manufactured at the plant, which is located in the southern Black Forest. The seals are employed in everything from electric toothbrushes to luxury watches costing as much as a compact car. In 2014, the figure was 636 million O-rings, and about 20 percent more electricity was consumed to make them back then. The secret behind this major increase in energy productivity can be found in the control cabinet displaying the four red digits. This is where the information on all the factory's electric power consumption comes together. Experts call the approach "energy monitoring." There are 120 smart electric meters mounted in the different production areas; they provide data on actual consumption at 15-minute intervals. Using a computer program, Kaiser can analyze precisely when, where and how much electricity is consumed. Like a cardiologist carefully analyzing the curve of an EKG, Kaiser looks at the trends in energy consumption twice a week. "You can quickly track down outliers – perhaps due to defects – in this way," said Kaiser, a certified electrician.

The energy monitoring system was set up step-by-step after a basic plant reorganization that added 1,000 square meters

(10,700 square feet) of production space. "This was almost a new construction," said Business Unit Manager Angelo Acerboni. "We updated nearly the entire electric system, creating the basis for improved energy management." As they set up the monitoring system, the staff benefited from the experience that Freudenberg's plant in Öhringen, Germany, had gained earlier. But Kaiser and his colleagues were not content to merely observe and cut electric power consumption. They wanted to actively control it. To avoid expensive peak loads, special software forecasts the average output for the current 15-minute interval. If a limit looks as though it is going to be exceeded, certain machines are automatically instructed to take a break – so current manufacturing operations are not impaired. For example, this can be done with the electric furnaces used to heat up the tools that are needed later. The Oberwihl team has identified about 25 installations that it can use to control levels of operation. Energy experts call this process "demand-side management." It is considered a key technology to safeguard energy supplies in a system based on the fluctuating availability of wind and solar power. "I am proud of the fact that we've already gained experience with this," Kaiser said.

**SMALL STEPS,  
GREAT EFFECT**

ROLAND DAMRATH  
Responsible for energy management  
at the Oberwihl plant



But systematic energy management in Oberwihl does not just involve electric power. Over the past few years, all the processes involving cooling and heating were examined. Sometimes it was easy to find real savings – for example, as Acerboni noted, the cooling unit in one hall during the summer was always working at maximum power – still, the temperature never reached the set level of 18 °C (64 °F) due to waste heat from production operations. Now that the target temperature has been increased to a more realistic 23 °C (73 °F), the company has been saving 50,000 euros on electricity per year. Nonetheless, it is cooler in the manufacturing area than before the restructuring. That's because the waste heat produced at the injection molding machines is suctioned away with the air and partly used for other processes with the help of heat exchangers. And with smart heat management, the consumption of heating oil



**HEAT MANAGEMENT**

Depending on the season, the heating oil use at the Oberwihl plant can be cut by up to two-thirds.

has been reduced by up to two-thirds, depending on the time of year. The compressed air supply also deserves close attention. The management of the energy-devouring compressors is now based on demand. Unlike the previous system, just one compressor operates at full load. A second compressor operates variably and ensures that the output actually fits the use. Kaiser programmed the controls himself and built the electrical circuit with trainees' help. The compressed air travels a long way through the factory on its trip to the energy consumer. The lines are checked weekly because every leak from which the compressed air can escape leads to more work for the compressors –

and thus greater electric power consumption. "A small hole that no one notices can cost up to 8,000 euros a year," he said.

But it is not mainly the savings that drive Kaiser. "Every form of electric power generation is associated with an environmental impact that we have to minimize," Kaiser said. In his three-family home, he has long had a mini-combined heat and power unit. So far, the small power station has fed excess electricity back into the grid. In the future, Kaiser plans to charge up the hybrid vehicle that he has already ordered – demand-side management works at home, too. ©

"A SMALL HOLE THAT NO  
ONE NOTICES CAN COST UP  
TO 8,000 EUROS A YEAR."





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# THE WAY OF HYDROGEN

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When couples marry in Korea, they often receive wooden ducks from their relatives. The tight bond attributed to these waterfowl is supposed to rub off on the newlyweds.

This kind of bond can also be found in the realm of elements – between hydrogen and oxygen, for example.

Together they form water and can only be torn apart with great effort and energy. On its own, hydrogen is a volatile character. Under normal conditions, it is a colorless, odorless gaseous molecule consisting of two atoms. It must be stored under high pressure in well-sealed gas tanks or cylinders. It actually only wants one thing: to get back to its beloved oxygen and become water again. As an expression of gratitude, it releases some of the energy expended at its separation.

That is the cycle that people can utilize as they move toward a climate-neutral world.



### STATION 1 WATER

Water is a chemical compound consisting of two elements, hydrogen and oxygen. Each water molecule is made of two hydrogen atoms and one oxygen atom. In nature, water usually contains dissolved quantities of salts, gases and organic compounds. It covers 71 percent of the earth's surface and has a total volume of 1.4 billion cubic kilometers; 3.5 percent of the total is freshwater, which still amounts to 48 million cubic kilometers, the equivalent of a cube 363 kilometers (225 miles) high. Water is basically abundant but unevenly distributed on the planet.

### STATION 2 CLIMATE-NEUTRAL PRODUCTION OF ELECTRICITY

Electric current generated by the wind, the sun or hydropower is made available to consumers and industry. But in certain weather conditions – for example, when there is plenty of wind and sunshine – wind turbines and solar facilities are increasingly producing too much electricity. The more a country expands its renewable facilities to produce electricity, the more often the supply exceeds the demand. Since the surplus electricity travels at nearly the speed of light through the lines as an electromagnetic wave, it has to be used or stored immediately. One possibility: It could be fed into an electrolysis facility to produce hydrogen.

### STATION 3 ELECTROLYSIS FACILITY

In the electrolysis facility, electric current is introduced into water. The application of electrical energy separates it into hydrogen and oxygen. While freshwater is primarily used here, scientists are also working on catalysts for hydrogen electrolysis directly from seawater. Today's facilities use a process in which a membrane that is solely permeable to protons serves as a separator between the anode and the cathode, virtually a fuel cell in reverse. If external voltage is applied, the water breaks down at the anode. The result is oxygen, hydrogen ions and free electrons. The membrane only allows the hydrogen ions through to the cathode, where they encounter free electrons and combine with them to become hydrogen.

### STATION 4 HYDROGEN DISTRIBUTION

To use hydrogen as an energy source in vehicles, it has to be transported from the electrolysis facility to the consumer. Special tank trucks and railway cars are used to store and transport the hydrogen as a pressurized gas. There are also tanks that are cooled to  $-253\text{ }^{\circ}\text{C}$  ( $-423\text{ }^{\circ}\text{F}$ ) so they can carry liquefied hydrogen. But in a largely climate-neutral world, these trains and trucks would have to run on renewable energy or on fuels derived from them. One alternative: transporting the gas over long distances and in large quantities through pipelines, with a relatively low expenditure of energy.

### STATION 6 VEHICLE WITH FUEL CELL

While the fueling processes for fuel cells resemble those for internal combustion engines, the hydrogen is actually powering a true electric vehicle. The gas is converted back to electricity in a fuel cell and then used to feed energy into an entirely normal electric motor. In relation to mass, hydrogen has a greater energy density than any other fuel. That means it can deliver acceptable ranges for buses and trucks. One disadvantage is that hydrogen is very light and its energy density in relation to volume is very low. That's why it has to be highly compressed. Even then, hydrogen tanks take up more space than conventional fuel tanks – but still considerably less than today's lithium ion batteries.

### STATION 5 HYDROGEN FUELING STATION

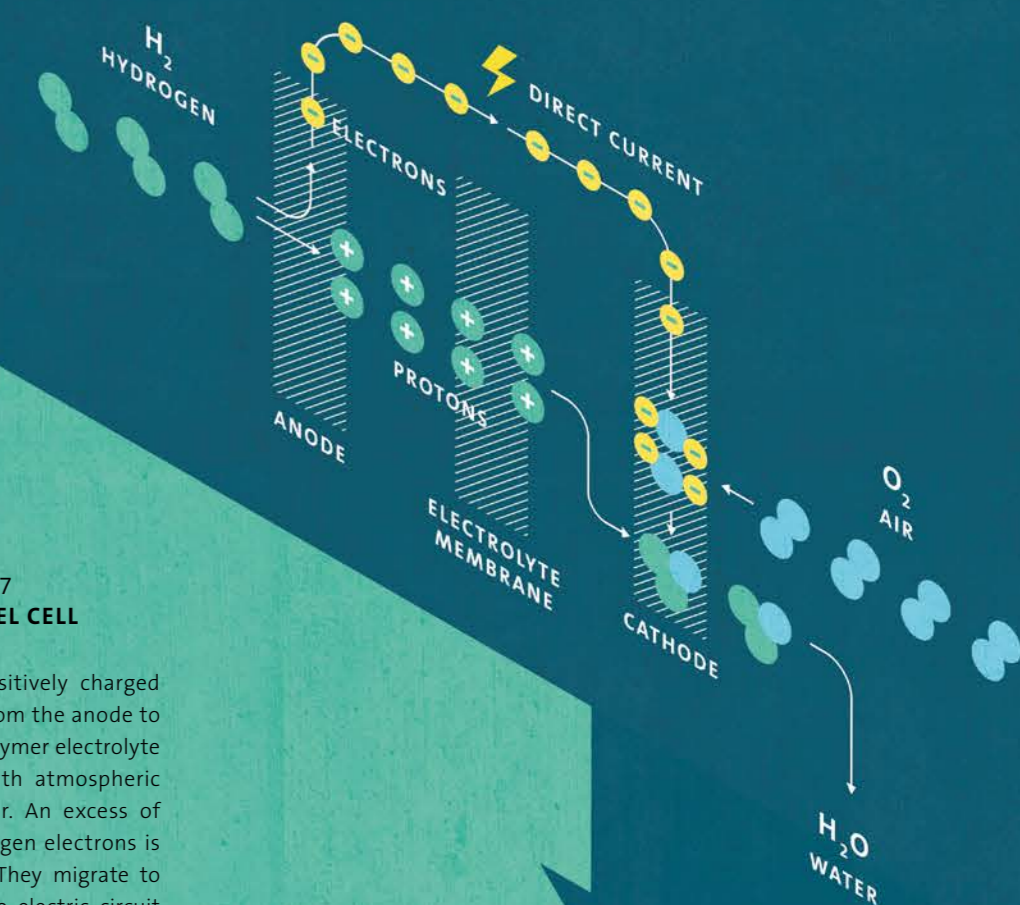
Aside from the fact that the pumps are operated a bit differently, fueling vehicles with hydrogen hardly differs at all from fueling them with liquid fuels. The gas must be conveyed into the vehicle from the supply at the substantial pressure of 700 bar. As a result, the filling hose is firmly locked with a coupling at the vehicle's nozzle and is automatically tightened. The vehicle data that are important for fueling are communicated to the fuel dispenser via an infrared interface. The actual fueling process takes three to four minutes for a car and is comparable to current fueling processes, although the ranges of 400 to 500 kilometers (250 to 310 miles) are somewhat less.

### STATION 7 INSIDE THE FUEL CELL

Within the fuel cell, positively charged hydrogen ions migrate from the anode to the cathode through a polymer electrolyte membrane and react with atmospheric oxygen to become water. An excess of negatively charged hydrogen electrons is produced at the anode. They migrate to the cathode if a separate electric circuit connects them to it. That means electricity is flowing – although it is only half of the current used to produce the hydrogen. To boost efficiency, a gas diffusion layer from Freudenberg feeds the gases to the reaction process as homogeneously as possible. Water vapor is the only waste product to reach the environment. The water returns to the circuit.

### STATION 8 = STATION 1 WATER

Circuit closed.





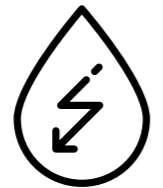


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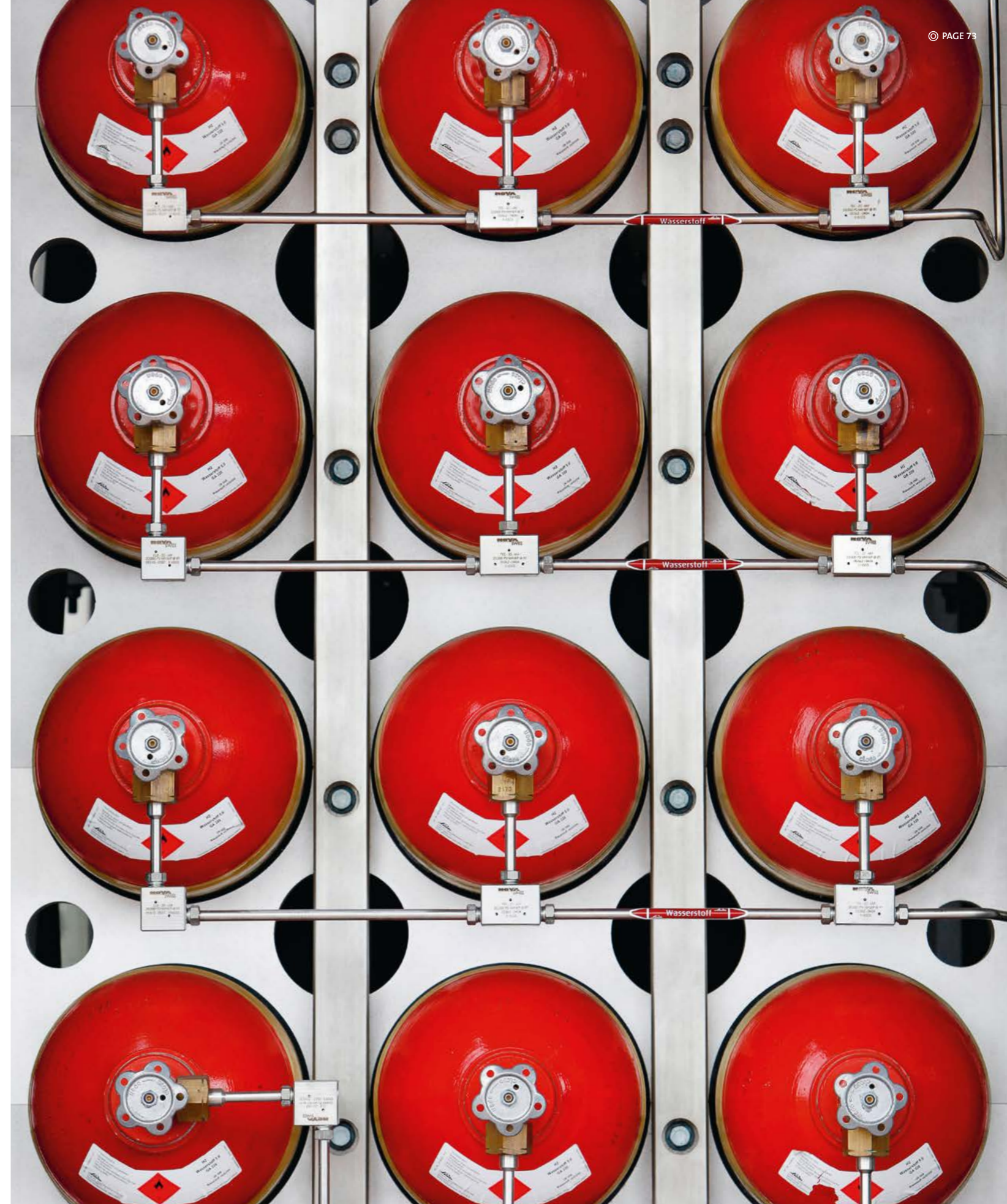
# “HIGHLY COMPLEX DESIGN”

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Fuel cells sometimes drift out of the spotlight in discussions about electric mobility. That’s unfortunate since they will certainly be one of the powertrains of the future. In an interview, Rainer Joest, President Automotive Sales, and Nils Martens, Senior Vice President Battery and Fuel Cell Systems Division, discuss why the industry first heralded fuel cells so long ago, what is still needed for a breakthrough and why seals pose huge challenges.



READY FOR TAKEOFF  
The hydrogen needed for fuel cells is transported in high-pressure containers.





**MR. JOEST, MR. MARTENS, WHY DOES THE FUEL CELL COME UP SO RARELY IN PUBLIC DISCUSSIONS ABOUT POWERTRAIN TECHNOLOGIES?**

**Rainer Joest:** To start with, it is a very complex technology, and it continues to be very expensive. For stationary applications such as generators, it is relatively easy to handle – but the difficulties grow when it is for mobile propulsion. In that case, environmental effects, such as temperature fluctuations, moisture and vibration add to the challenges. They lead to costs that today’s drivers are not willing to pay. No one is ready to spend more just because an advanced technology is interesting.

**Nils Martens:** Fuel cells have actually been around for a long time. During the 1990s, many major manufacturers experimented with hydrogen. The notion that the technology is just a few years away from maturity dates back to that time. Nothing came of the experiments. Many manufacturers got on the wrong track and were unable to solve the technical challenges to their satisfaction. European car companies in particular cut back on their development work or put it on ice.

**DOES THAT MEAN THERE ARE REGIONAL DIFFERENCES? IS THE POTENTIAL OF THE FUEL CELL EVALUATED DIFFERENTLY AROUND THE WORLD?**

**Joest:** Japan is betting heavily on fuel cells, to the point that some manufacturers have neglected the development of battery-electric vehicles. But today we are basically talking about global collaboration when it comes to many of these trends. Manufacturers are looking for partners. For example, Toyota is working on fuel cells with BMW, while Honda is doing research with General Motors. No one deals with complex development issues alone anymore.

**WHERE DO THE DIFFERENT ASSESSMENTS COME FROM?**

**Martens:** For a long time the crucial argument for Toyota was the fact that fuel cell cars are comparatively safe, and the fuel tanks are handled much as they are in today’s gasoline-fueled vehicles. The likelihood that a lithium ion battery would catch fire is greater than something happening with a fuel cell. But fuel cell vehicles and the required infrastructure also pose potential risks – namely from the high-pressure tanks. It is imperative to deal with the issue. After all, we are talking about pressures in the 700-bar range. Even the tank trucks would be considered carriers of hazardous material, and installing infrastructure in urban centers is no easy matter. Make no mistake: All of these factors have to be dealt with. There is a need for new developments and innovations, and they have to be accepted.

“THE ADVANTAGES CONTINUE TO BE QUITE IMPRESSIVE. FUEL CELLS PRODUCE NO EXHAUST GASES. THEY CAN BE FILLED UP AS QUICKLY AS A DIESEL CAR.”

**RAINER JOEST**  
President Automotive Sales

After his studies in mechanical engineering at TU Darmstadt, he joined FST’s research department. A number of positions followed: development engineer, manager of the special sealing products unit, and, as of 2011, head of the Gaskets Division. In 2016, he took over sales and marketing for the automotive business.



**Joest:** There are even more impressive advantages: Fuel cell vehicles produce no exhaust gases and run on hydrogen. They can be filled up just as quickly as a diesel. Still, there are only about 50 hydrogen stations in all of Germany.

**PEOPLE OFTEN FOCUS ON CARS – AND WE HAVE EVEN TAKEN THIS PERSPECTIVE IN OUR INTERVIEW. FOR WHAT OTHER TYPES OF VEHICLES WOULD FUEL CELLS BE OF INTEREST?**

**Martens:** For trucks and buses, especially any kind of overland transportation. If you are going to be driving a heavy-duty vehicle 600 kilometers (370 miles) a day, you probably won’t be using an all-battery-electric version, even in the future. That would require a massive battery and long charging times.

**Joest:** Fuel cells are also opening up new opportunities for boats and ships. Strict exhaust gas rules are in force on lakes, and boats with fuel cell propulsion would be most welcome there. Or think about ferries and cruise ships – the latter pollute air and water, they could easily come into port using a fuel cell instead of burning heavy fuel oil, and they could even have hybrid systems. Incidentally, all these environmental issues will be coming our way to a greater degree in the future.

**HOW LONG HAS FREUDENBERG BEEN INTERESTED IN FUEL CELLS?**

**Joest:** For quite a long time – since the end of the 1990s when the auto industry discovered the topic across a broad front for the first time. But here’s the crucial issue: As many automakers lost interest, we decided we would stay with it. So, we have been working in this area nearly 20 years, partly in cooperation with academic partners and partly with customers. We began to develop seals early on. The seals between the individual cells play a decisive role in their operation and for the lifespan of the fuel cell stacks.

**Martens:** That means that we have a ten- to fifteen-year lead on our competitors in our development work. Seals are an absolutely integral part of the so-called stack of a fuel cell. Several hundred plates are stacked up to create a cell. If one seal doesn’t work, the whole structure doesn’t function. Seals have to ensure the transfer of gases.

“BACK WHEN WE DID CALCULATIONS WITH SCENARIOS AND PREDICTED THE BREAKTHROUGH FOR 2030, A LOT OF PEOPLE SAID WE WERE CRAZY. TODAY MOST EXPERTS EXPECT IT IN 2025.”



**NILS MARTENS**  
Senior Vice President Battery and Fuel Cell Systems Division

At FST since 2012, initially with Strategic Board Projects, later in charge of Global Industrial Applications and Electric Mobility. Martens previously worked for several years at the Boston Consulting Group. Since March 2018, he has led the new FST business unit for the development and sales of fuel cells.



#### WHAT DIFFERENTIATES SEALS FOR FUEL CELLS FROM OTHER APPLICATIONS?

**Martens:** Their highly complex design makes the difference! The material must be very thin. Otherwise the whole stack would be too high. But it must also provide the right temperature and gas resistance. Each individual product must be perfect. For example, one seal has three lips at its edge, to rule out even microscopic damage.

**Joest:** We have also developed a special made-to-order material that, in this form, is only used in fuel cells. Its crucial characteristics are its media resistance, permeability and the opportunity to apply the material very thinly. Of course, we can exploit our material expertise here. As is the case for so many of our developments, the material mixture is decisive. But now we have to take the next step, what you might call: from sample production to industrial mass production.

#### WHERE IS THE TREND HEADED? WILL WE SEE THE BREAKTHROUGH FOR FUEL CELLS IN THE NEXT FEW YEARS?

**Martens:** That's not easy to answer because the market is now highly dependent on subsidies. If the Chinese government continues to support fleets of fuel cell buses as strongly as it has, for example, it will develop the market much more quickly. In Europe, the focus is still largely on battery-electric powertrains. At Freudenberg Sealing Technologies, we don't just want to put our faith in one powertrain technology – we are looking at them all, and each has its own rationale. In the future, the vast majority of fuel cell vehicles will be hybrids designed to exploit the advantages of a battery as well.

**Joest:** That's why we are going to tackle many niche applications over the next few years: trucks, buses, ships and rail vehicles. The advantage is that we can continue to deal with the technology and to learn more about it as we work on specific developments.

#### TO BE READY WHEN AUTOMAKERS REACH A CERTAIN POINT?

**Joest:** Yes. We can apply seals to different fuel cell components, depending on the customer's preferences. As a result, we've created a clear competitive edge for the company. We can present other fuel cell elements with our partners, such as thermal management and electronics management. It is definitely our goal to provide the entire fuel cell module, that is, all the elements that are part of a stack.

#### SO, YOU WOULD RATHER NOT MAKE A PREDICTION ABOUT THE BREAKTHROUGH AT THIS TIME?

**Martens:** Back when we did calculations with scenarios and predicted it for 2030, a lot of people said we were crazy. Today most experts expect it in 2025.

**Joest:** Starting in 2020, we will likely see things more clearly. That's when the first manufacturers plan to bring out larger volumes, and the infrastructure will increase in parallel – as will consumers' willingness to buy the technology. But even then, there will hardly be any filling stations.

**Martens:** As you know, innovations tend to follow an S-curve. The turning point will come.

**Joest:** Think back to the time when the flat screen was introduced. These televisions cost 5,000 euros at first, and then the price dropped to that of a tube TV, and within a few months you couldn't give a tube TV away.

**Martens:** Once a critical threshold is reached, and you see more of the innovation than you see the outdated technology – no one buys the old product anymore just due to the fear of not being able to get rid of it.

**Joest:** It will be gone in a flash. ©

#### FUELL CELL

In a fuel cell, a chemical reaction between hydrogen and oxygen generates electricity to power a vehicle's electric drive. The advantage is that it can be filled up in just a few minutes. A fuel cell car requires about 1 kilogram of hydrogen for a range of 100 kilometers (62 miles). "Hot air" in the form of water vapor is emitted as the exhaust.



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## MULTIFACETED MATERIAL

**With its new material FluoroXprene, Freudenberg Sealing Technologies is making a contribution to a sustainable, resource-conserving economy. The innovative material also has outstanding properties for new, pioneering sealing solutions.**

FluoroXprene was first developed to reduce the permeation of fuel vapors through the walls of feed lines, decreasing them to a fraction of their usual quantity. It is effective with standard fuels as well as aggressive, alternative plant-based fuels such as E10 and E85. FluoroXprene also makes fuel systems safer thanks to its electric conductivity, which eliminates static discharges.

With FluoroXprene, Freudenberg Sealing Technologies has succeeded in developing a process-friendly compound of two highly fluorinated materials. The high chemical resistance of fluoro rubber (FKM) is combined with the easy process-ability of thermoplastic elastomers (TPE). With changes in the proportions of the two components or other ingredients, the product's characteristics can be adapted to a wide range of complex requirement profiles.

Thanks to Freudenberg Sealing Technologies' innovative manufacturing process, material and energy are saved during processing – and waste is reduced. FluoroXprene is thus a good example of how a company can manufacture products while conserving resources and boosting sustainability and efficiency at the customer's end. ©



## “CULTIVATED” THERMOPLASTICS

**Robust housings and seals have to shield the sensors for driver assistance systems and highly automated driving from environmental influences. Aluminum carrier housings are used for this; Freudenberg Sealing Technologies seals them with liquid silicone (LSR) seals. Now the company has successfully carried out research on plastic carrier housings.**

The increased demands on radar sensors due to automated driving are associated with increasing power density and hotter temperature trends. This has consequences for the use of plastics: They must have a certain amount of thermal conductivity. In addition, electronic components have to be shielded against electromagnetic interference. Certain base polymers are suited for a plastic mixture offering these characteristics, but they are affected by fillers and additives. Freudenberg Sealing Technologies has succeeded in developing a thermoplastic with ten to 100 times the heat conductivity of the current solutions, and it offers thermal management and electromagnetic compatibility as well. The thermoplastic is made with a special recipe that improves the adhesion between the housing and the silicone seal. The component is also up to 50 percent lighter, and the injection molding process makes it easier to produce.

As it develops future sensor concepts, Freudenberg Sealing Technologies can create material properties in a plastic that are precisely suited to a particular use and then create the design. That's because the properties of thermoplastics can be deliberately “cultivated.” ©





## FEEDBACK & CONTACT

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**FREUDENBERG SEALING TECHNOLOGIES GMBH & CO. KG**

**ISOLDE GRABENAUER**  
+49 6201 80-7467  
[isolde.grabenauer@fst.com](mailto:isolde.grabenauer@fst.com)

**ULRIKE REICH**  
+49 6201 80-5713  
[ulrike.reich@fst.com](mailto:ulrike.reich@fst.com)

### COMPANY INFORMATION

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**CONTENT RESPONSIBILITY**  
Ulrike Reich (V. i. S. d. P.)

**EDITOR**  
Isolde Grabenauer

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