ESSENTIAL

FREUDENBERG SEALING TECHNOLOGIES

AT LAST!

Alternative Powertrains

WHERE ARE WE HEADED?
Futurist Peter Schwartz on electric propulsion and hydrogen.

VIENNA WALTZ
Emblem of an upheaval: The Vienna Motor Symposium in transition.

PIONEERS ON A MISSION
The startup Nikola wants to take fuel cells into the mainstream.

the magazine 1_20

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IN FIFTY WORDS

Breakthroughs in alternative powertrains have been announced a number of times and just as often delayed. But now we're convinced their time has finally come. Powertrains such as fuel cells and electric motors have joined combustion engines as features of everyday life. Sustainability, efficiency and user behavior are becoming more and more important. A special edition on the "not-so-alternative" powertrain mix of the future.

At Last!

An Essay by Claus Möhlenkamp, Chief Executive Officer, Freudenberg Sealing Technologies

Breakthroughs in alternative powertrains have been announced a number of times – and just as often delayed. But this time it's different. Really? The answer is yes. Not least of all because of the diverse range of future powertrains and their users' readiness for change.

The vehicles on our roads might look different today if the United States had not passed Prohibition in 1919. What does a ban on alcohol have to do with cars? At the start of the 20th century, many high-level engineers and automotive pioneers assumed that alcohol would be their fuel. Nikolaus August Otto, the father of the compressed-charge internal combustion engine, used potato fuel. According to Henry Ford, "The fuel of the future will be extracted from fruit, from the sumac that grows on the roadside, from apples and weeds." That observation positioned bioethanol as one of the midwives of the automobile until Prohibition pulled the rug out from under the distilleries.

"The fuel of the future will be extracted from fruit, from the sumac that grows on the roadside, from apples and weeds." (Henry Ford)

By the way, the first Porsche was an electric car that made its debut in 1898. The passengers sat on top of a battery box weighing 500 kilograms (1,100 pounds). It had a range of 80 kilometers (about 50 miles). From that standpoint, it wasn't anything special. In the 1890s, engineers in France, England and the United States also designed electric motors for buses, delivery vehicles, fire trucks and the first forklifts, as well as for cars.

Today, we call them "alternative powertrains" if they aren't fueled by gasoline or diesel. We focus on their distinctiveness, not their special benefits. That is astonishing given how long these propulsion technologies have been around. But this has to do with history: Fossil fuels have been the standard for our mobility for a century. Over generations, they have powered nearly everything that is driven, flown or operated on water.

The turn-of-the-century was not the only time when alternative powertrains seemed to be on the verge of a breakthrough. Even after the oil crises of the 1970s, there were scattered initiatives to replace fossil fuels. During that decade, Mercedes-Benz introduced a natural-gas bus, an electric van, a methanol-fueled internal combustion engine and a hydrogen van with hybrid propulsion. Engineers who worked on these and similar concepts were considered to be "alternative types" – and the term wasn't meant to be a compliment. It emerged at the Hofburg in Vienna, at the world's largest conference of powertrain engineers, and it was almost always accompanied by headshaking and smirks. The breakthrough wasn't expected anytime soon.

At least not until the 1990s when there was another oil crisis, this time triggered by the Gulf War. Once again, automakers announced that they were betting on alternative technologies like electric propulsion and fuel cells. It was a time when Toyota dedicated itself to hydrogen propulsion – and other manufacturers followed suit, at least with test vehicles. It was the decade when electric cars apparently experienced a renaissance. Breakthrough? Not at all. The research ground to a halt, and the market showed no interest. Most of the ideas were put on the back burner.

2020 is a different world. Strict CO_2 regulations, electric rates, massive societal pressure to protect the climate. You don't see head-shaking and smirks anymore. Reverent whispers are the rule. The onetime "alternative types" deserve the full attention of CEOs, CTOs and research and development chiefs. Instead of wondering when the breakthrough is coming, the issue is which manufacturer is moving to alternative powertrains too slowly and is being left behind.

But the situation is not black-and-white. There is much to suggest that the old duality will no longer hold in the future. It is the idea that "the internal combustion engines are on one side – and the alternatives are on the other side." The new world of propulsion will be a more diverse place than the old one, and combustion engines will also have a place in the future – whether because certain applications such as air transport will have a hard time doing without them or because they will consume CO_2-neutral fuels. In any case, the view of just a vehicle's CO_2 emissions falls short. In the end, it is just as important to consider the emissions from the production or transport of individual parts or the construction of the energy carrier.

There is one issue that will be more important than the question of the technology: Which machine should be driven – and where, how far and how fast does the user want to drive it. The focus is on the goals and purpose of mobility.

We need to discuss all these issues, do research on them and make decisions for the future. This edition of ESSENTIAL magazine is intended as food for thought. It highlights the diversity of powertrain systems, their users and their applications.

Freudenberg Sealing Technologies is ready for the powertrain of the future – or, to put it more precisely, the powertrains of the future, whether combustion engines, electric motors, fuel cells or possibly something completely different.

The new world of powertrains will be more diverse than the old. Internal combustion engines will continue to have a home in it.

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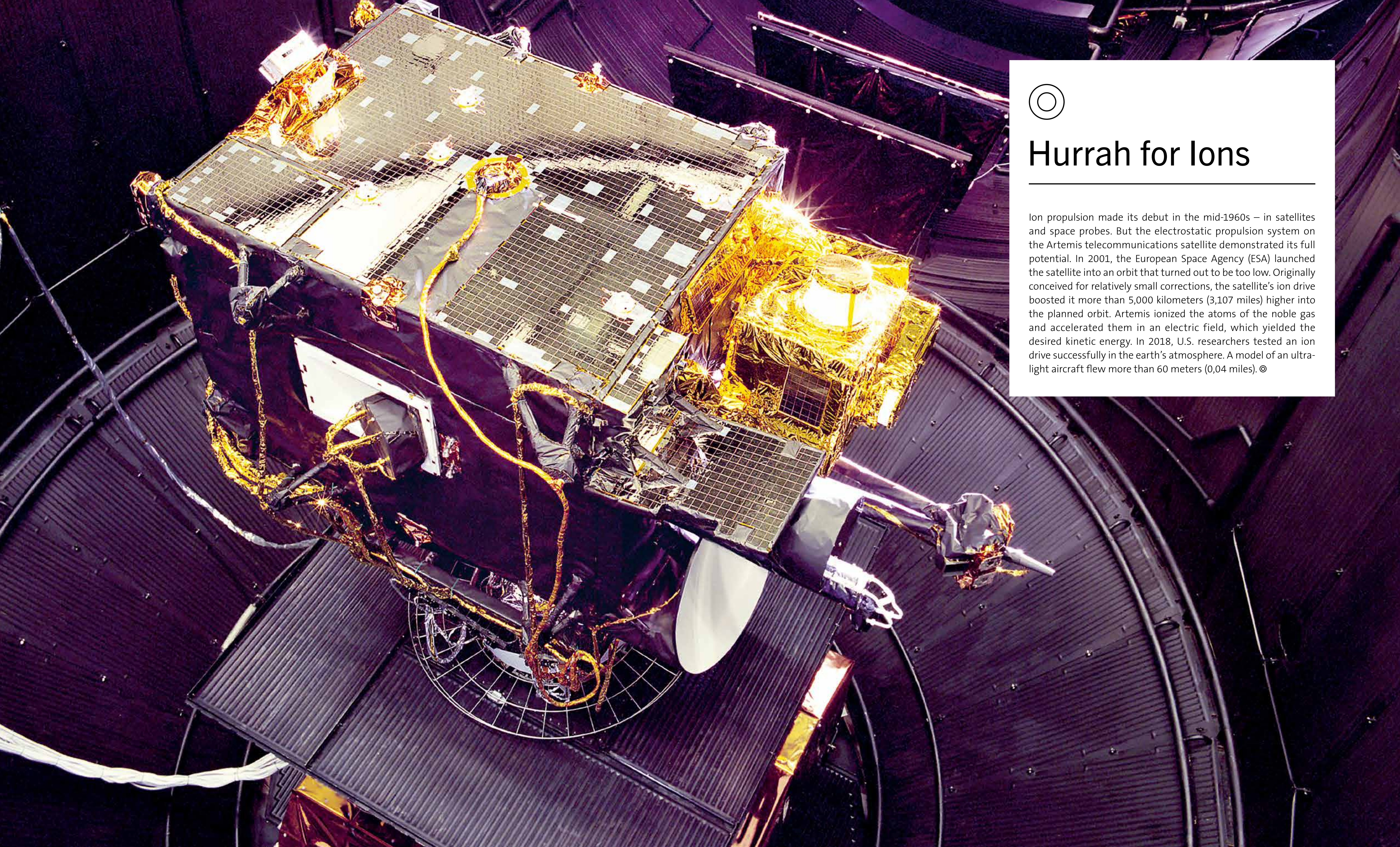
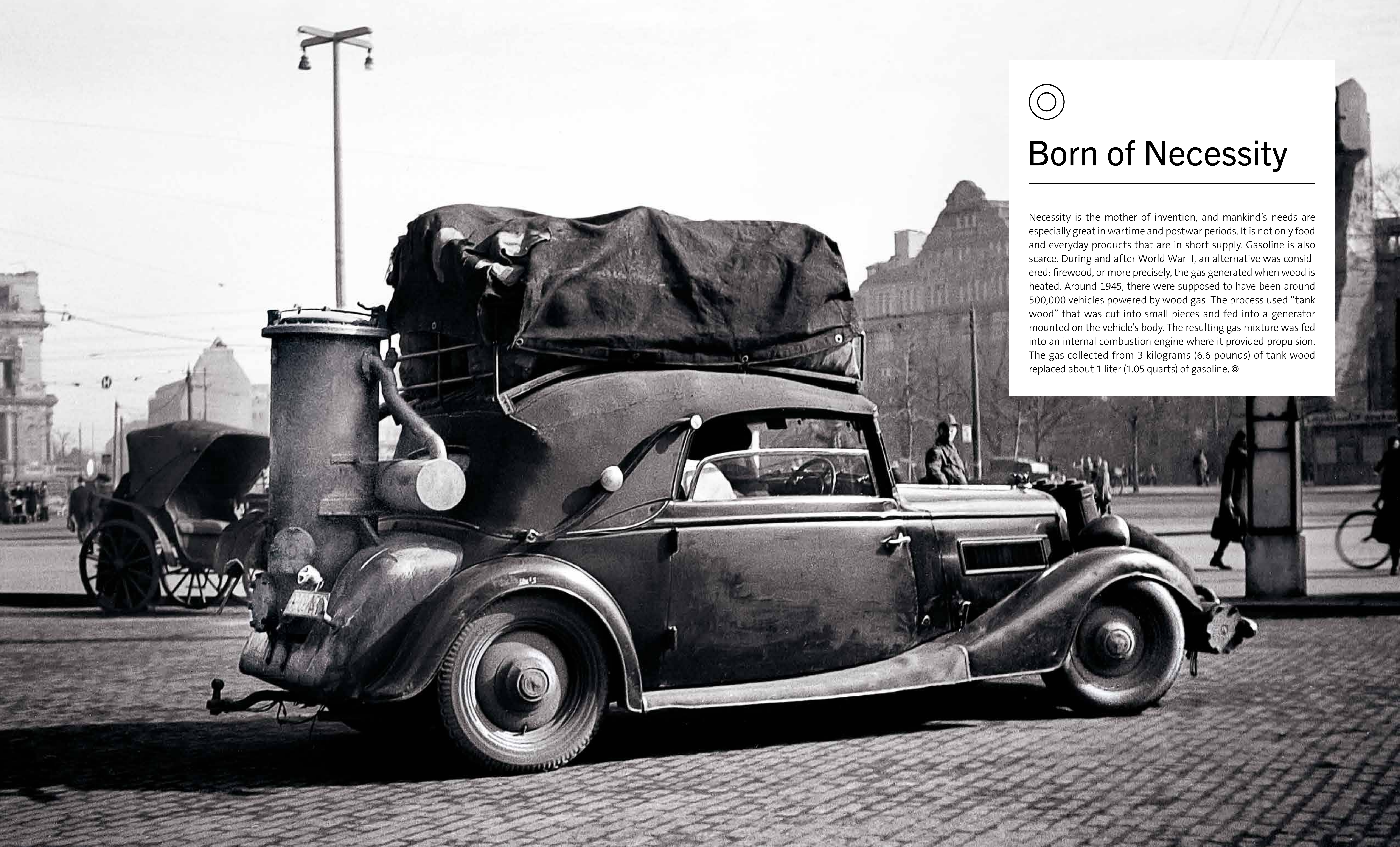


Hurrah for Ions

Ion propulsion made its debut in the mid-1960s – in satellites and space probes. But the electrostatic propulsion system on the Artemis telecommunications satellite demonstrated its full potential. In 2001, the European Space Agency (ESA) launched the satellite into an orbit that turned out to be too low. Originally conceived for relatively small corrections, the satellite's ion drive boosted it more than 5,000 kilometers (3,107 miles) higher into the planned orbit. Artemis ionized the atoms of the noble gas and accelerated them in an electric field, which yielded the desired kinetic energy. In 2018, U.S. researchers tested an ion drive successfully in the earth's atmosphere. A model of an ultra-light aircraft flew more than 60 meters (0,04 miles). ◎

Effortlessly Forward

There are ocean-dwellers that rely on the principle of reaction propulsion to move through the water. Jellyfishes, like the compass jellyfish shown here, are an example. This form of propulsion is powered by the lightning fast contraction of their muscles. As scientists have observed, the ear jellyfish, a member the same species, covers only one-fifth of the distance it travels with muscular contraction. The remainder is handled by the relaxation of its umbrella-shaped bell, which creates a vortex that produces additional thrust. This makes the ear jellyfish a tremendously efficient swimmer. Scientists believe this principle of forward movement can serve as a model for the development of watercraft with highly economical drive technologies. ◎



Born of Necessity

Necessity is the mother of invention, and mankind's needs are especially great in wartime and postwar periods. It is not only food and everyday products that are in short supply. Gasoline is also scarce. During and after World War II, an alternative was considered: firewood, or more precisely, the gas generated when wood is heated. Around 1945, there were supposed to have been around 500,000 vehicles powered by wood gas. The process used "tank wood" that was cut into small pieces and fed into a generator mounted on the vehicle's body. The resulting gas mixture was fed into an internal combustion engine where it provided propulsion. The gas collected from 3 kilograms (6.6 pounds) of tank wood replaced about 1 liter (1.05 quarts) of gasoline. ◎

"Charging and Fill-ups Will Be Equally Fast!"

Futurist Peter Schwartz has been active in developing future scenarios for nearly a half-century. What does he think about the path to electric mobility?

Peter Schwartz (born in 1946)

Schwartz, an American, is an internationally recognized futurist and business strategist. He has specialized in future scenarios and is an advisor to companies and governments. He is also the co-founder of the Global Business Network, and has worked as Senior Vice President of Strategic Planning at Salesforce, a provider of cloud-computing services, since 2009. Schwartz is also the author of several books and an advisor to screenwriters.

PETER SCHWARTZ, YOU DEVELOP FUTURE SCENARIOS FOR COMPANIES. WHAT DO COMPANIES TEND TO BE MORE INTERESTED IN: SEIZING OPPORTUNITIES OR MINIMIZING RISKS?
Both. It usually isn't either/or. Some companies are just interested in assessing opportunities at first. But to do that, it is essential to consider various scenarios. Naturally, this is where the risks come in: What are the problem areas? Do we need to delay the introduction of a new product?

WHAT KEY PARAMETERS DO YOU APPLY IN YOUR WORK?
That depends on the company. But only regarding the particular weight of the parameters. The basic idea is that you have to broaden your view. We always take five categories into consideration: social, technological, economic, environmental, and political. Then we have to evaluate which category is the most important or represents the greatest uncertainty.

HAVE THE CATEGORIES CHANGED OVER THE DECADES?
No, but the circumstances change, of course. Just think about the dot-com bubble twenty years ago. The world has changed. It is more fragmented. But the categories that we worked out back then are still valid.

Twenty years ago, there were basically three options for the alternative drive of the future: batteries, fuel cells and hydrogen as a fuel in combustion engines. Batteries won the race."

Peter Schwartz, Senior Vice President of Strategic Planning, Salesforce

WHAT IS THE HARDEST PART ABOUT DEVELOPING SCENARIOS FOR THE FUTURE?
To combine the basic analysis with the right amount of imagination. If you allow too little imagination to flow into the scenarios, your look into the future gets stale and is just an extension of the present. If you let too much flow in, you end up with science fiction.

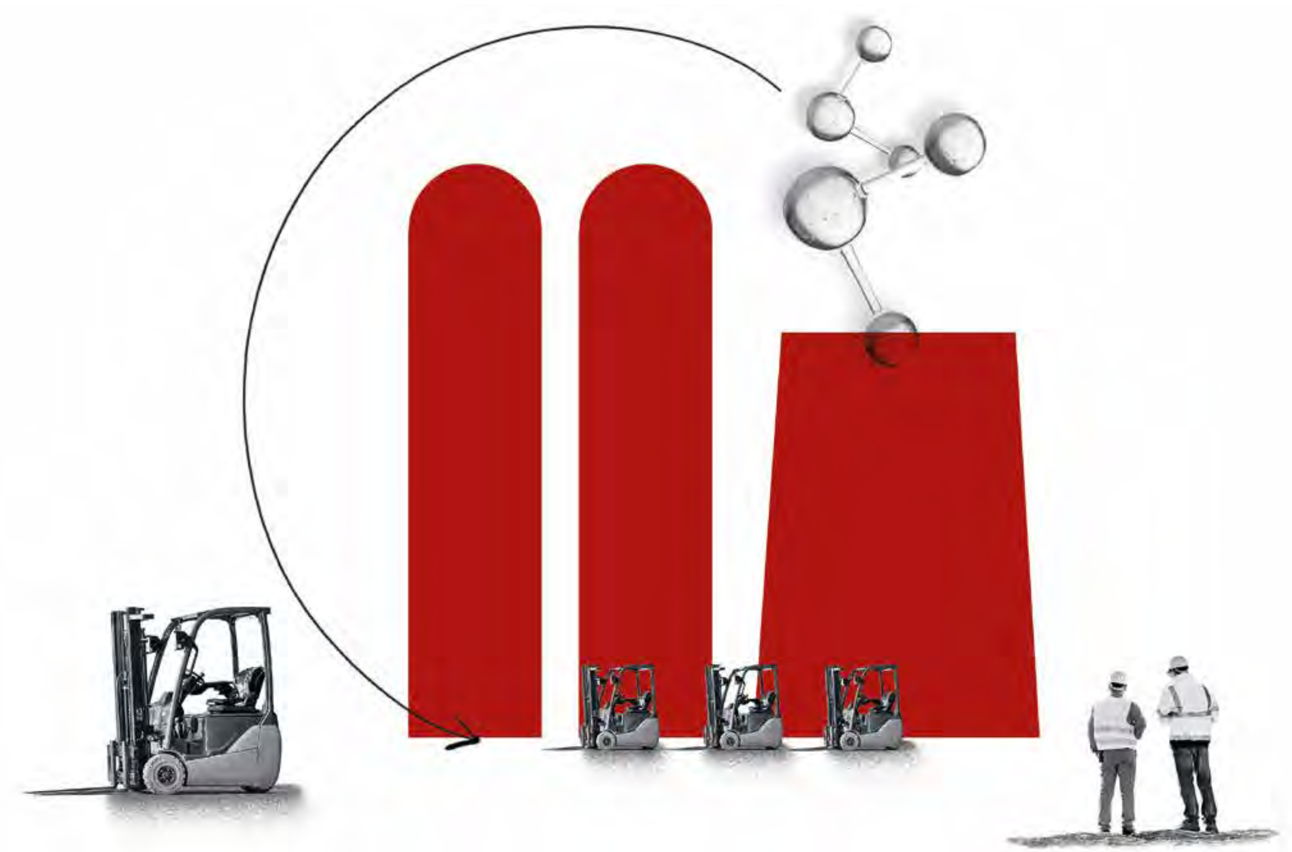
AND WHAT WENT WRONG IN 1999 WHEN YOU PREDICTED THAT IN 2020 NEARLY EVERY NEW CAR WOULD BE FUELED WITH HYDROGEN? WAS THAT TOO MUCH IMAGINATION?
I knew a lot about fuel cell technology back then. The main problem with the prediction was probably that I, along with other people, underestimated how costly and difficult it is to implement fuel cells on a practical basis. Toyota is the only manufacturer to ambitiously develop a model. The technology has been a much greater challenge than we imagined back then.

WHERE DID THE CHALLENGE LIE?
In the core mechanism of the fuel cell. The problem was that, on the one hand, the materials are very expensive – we're talking about components made of platinum and rare earths. On the other hand, hydrogen offers rather poor efficiency. In short, the input is very high and the output has been very poor for a long time. Batteries have proven to be more efficient. Look, twenty years ago, there were basically three options for the alternative drive of the future: batteries, fuel cells and burning hydrogen in a combustion engine. Batteries won the race.

SO IS HYDROGEN NO LONGER A FACTOR AS AN ALTERNATIVE DRIVE SYSTEM?
It certainly is. But I see the greatest opportunity where hydrogen is easily available. Cities such as Hamburg and San Francisco have large numbers of refineries where hydrogen occurs anyway in their operations. That's why we have hydrogen buses in San Francisco that use fuel cells. Hydrogen also seems to be ideal for vehicles that handle the last mile. Factories that already run their forklift fleet on hydrogen are another example. Companies can produce it themselves on their premises.

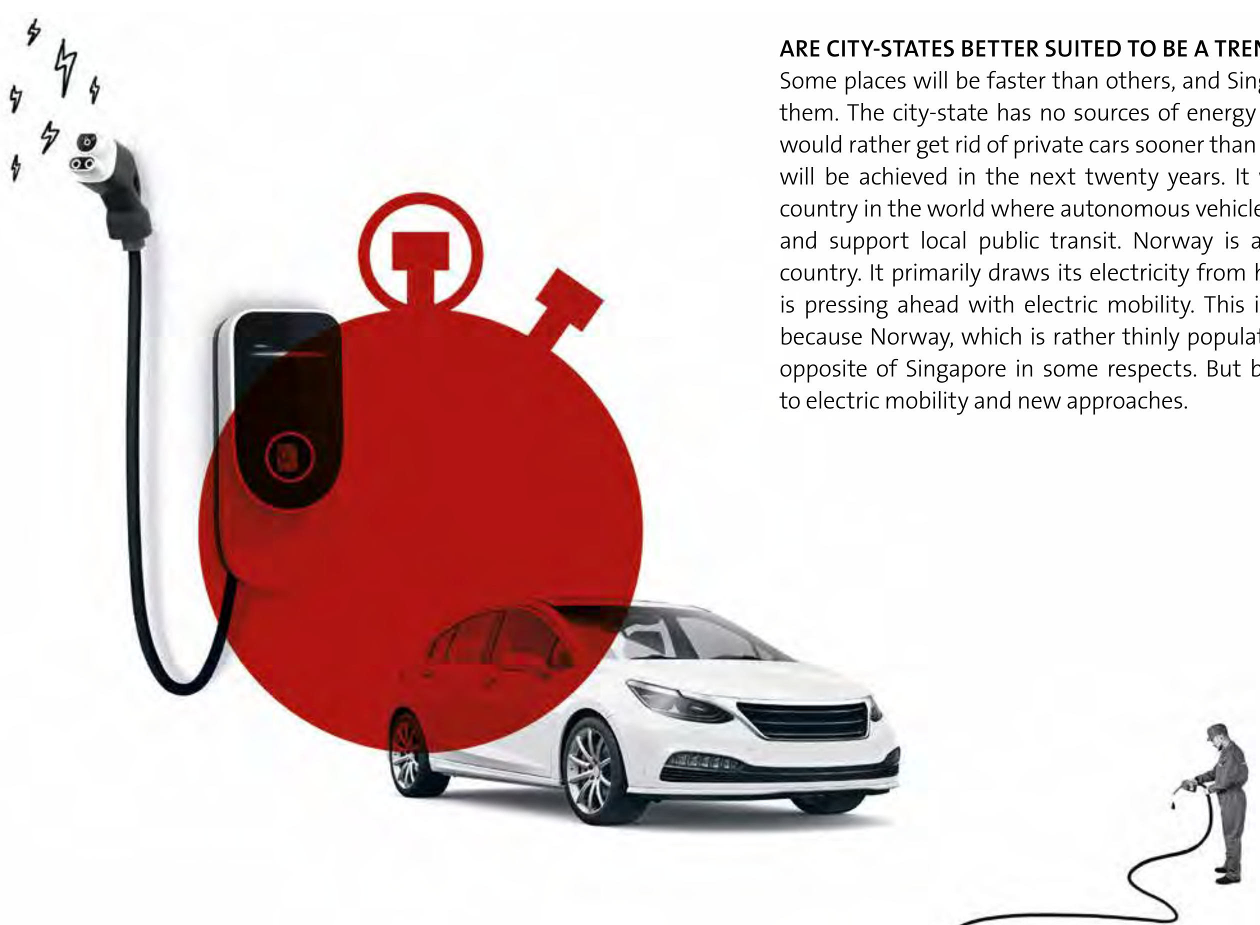
WITH REGARD TO PRODUCTION: NOT EVERY ENERGY SOURCE USED IN THE PRODUCTION OF HYDROGEN AND ELECTRIC BATTERIES IS GREEN.
I really consider this to be a major issue. Lee Schipper, the now-deceased physicist and energy efficiency expert, once said that many electric vehicles are not, strictly speaking, "zero emission vehicles," but rather "elsewhere emission vehicles." In other words, the exhaust is emitted somewhere else, perhaps in a coal-burning power plant that generates the electricity. Vehicles are only really clean when they are in fact powered with electricity from renewable sources. Only then does it all makes sense. With its exit from nuclear energy, Germany in particular has set a high hurdle for itself. It is now even more dependent on coal.

WHY HAVE ELECTRIC POWERTRAINS HAD SUCH A HARD TIME? AFTER ALL, THEY HAVE BEEN AROUND A LONG TIME.
Humanity started out with electric mobility even before there was gasoline. In this sense, we've already been developing batteries for a very long time and have been trying to improve them – and the progress has been rather modest by this standard. While they still don't perform great, they function fairly well at this point. Today, batteries are comparatively efficient because they can be produced in higher volumes.



Is the Hydrogen Era Beckoning?

In 1999, Peter Schwartz and two co-authors looked into the future in his much-quoted book, "The Long Boom." His focus: How was the world going to develop over the next twenty years? The Washington Post said the "future history" was a "challenge." The authors forecast a long-lasting global economic boom, citing nanotechnology, hydrogen and innovations in information technology as the drivers. They even claim that hydrogen will be able to establish a new era.



CHARGING SPEEDS ARE GOING TO BE A CRUCIAL FACTOR FOR THE LONG-TERM SUCCESS OF ELECTRIC MOBILITY. HOW WILL THIS TREND PROGRESS?
Charging times will definitely come down. It will soon no longer matter whether a car is filled up with fuel or charged up. The methods will be equally fast. They will be at the same level in five to ten years. By contrast, I don't think that the idea of simply replacing an electric battery with a new one when its energy runs out will work out very well. There's also the fact that the charging infrastructure is getting better. Subsidies from government will be needed, but the trend will be quite linear.

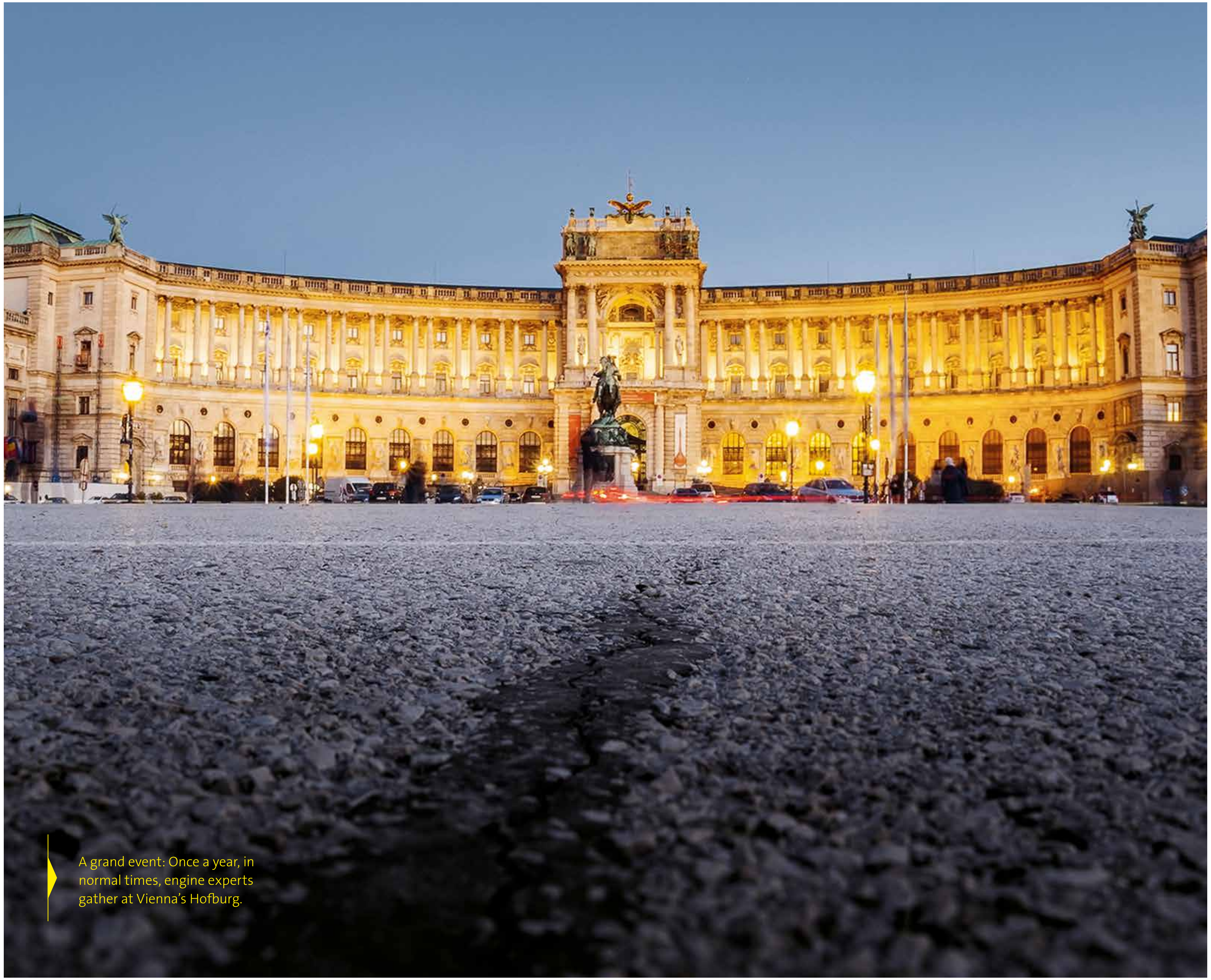
DOES THAT MEAN WE WILL SOON SEE ELECTRIC CARS ON THE ROAD EVERYWHERE?
In a decade, at the latest, I think every new car will at least be a hybrid with a small internal combustion engine on board. But that doesn't mean purely internal combustion powertrains will disappear from the roads. Trucks in particular will pose a challenge. Of course, there will still be older cars driving around. Singapore is the only country I am familiar with where you aren't allowed to drive a car that is more than ten years old.

ARE CITY-STATES BETTER SUITED TO BE A TRENDSETTER?
Some places will be faster than others, and Singapore is one of them. The city-state has no sources of energy of its own, and would rather get rid of private cars sooner than later. I think this will be achieved in the next twenty years. It will be the first country in the world where autonomous vehicles displace them and support local public transit. Norway is another exciting country. It primarily draws its electricity from hydropower and is pressing ahead with electric mobility. This is so fascinating because Norway, which is rather thinly populated, is the exact opposite of Singapore in some respects. But both are turning to electric mobility and new approaches.

HOW WILL AIR AND SEA TRANSPORT CHANGE?
That's an exciting question. Shipping is a bit more straightforward. Here opportunities in liquid natural gas and fuel cells are conceivable. But aircraft are a real challenge. Because they fly so high, their contribution to the greenhouse effect is all the more serious. Their CO_2 values continue to climb. Jet fuel may become cleaner with the addition of biofuels. But no more than that. There is still no scientific breakthrough in sight.

WHAT IS THE BOTTOM LINE FOR THE LARGE INTERNATIONAL AUTOMAKERS?
They all understand that the shift to electric mobility is unavoidable. The question is how quickly they do it, how they do it, and who takes the lead. Many German manufacturers are limping along because they haven't believed in electric cars for a long time. A number of Japanese manufacturers have a clear edge. Toyota started out more than twenty years ago. General Motors also jumped in early. It's not that easy to catch up. But it's also very clear: We wouldn't do all this if we weren't facing climate change. The more we feel its effects, the faster we'll react.

SO PEOPLE ONLY REACT WHEN A CATASTROPHE IS ON THE DOORSTEP?
Yes. So it appears, unfortunately. But we have a new generation now, young people for whom the automobile is no longer a ticket to freedom. That's already a great change in mentality. Even today, the majority of New York City's residents don't own a car. It just doesn't pay off. They would only spend all their time looking for a parking space.



A grand event: Once a year, in normal times, engine experts gather at Vienna's Hofburg.

Vienna Waltz

The International Vienna Motor Symposium has long been considered a bastion of the internal combustion engine. Today, its handling of alternative powertrain concepts mirrors a sector in upheaval in response to climate change.

A group of Chinese tourists, each wearing earphones, followed a petite woman who was talking into a microphone. They stopped in St. Michael Square where the carriages stand. The guide was probably not dwelling on the hardships of the persevering horses, but rather drawing attention to the exposed foundation walls of an outlying Roman encampment. They date back to a remote past, like so much in this city. Men in suits with nametags on their jackets were making their way through the visitors from the Far East. Their destination was nearby: the Hofburg, or to put it more precisely, its roughly 1,000-square-meter (nearly 11,000-square-foot) Hall of Festivals, which is used for international conferences as well as gala evening balls. The International Motor Symposium has taken place there for four decades, as the chestnut flowers begin to bloom in Vienna each year.

Dr. Eberhard Bock vividly recalls his first visit more than ten years ago. "As a young engineer and team leader, I was impressed by the fact that a veritable 'Who's Who' of the auto industry gathered here," said Professor Bock, who now heads Advanced Product Technology at Freudenberg Sealing Technologies. "Back then, I had the feeling that you've made it if you ever get the chance to lecture here." In fact, among the many conferences that deal with powertrain technologies, Vienna is considered the most elite by far. Some even refer to it as the "Opera Ball of Powertrain Engineers." Using elaborate animation, top development managers delve into the technical details of new engines ranging from three to sixteen cylinders. Whether the focus is on a new piston bowl shape or a new cooling channel guide, nothing is too inconsequential to send an unmistakable signal: We build the world's best engines. Major suppliers have always seized opportunities in Vienna – and not just as exhibitors. They can introduce new technologies after stringent testing. At the event in 2014, Dr. Bock presented the friction-free seal Levitex for the first time.

2009

E-Mobility: Long a Niche Topic

When the CO_2 fleet limit of 95 grams was announced in 2009, the majority of the lecturers were still convinced that the future belonged to the internal combustion engine. Electric mobility was a niche topic, they said.

2013

In the beginning, there were just a handful of lecturers who broke free of the mantra. They included Bosch CEO Volkmar Denner, who in his opening lecture in 2013 acknowledged that 2-ton SUVs no longer had a chance to meet weight-specific limits. Two years later, it became clear that the driving cycle used to measure fuel consumption to that point was being changed. So the experts at the symposium discussed countermeasures such as variable compression and cylinder shut-offs. At the end of the conference, BMW Board Member Klaus Fröhlich summed up the situation. "With the new emissions specifications, the costs for internal combustion engines and electric powertrains are approaching one another – unfortunately, at the wrong level."

2016

In 2016, the debate over the diesel's future was in full swing – in part because emissions during real-life driving, and not just on the test stand, were becoming important for vehicle approvals. But little of the debate penetrated the Hofburg. Mercedes-Benz presented a four-cylinder diesel engine that was supposed to secure the diesel's future thanks to its combustion behavior and a very closely coupled exhaust gas treatment system. BMW countered with a six-cylinder diesel, which reached a rated output of nearly 300 kilowatts with a total of four turbochargers. And Audi introduced its new generation of V-8 diesels with torque as high as 900 newton meters, which would be sufficient for a 12-ton truck. Only Gilles Le Borgne, then PSA's development chief, made the case for greater honesty. He pointed to fuel consumption measurements made on public roads in cooperation with the non-governmental organization "Transport and Environment." The truth hurt: The Peugeot 308 with a 1.6-liter diesel engine, which officially consumed 3.2 liters of fuel over 100 kilometers (62 miles), actually burned 5.0 liters under the new specifications. In the corridors of the Hofberg, the lecture was deemed to be "politically unwise."

2017

Other manufacturers responded a year later. Fritz Eichler, who would soon move into chassis development, presented Volkswagen's diesel powertrain program. The small TDI three-cylinder option came out of the lineup. From then on, VW's diesel options started out with an engine displacement of 1.6 liters. Going forward, VW wanted to leave overstatement behind. The "muscleman" with a per-liter output of 100 kilowatts that was announced in Vienna a few years earlier was as far from realization as the 10-speed, dual-clutch transmission. But the lectures on new alternative powertrains continued to take place mainly in small quarters next-door, as they had for years.

2019

A New Spirit of Departure

The industry finally turned the page in 2019. At least one out of every two lectures was devoted to hybrid or battery-electric powertrains. As "Fridays For Future" activists gathered in front of the Hofburg for a demonstration, Andreas Trostmann, BMW's production chief, was beginning his closing speech with a quotation from Greta. Only the battery-electric vehicle is promising a fast track to climate neutral powertrains, he said. In his lecture on the electric propulsion of the ID.3, Frank Welsch, Trostmann's colleague on the development side, described the technology in a way that had only been reserved for combustion engines in the past – in the grand hall, with elaborate technical animation and in a voice filled with pride.

It's still not a settled matter whether Vienna will retain its role as the leading symposium for powertrain technology. BMW, Daimler and Volkswagen have significantly reduced their presence already. "For a long time, alternative powertrains were not really taken seriously here," Dr. Bock said. "It is only now that the switch has been thrown." The success of the adjustment process will likely depend on who sets the pace at the Opera Ball. Last year, Bernhard Geringer, a professor at the Technical University of Vienna, took control of the symposium. He said: "The internal combustion engine is certainly not dying or dead. But the range of new, pure combustion engine powertrains will decline, and hybridization, the combination of internal combustion engines with electric propulsion, will grow."

Nikola Motors wants to lead fuel cell trucks to a breakthrough.

The Challenge: A Cleaner Solution Beyond Diesel

Nikola Motor Company is a startup that intends to move hydrogen propulsion into the mainstream. In the process, it plans to solve a "chicken or egg" dilemma.

Does Jesse Schneider, EVP of Hydrogen Fuel Cell Technologies for Nikola Motor Company, consider himself a veteran or pioneer? The question is a bit rhetorical since Schneider is one of the world's leading experts in fuel cell technology. He has been advancing the cause of fuel cell propulsion for more than twenty years and has worked for companies such as BMW and Mercedes. Schneider has co-developed standards for fuel cells and electric and hydrogen-fueling infrastructures. Fast forward to 2018 when Schneider began leading the hydrogen and fuel cell technology initiative at Nikola Motor Company in Phoenix, Arizona.

Schneider nonetheless answers without hesitation: "It's more definitely the latter. At Nikola, we're the pioneers bringing Class 8 (37-40t) fuel cell trucks to market. Nikola is very fast paced." Founded in 2015, the company is pursuing the ambitious goal of launching hydrogen-fueled powertrains in the heavy-duty market. Before long, test fleets of Nikola trucks powered by fuel cells will be rolling across Europe and the United States. All three of Nikola's Class 8 vehicles — Nikola One, Two and TRE — are being developed in FCEV applications. The Nikola TRE will be co-developed as a BEV with CNH Industrial of Europe, the parent company of IVECO and FPT Powertrain.

> We are rolling out stations in parallel with our fleets of vehicles. A customer buys a few hundred trucks, and then we build the stations for that specific fleet."
>
> Jesse Schneider, EVP Hydrogen & Fuel Cell Technology

Why Now?

Decades ago, fuel cells were already being praised as the powertrain of the future. Why didn't they replace their diesel and gasoline counterparts a while ago? "It certainly takes time to make a transformative technology," Schneider said. "Battery-electric propulsion was the first revolution for light-duty vehicles that we experienced on the way to emission-free mobility. The greater the mass and range needs of the vehicle, the more the fuel cell makes sense." For zero-emissions in long-haul trucking, Schneider went on to say, "there is no comparison." In the case of the Nikola TRE, the battery-electric version for the European market has a range of up to 400 kilometers (roughly 248 miles), while the U.S. fuel cell version carrying 60 kilograms (132 pounds) of hydrogen has a range of up to 800 kilometers (497 miles).

Many of hydrogen's advantages are obvious: A fuel cell powertrain can be fueled ten times as fast as a battery can be charged. As a fuel, hydrogen is also lightweight, making longer ranges possible. But even just a few years ago, there was a major caveat. The process of extracting hydrogen from water using electrolysis was considered too costly, and it was deemed unsustainable if the electric current came from fossil sources such as coal. Since then, greater awareness of climate change and the global efforts to limit CO_2 emissions have accelerated the growth in renewable energy from solar, wind and hydropower sources, resulting in green production of hydrogen and changing the baseline for the evaluation of hydrogen technologies. "The missing link?" asks Schneider. "Renewable energy costs have decreased dramatically. For instance, renewable power is between 2 and 4 cents per kWh today."

So, is now the right time for hydrogen-fueled propulsion? "The answer is definitely yes," Schneider said. "There are different factors that are bringing hydrogen to market faster than we thought." On the one hand, there are the ecological aspects affecting companies worldwide, motivating them to lower their CO_2 footprint. On the other, there are the legislative guidelines such as Europe's climate protection goals for 2030. They require certain sectors to cut their CO_2 emissions by 30 percent compared to 2005. "Many truck makers are realizing that very soon there's going to be a zero-emission vehicle (ZEV) mandate, not only for light-duty vehicles as in California today, but for heavy-duty vehicles as well. And that is pushing hydrogen forward, as the only option for long-haul trucking (40t) and beyond," he explained. Experts expect up to 13 percent of Class 8 trucks to be hydrogen-fueled in 2030 in Europe due to CO_2 regulations and in the U.S. states with the ZEV mandate.

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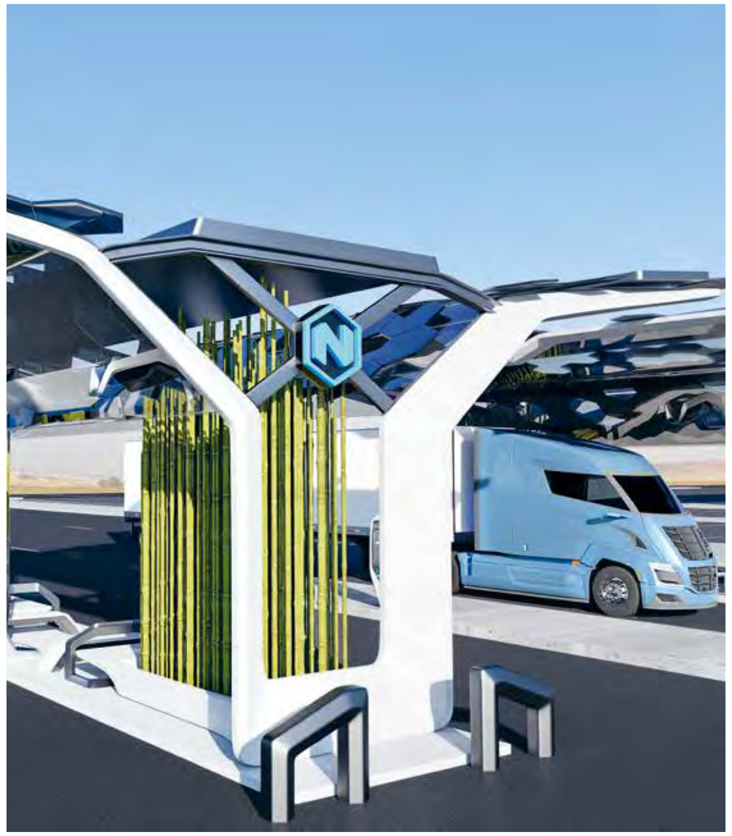

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1_H_2 truck stop: Nikola plans to build a network of 700 hydrogen fueling stations in the U.S.

2_Cockpit view of a Nikola truck: Most driving functions are controlled digitally using a touchscreen display.

3_For zero-emission transport: The Nikola Two will be produced in both a hydrogen and a battery-electric version.

745 miles

Nikola trucks have a range of 1,200 kilometers (745 miles) with a full tank of hydrogen.

Like a new technology itself, changes of thought also pose a challenge. Schneider points to the which-comes-first challenge. “We are always reminded of the ‘chicken or egg’ dilemma. Does the infrastructure or the vehicle come first? That has always been the question,” Schneider said. “There are around a hundred hydrogen stations in the U.S. and about the same number in Europe, and that’s not close to being competitive with fossil fuels or even electric charging, so far. What happened was that the investment didn’t come in hydrogen, but now it is coming. That’s really a big difference.”

The rethinking has begun. “Customers now want to reduce their ecological footprint and transport their freight emissions-free. But they don’t want to make any compromises,” Schneider noted. “With hydrogen, you can do fast fueling and get the same range. And with renewable hydrogen, you can get well-to-wheel zero-emissions on both the truck and the infrastructure.” It is difficult for long-haul trucking companies to justify waiting hours for charging and giving up that much cargo. Time is money, and that is especially true for cargo weight. Class 8 BEV trucks have 7 tons of battery alone.

The Nikola Strategy: Everything from a Single Source

Nikola plans to solve this dilemma with a smart business model requiring massive investment: “Regarding the ‘chicken or egg’ dilemma, Nikola is bringing the omelet. We are rolling out stations in parallel with our fleets of vehicles,” Schneider explained. With the company’s ‘Total Cost of Ownership’ leasing model, the goal is that the cost to customers would be predictable since they pay a fixed cost, price per mile, considering that the truck, fuel and maintenance are all included.

Hydrogen is expected to be produced right at the stations using current from renewable sources, supplemented by grid electricity and then stored at mass quantity (10 tons of hydrogen / or 1.25 days of storage) to provide power flexibility and backup hydrogen. The company intends to produce green electricity in its own solar farms while buying surplus electric current from suppliers of wind energy and hydropower.

According to the company, there are already 14,000-plus pre-orders for the trucks, including 800 for Anheuser-Busch InBev. The network of hydrogen-fueling stations is expected to grow all along the primary American truck routes, focusing first on California.

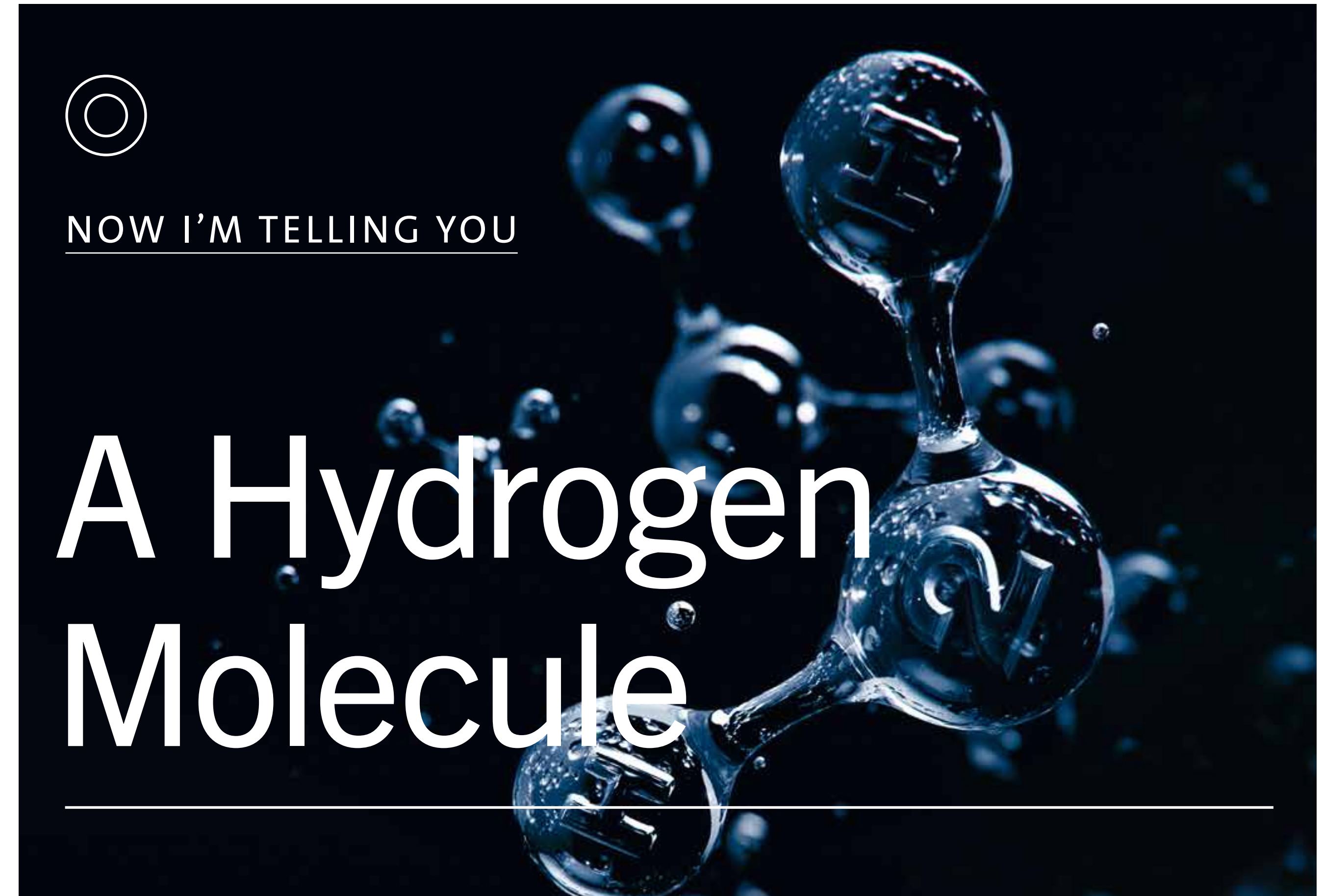
The startup is betting on collaboration with a range of companies, including the German auto supplier Bosch and the commercial vehicle manufacturer CNH Industrial (IVECO and FPT Powertrain) that Nikola is partnering with to build the Nikola TRE BEV in Ulm, Germany. The company’s hydrogen infrastructure partner is Nel ASA, and Hanwha is providing solar panels for the production of electricity. In early March, Nikola announced its merger with VectoIQ, becoming a publicly traded company to be listed as NKLA later this year.

Vision: The Largest Hydrogen Network in the World

For light-duty trucks, fuel cell technology has already matured to the point that a fill-up only takes five minutes and is good for 300 to 500 kilometers (186 to 310 miles). Now it’s the heavy-duty trucks turn. In heavy-duty, Nikola is developing fuel cell hardware to compete with diesel in performance (300 kW), fueling time (15 minutes) and range (800 kilometers or roughly 500 miles).

Starting in 2023, Nikola and IVECO plan to launch the TRE, along with hydrogen-fueling stations in the United States as well as Europe. Schneider outlined the timeframe: “Next year, we want to produce one to two tons of hydrogen via electrolysis. In 2022, our goal is to quadruple that amount by producing eight tons in an expanded electrolysis station. By the end of the decade, we plan to have hundreds of stations in the U.S. Every station will serve at least 200 vehicles.” It’s the vision of Trevor Milton, Nikola’s founder and CEO, to operate the world’s largest network of hydrogen-fueling stations.

In January 2020, the Hydrogen Council forecast steep declines in the costs of producing hydrogen. Schneider is convinced that this will accelerate the use of fuel cells. “If you can get the price down to \$5 to \$6 a kilogram (\$2.2 to \$2.70 per pound), then you are starting to compete with fossil fuels today,” he said. Schneider is certain about one thing: “The fuel cell is ready to reach the range and power of the diesel. We’re essentially replacing the diesel one-to-one.”



NOW I’M TELLING YOU

A Hydrogen Molecule

Let’s be honest: Do you believe in the cycle of life? Eternal rebirth and so on? Based on my experience, there is something to this. I come from water and will return to it, at least if all goes well. In a water molecule, my twin brother and I are firmly bound to an oxygen atom. This is a rather unequal partnership, incidentally. While we are infinitesimally small and light – each of us only consists of one proton and one electron – one could easily call an oxygen atom downright obese. It weighs nearly sixteen times as much as an atom of hydrogen.

People have been using technical means to extract me in pure form from metals for 300 years. How anachronistic! Today, when I am discussed as an energy carrier of the future, the idea is to use electric current from solar or wind systems to tear us away from oxygen. Then we are compressed for transport. When I finally end up in the tank of a fuel cell vehicle, I am subjected to compression 700 times more powerful than typical atmospheric pressure. The effect is brutal, but the tank would have to be much larger than a car if the pressure were much less.

But then I regain my freedom. Fuel cell cars need electricity to propel them over every mile they are driven. And fuel cells produce it by combining us, in the form of two tiny pairs of twins, with one oxygen pair. In the new configuration, we exit the car via the exhaust as pure water. Didn’t I say earlier that eternal life exists?

Three, Please – with Everything!

Electric cars need green electricity. Fuel cell vehicles need hydrogen. Neither is available in abundance. And now internal combustion engines are expected to run on synthetic fuels. Is all this going to pay off? An essay.

"It is better to have than to need." No one knows where this saying came from, but the originator might have been a civil or electrical engineer back in the early 20th century. Then, as the infrastructures for the electric industry and transportation emerged, allowances were always made for the unforeseen. And that worked out quite well for a while. But the times are long gone when a country would more or less build economically important infrastructure in reserve. Meanwhile, the climate neutrality that society is targeting requires substantial investments. There is still the need for "filling stations" for electric cars. Even if the electricity for the e-vehicle, in the absence of a Wallbox, comes out of an electric outlet, it still has to be generated. This applies to the hydrogen that will power fuel cells as well. Incidentally, synthetic e-fuels do not bubble up from desert sands either.

Now the burning question is, how can an infrastructure be created at the least possible expense that would enable climate-neutral transportation? And does it really make sense to bet on different technologies and have to finance several infrastructures in parallel? Several studies recently investigated what an overall transportation strategy might look like if it were optimized for economic costs.

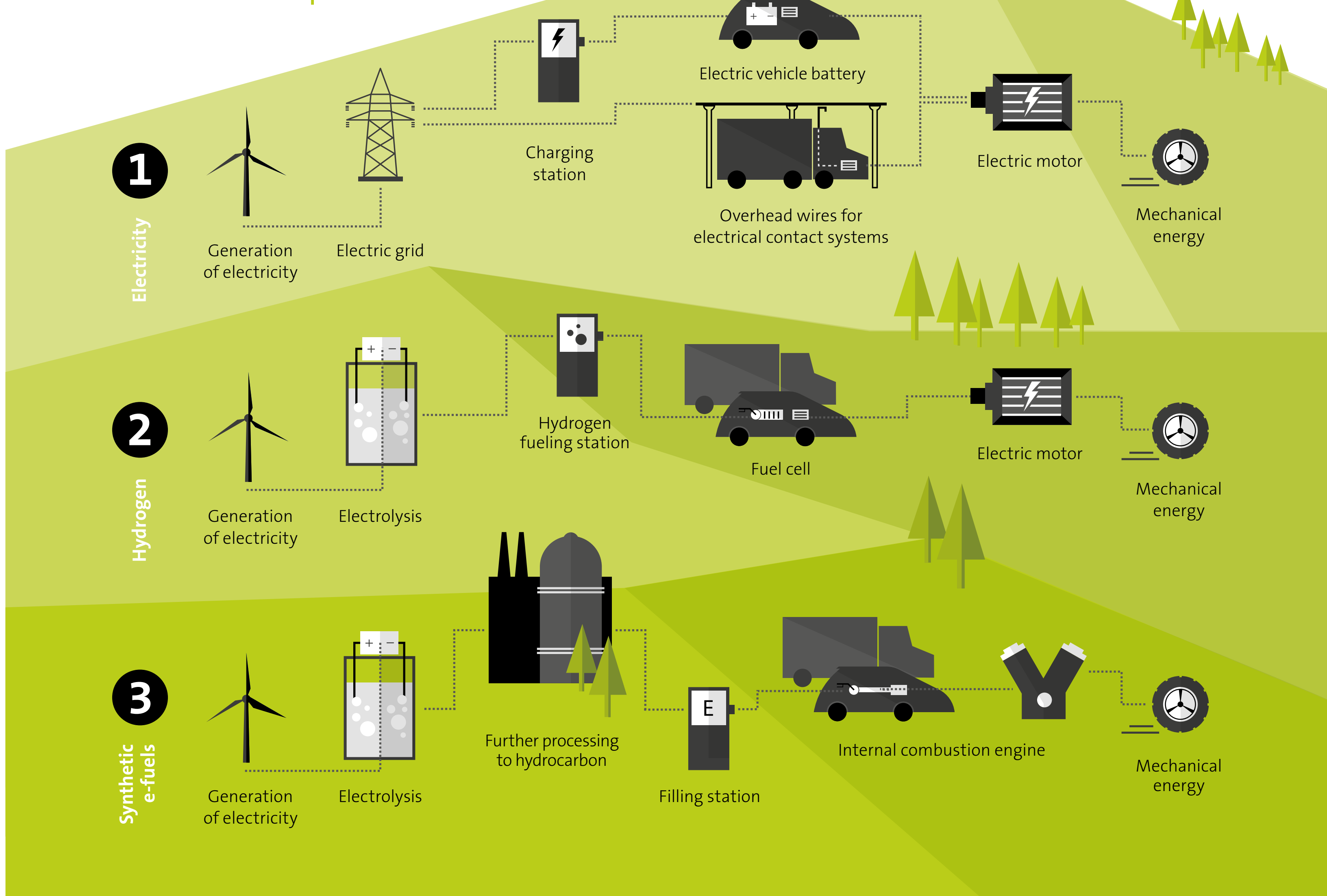
Fuel Cells Optimize Costs

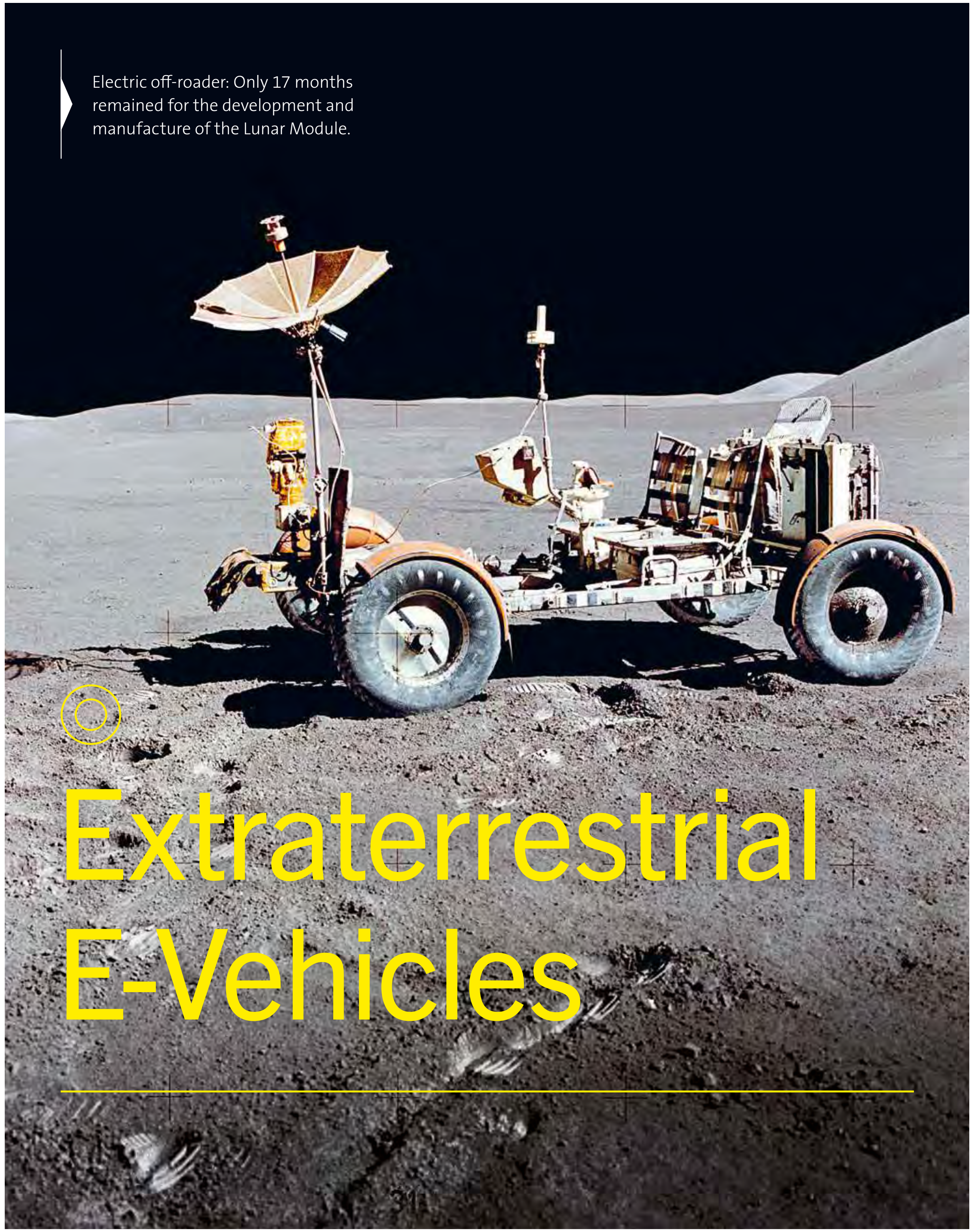
For example, the Jülich Research Center explored several "Paths to the Energy Transition." As the phrase suggests, transportation is just part of a comprehensive transformation that is supposed to bring an 80 percent reduction in greenhouse gases, or, in a second set of scenarios, to a 95-percent reduction. In some ways, the findings are no surprise, but they are seldom articulated so openly. The objective itself makes a big difference. If you plan on just an 80-percent reduction, you are potentially making a disastrous investment. Only a 95-percent goal makes it possible to achieve the two-degree objective of the Paris Climate Accord and therefore a viable course for the future. In the transportation sector, this means no fossil fuels will be used after 2050, not even natural gas. All-electric, battery-powered vehicles will reach just a 25 percent market share in the car segment and even less than 10 percent for trucks. By contrast, fuel cells will provide the propulsion in a third of all cars and three-quarters of all trucks. An infrastructure to generate, transport and store hydrogen would have to be created for industrial applications anyway, according to the Jülich researchers. They point out, however, that a 95-percent reduction could hardly be achieved without energy imports in the form of hydrogen and synthetic fuels. And they admit their analyses show that "a relatively small variation in production costs leads to a significant change in the selection of powertrain technologies."

It is above all the purchase price of the vehicle that determines how costly climate-friendly mobility will be for the consumer. In the end, the cost of an energy infrastructure, amortized over a 20- to 30-year cycle, is ultimately not so high that it would produce a clear preference for specific types of powertrains. A study by the Research Association for Combustion Engines involving more than 40 experts from various sectors demonstrates this. If you determine the best case in each instance, the total mobility costs are 29.50 euros/100 kilometers for electric, 29.90 euros for fuel cells and 28.40 euros e-fuels (around $51.30, $52 and $49.40/100 miles).

Less than 30 cents per kilometer (around 50 cents per mile) for a climate-neutral vehicle in the C-segment? And all the wind turbines, electric lines, electrolyzers and so on are thrown into the calculation? Well, let's order three with everything! There is just one small flaw in the computation: It doesn't cover taxes and fees. ◎

Three Paths to Climate-neutral Transportation





Electric off-roader: Only 17 months remained for the development and manufacture of the Lunar Module.

Extraterrestrial E-Vehicles

Astronauts didn't just leave footprints on the moon's surface – they also left three lunar rovers behind. And they happened to be great electric vehicles.

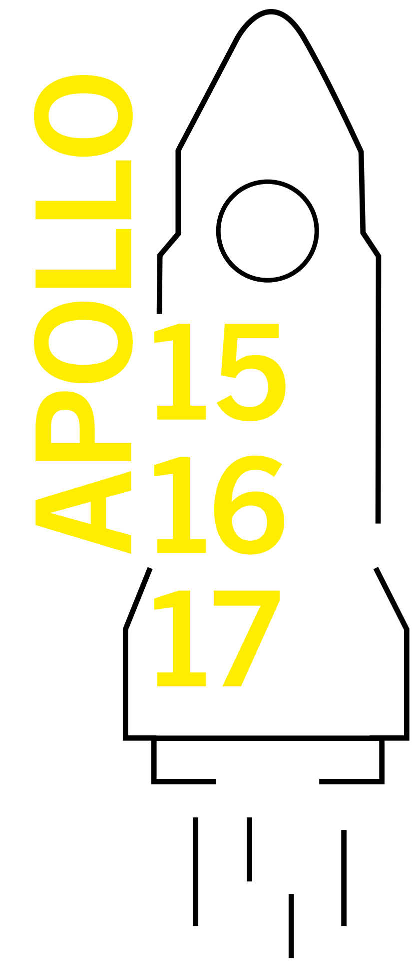
The Apollo 15 mission during the summer of 1971 was the fourth expedition to carry human beings to the moon. The American astronauts had a novel object on board: a Lunar Roving Vehicle (LRV). The homely buggy-like vehicle gave the space travelers a number of advantages: It greatly expanded their range of movement since it used energy sparingly and allowed relatively long stays out in the hostile lunar environment. It could also transport extra tools, making it possible for the astronauts to collect more samples from the moon's surface.

Short Development Phase

The engineers assigned to the LRV had just 17 months to develop the vehicle. It was a short timeframe compared to the 60 months needed for the astronauts' spacesuits. The U.S. space agency NASA had been working on lunar vehicles for a fairly long time, but it was the moon landing in the summer of 1969 that accelerated the project. The Apollo 14 mission in February 1971 underscored the importance of this type of vehicle. The astronauts on that mission had to use a kind of handcart during their excursions, which proved to be difficult and time-consuming.

A Collapsible Solution

Boeing won the bid to develop the lunar vehicle in the fall of 1969. NASA provided concrete specifications, and General Motors and other U.S. companies also took part in the $38 million project. The vehicle had to be highly reliable and safe. It also had to be lightweight, which is why metals like aluminum and titanium were used. Once complete, the lunar rover weighed just 210 kilograms (463 pounds), but it could transport significant additional weight. Since there was no room for it inside the lunar module, it had to fit into a triangular chamber between two of its feet. The solution was a foldable chassis with slanted tires that unfolded almost completely by themselves when the chamber was opened. The LRV consisted of an undercarriage, four wheels made of a dense mesh of galvanized steel wire, two seats, and superstructures containing instruments and drive systems.



Navigation System

Despite its spartan appearance, the Lunar Rover had ground-breaking systems onboard, including a navigation system. It gave the astronauts a direct route back to the shuttle if they traveled out of sight. The system is based on a directional gyroscope unit aligned with the lunar north, supported by a position indicator and solar-shadow tracking device. It uses lunar north and the sun as key reference points.

1


2

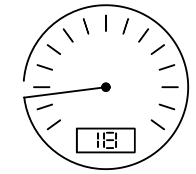

3


1_When folded up, the Lunar Rover fits into a three-cornered chamber.
2_The rear-end folds out and the rear wheels spring into position.
3_The front-end unfolds and the front wheels spring into position.

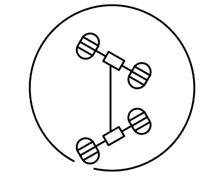
The Search for the Right Propulsion
But how would the drive system actually work? Several scientists had already addressed that issue before NASA did. Their concepts involved rocket fuel, hydrogen peroxide and hydrogen, which were supposed to deliver energy by means of gas, steam turbines or fuel cells. But NASA had a different form of propulsion on its wide-ranging specifications list: a battery drive system in which each wheel would be powered by an electric motor. The lunar rover was going to be an electric vehicle.

Electric Motors in the Wheels
In the end, two 360-volt, silver oxide-zinc batteries would propel the LRV. They featured low self-discharging at a comparatively high capacity and a low power-to-weight ratio. NASA had already used batteries of this type on its lunar module. While one of the two non-chargeable batteries provided the LRV's independently controllable axles with energy, electricity from the other flowed into the wheels. In its hub, each contained a 180-watt, direct-current electric motor with an output of 0.25 horsepower. This guaranteed that the vehicle could still be driven even if several motors broke down. If one battery ever malfunctioned, the other would take over its tasks. One key function was managing battery temperatures, as the surface of the moon ranges from −155°C (−247°F) to +120°C (+248°F). Multilayer insulation and wax boxes helped to regulate battery temperatures.

Still Drivable
The three lunar rovers from Apollo 15, 16 and 17 are still on the moon. They covered a total of 90 kilometers (56 miles) during their missions and completely fulfilled the expectations for them. No astronaut has ever expressed the need for their improvement. Today, one of their developers, Ferencs Pavlics, would merely make changes to their batteries and electric motors. In those cases, today's enormously compressed energy and the progress that has been made in efficiency and weight are too significant to ignore. Still, the lunar rovers are likely to be drivable even today and would merely need to be supplied with a few new components. ◎

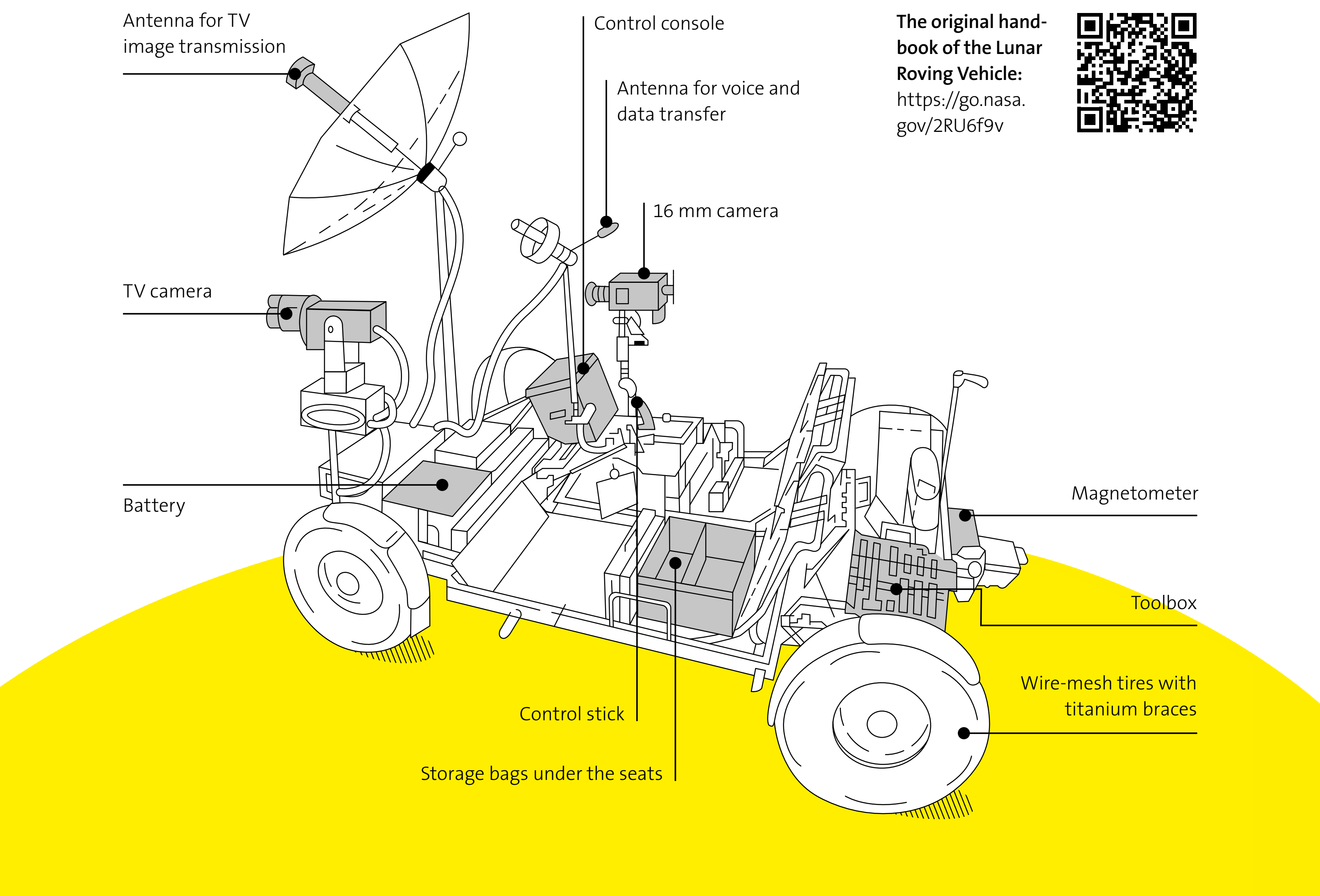


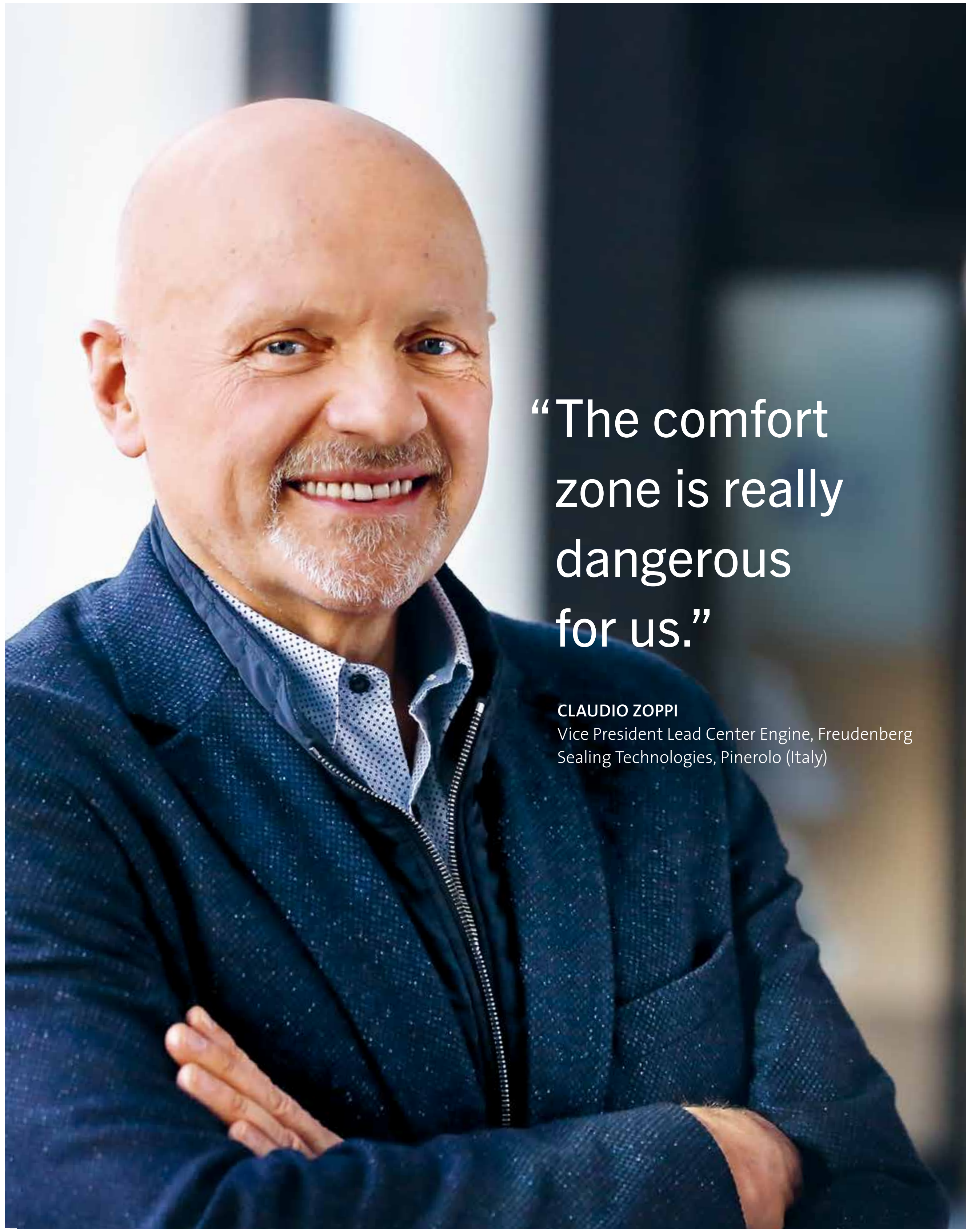
11 mph
was the highest speed that the Lunar Rovers achieved on the moon.



9 ft., 10 in.
was the turning circle of the LRV, thanks to independently controllable axles.

The original handbook of the Lunar Roving Vehicle:
https://go.nasa.gov/2RU6f9v





“The comfort zone is really dangerous for us.”

CLAUDIO ZOPPI
Vice President Lead Center Engine, Freudenberg Sealing Technologies, Pinerolo (Italy)

“We have lived through a great deal of change.”

MELANIE SCHNEIDER
Vice President Sales, Freudenberg Sealing Technologies, Weinheim (Germany)

"There Is A Time for Every Invention"

How do we deal with change? Two Freudenberg Sealing Technologies managers, Claudio Zoppi and Melanie Schneider, talk about disruption, innovation and the future of alternative powertrains.

MS. SCHNEIDER, MR. ZOPPI, LET'S TALK ABOUT CHANGE. HOW HAS YOUR NORMAL WORK ROUTINE CHANGED SINCE THE START OF YOUR CAREER?

Claudio Zoppi: There were no computers back then. That's the obvious change. But I find it much more exciting to look at the way people used to work and how it has changed: the speed of our communications. The frequency of discussions, email messages, and the exchange of information. What once took a week now takes a day.

Melanie Schneider: I've now worked at Freudenberg Sealing Technologies for twenty years, and everything has become faster and more complex over this period. Today, all employees really work globally. They have to keep an eye on time zones and their intercultural projects.

DOES THIS CHANGE YOUR LEADERSHIP STYLE?

Schneider: Certainly. The approach used to be "command and control." Today, there is much more information. To some extent, each of us has become a sensor in a complex world. And it has become important for managers to pick up even the faintest signals.

Zoppi: That is a nice image. I've also had to expand the range and adjust the orientation of my antennae. Gearing them to other cultures, for example. Sometimes certain details mean absolutely nothing to you. In other cases, they mean a great deal. I am sure that I've rushed through discussions too quickly at times.

Schneider: And that is a major challenge. Moving more slowly so you are ultimately faster.

Zoppi: Yes. If you proceed more carefully, you're more likely to reach your goal.

WHY DO PEOPLE OFTEN FIND CHANGE SO DIFFICULT?

Zoppi: It's always unpleasant to leave your comfort zone. It's only human to want to stay in a safe, protected area. As a company, we have to create spaces where people feel safe. Employees who worry that their supervisors will criticize them will never leave their comfort zone. But then they don't grow, they don't develop, and they will never be innovative.

NOBODY LIKES TO MAKE MISTAKES.

Zoppi: But you have to make mistakes if you're going to learn.

Schneider: Even scientific progress works that way. Testing is used to determine what doesn't work, in order to show what is possible. If you don't get rolling, you aren't going to reach your destination. Incidentally, that is a strong argument for diversity: The more diverse the participants are, the greater the diversity of ideas.

Zoppi: Any change is costly. But we always come out ahead in the process.

Schneider: Good point. We certainly give something up, but we get something in return.

Zoppi: Letting go is always difficult. This comes back to changes in management. Many managers have had a hard time giving up power, and that's still the case, especially if they fail to understand how many new options they gain in the end.

> It is only human to want to stay in a safe, protected zone.

BUT WOULDN'T IT MAKE MUCH MORE SENSE RATIONALLY FOR COMPANIES TO CONTINUE TO DO WHAT THEY DO BEST?

Zoppi: If animals keep going to the same waterhole, and it dries up, they die of thirst. You have to look for other water sources ahead of time. It is really dangerous for us to be in our comfort zone long-term.

Schneider: The path to innovation can be tough going. It takes someone who will encourage staff. That is another reason why agile work is so popular today: achievable milestones, one after another.

Zoppi: And staff should be recognized as well. If everything goes well, employees and supervisors often believe the work was just a job that had to be done. No, the supervisor should congratulate the employees at the point where there is something to celebrate.

Schneider: Many people are their own biggest critics. What good does it do if I, the supervisor, add to the criticism? It is much better to encourage employees if they have reflected on their work themselves.

HOW WOULD YOU DESCRIBE THE CURRENT STATE OF ALTERNATIVE POWERTRAINS?
Schneider: The market has been completely and violently shaken. I am really curious as to what the next couple years will bring. Everyone used to have their own car. In the future, people may turn to car-sharing. There's so much going on in the field. You can sense it at Freudenberg Sealing Technologies, where we have taken a major step forward by acquiring the battery manufacturer XALT Energy and the fuel cell company Elcore.

Zoppi: It all reminds me of the first iPhone. My son had one. At the time, I was convinced that I would never use it. And, of course, I have a smartphone today. Even the people who've been saying that they don't want an electric car will end up owning one.

Schneider: I grew up out in the country, and my driver's license was the ticket to freedom. But I don't believe this will still be the case for the next generation. A lot is going to happen in the next five to ten years.

Zoppi: Consider all the questions regarding infrastructure and range that we wonder about today – how do we know whether the coming generation will use cars exactly the way we've always used them.

Schneider: It's a paradigm change. People are buying mobility, not cars.

Zoppi: We do things with our smartphones that we hadn't even thought of a few years ago. That's why development timeframes are getting shorter and shorter. No one can afford to develop something over a period of years, only to see the requirements change long before it is finally finished. Think about the fuel cell. As a propulsion system, it has the potential to completely change the design of a car.

YOU SAY THAT WE ARE ON THE BRINK OF A BREAKTHROUGH IN ELECTRIC MOTORS. BUT THE ELECTRIC MOTOR IS MORE THAN 100 YEARS OLD. BREAKTHROUGHS HAVE BEEN ANNOUNCED A NUMBER OF TIMES. YET WE STILL DON'T HAVE THEM.
Zoppi: There is a time for every invention. Artificial intelligence has been around for a long time. But there was no opportunity to use it. It is only now that we have the computing power for neuronal networks, along with the cloud and Big Data. The situation with electric powertrains is similar.

3.5 billion

people have smartphones, the first appearing in 2007. In 2012, only one in seven had one.

It is like a bottle of ketchup: You never know precisely when the ketchup will actually come out or the exact amount. But when it comes to electric mobility, the bottle is now being thoroughly shaken.

HAVE AUTOMAKERS FIGURED OUT THAT THEY HAVE TO CHANGE?
Schneider: I think they have. Of course, they can keep doing what they already do best. We at Freudenberg Sealing Technologies will continue to bet on our strengths as well. But we are looking ahead.

Zoppi: A company can prepare for transitions. There is no disadvantage in at least thinking through the changes. There may still be automotive executives who say they don't believe in a fast transformation, but they are certainly getting ready behind the scenes. It is like a bottle of ketchup: You never know precisely when the ketchup will actually come out or the exact amount. But when it comes to electric mobility, the bottle is just being thoroughly shaken.

MUCH OF THE DISCUSSION HARKENS BACK TO FREUDENBERG'S HISTORY, WITH THE COMPANY STARTING OUT AS A TANNERY AND FINALLY MOVING INTO HIGH-PERFORMANCE PLASTICS. DOES SOMETHING LIKE THIS AFFECT OUR EVERYDAY ROUTINES?
Schneider: We like to guide our customers through our company exhibit, to point out that we have lived through a great deal of change over our history. We've proven we can do it.

Zoppi: I believe Freudenberg demonstrates this every day. Now we're ready to transform ourselves.

Schneider: That is something you can feel. For example, there's the fact that the company was ready to invest heavily in fuel cells and batteries. We're ready to tackle new projects. That encourages our employees. It is a signal. It makes us proud to move forward with our company.

SO YOU AREN'T AFRAID OF CHANGE?
Zoppi: No, on the contrary. I think we live in exciting times. I would be happy to pursue this as long as possible.

WHEN ARE YOU GETTING YOUR ELECTRIC CAR?
Zoppi: I think my next car could be a hybrid.

Schneider: My next car will certainly be an electric vehicle. If I even buy another one. Maybe I won't need it.

Zoppi: Wait a minute. You can't do that. We have to keep selling seals!

Schneider: That's true, but perhaps for other applications.

Zoppi: (laughs): Look, that sums up electric mobility quite nicely. I've heard that the growth of bamboo is totally unobtrusive when it starts out. It sends out its roots and remains inconspicuous. Then it suddenly shoots up and spreads out.

Schneider: We have to be patient. As the old saying goes, "You can lead a horse to water but you can't make him drink." But we can keep the trough filled. That's what we are doing. ◎

Read more here: https://bit.ly/3ewZQvw

Mobility Resources

Coal, petroleum, lithium and cobalt are key resources for mobility. Where are they found and what countries extract them?

Source: Britannica, NORD/LB und Reuters.

Coal Mining (Steam Locomotives / Steamships)

Mobility Heyday: 19th century to the interwar years.

	1870*	1904/05**	1930**
1	Great Britain	USA	USA
2	Germany	Great Britain	Great Britain
3	USA	Germany	Germany
4	Belgium	Austria-Hungary	France
5	France	France	Russia
6	Austria-Hungary	Belgium	Poland

*GESIS – Leibniz Institute for the Social Sciences. / ** Encyclopedia Britannica.
*** Our World in Data (University of Oxford).

Oil Extraction (Cars / Aircraft / Diesel Locomotives)

Mobility Heyday: From World War I down to the present.

	1920*	1970**	2018***
1	USA	USA	USA (incl. Fracking)
2	Mexico	USSR	Saudi Arabia
3	RSFSR (USSR)	Venezuela	Russia
4	Indonesia	Saudi Arabia	Canada (incl. oil sands)
5	Iran	Iran	China
6	India	Libya	Iraq

*Data is beautiful. / ** BP. / *** U.S. Energy Information Administration.

Lithium / Cobalt Mining (E-Mobility Batteries)

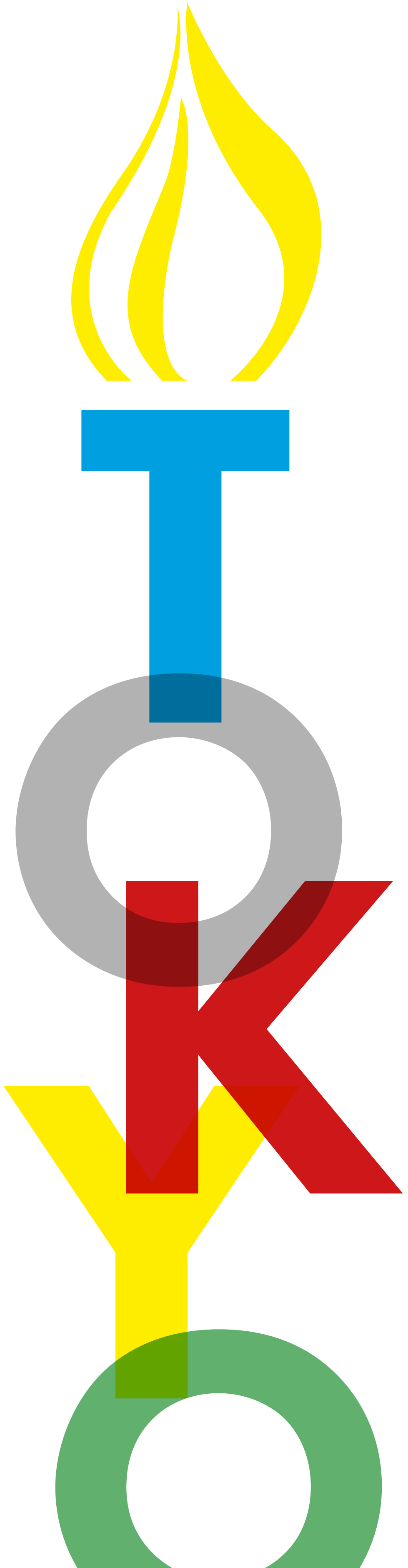
Mobility Heyday: Today

	Lithium 2019*	Cobalt 2019*
1	Australia	DR Congo
2	Chile	Russia
3	China	Australia
4	Argentina	Philippines
5	Zimbabwe	Cuba
6	Portugal	Madagascar

*Statista.

Fired Up for Hydrogen

Japan was the first industrialized country to adopt a national hydrogen strategy. The Olympic Games are expected to help secure a leading position for the nation in the technology.



If you want a zero-emission society, you need hydrogen – and a lot of it.

The Olympic Games are always an occasion for statements beyond pure sports competition. When Tokyo hosted the games in 1964, Japan presented itself as a high-tech nation with the help of electronic time measurement and the Shinkansen high-speed train. For the upcoming games in 2021, the organizers want to repeat this feat with robots and autonomous taxis. But their efforts are especially inspired by the dream of protecting the climate: The country wants to position itself as the torchbearer for a global hydrogen economy, in the truest sense of the word.

For the first time, the Olympic flame will burn hydrogen. It will come from the Fukushima Prefecture, the scene of the nuclear catastrophe of 2011, and will be extracted from water with the help of solar energy. An official of Japan's powerful Agency for Natural Resources and Energy stressed the symbolism of the arrangement. "This will heighten the public's awareness of the important role that hydrogen will play in the future."

Japan's government sees itself as the world's pioneer in generating electricity from hydrogen – and doing it without CO_2 emissions. It works like this: Hydrogen and oxygen enter into a chemical reaction inside the fuel cell. Heat and electricity are the result, with water as the sole byproduct. "Japan has led the world in the practical application of fuel cell technologies, for example, in the commercialization of fuel cells for cars and residences," the official said. To lock in the country's lead, the government adopted a national hydrogen strategy in 2017, and other countries followed suit. But Japan still stands out for its detailed, ambitious objectives as well as its close collaboration between industry and the country's political leaders.

Japan's Global Plans

The government has not limited its vision to Japan. By 2050, it wants to turn hydrogen into a real alternative to fossil fuels worldwide. On the one hand, over the course of this decade, it wants to build up a global supply chain capable of producing and distributing hydrogen on an industrial scale. On the other hand, it wants to quickly create mass markets to rapidly reduce costs, which are still high.

Vehicle manufacturing is an important sector in this regard. By 2025, the number of fuel cell vehicles in Japan alone is expected to rise from 3,600 currently to 200,000 and to 800,000 by 2030. Moreover, 1,200 buses and 10,000 forklifts are due to be powered with electricity from fuel cells.

Japan is also taking aim at energy production. Fuel cells are already providing electricity and hot water to apartments and individual homes, a market that requires no subsidies. Since 2009, 300,000 of the block heat and power plants, dubbed "Ene-farms," have been sold. In these cases, the "energy farms" still obtain their fuel from city gas, which has mostly been obtained from coal gasification. That is because the infrastructure for pure hydrogen is still insufficient. In 2021, the market leader Panasonic will introduce the first fuel cells to use pure hydrogen. If planners have their way, 5.3 million energy farms of both types will be in operation in 2030.

The national strategy also puts demands on electricity suppliers. Over the next ten years, they are supposed to build hydrogen power plants with an output of 1 gigawatt. That more or less equates to the capacity of a nuclear reactor. By then, the price of hydrogen is expected to fall 70 percent to $3 per kilogram. In 2050, the lightest chemical element is due to contribute as much as 30 gigawatts to Japan's electrical supplies.

Pioneer for an Emission-free Society

But the hydrogen plans had a difficult birth, Toyota engineer Katsuhiko Hirose recalled. He himself became a notable hydrogen convert in Japan. Toyota and Honda, which both sell fuel cell vehicles, had to put massive pressure on planners in the country's economics ministry to shift their focus away from electric-car batteries.

His own experience likely made it easier to convince them. After all, Toyota had selected him, of all people, the co-developer of hybrid cars, to design the automaker's fuel cell car, the Mirai. Until that point, he considered battery-electric and hybrid cars to be the quicker and better solution, not least because of high energy losses associated with hybrid propulsion and the lack of infrastructure. But Hirose is now singing a different tune: "You need a holistic vision for the de-carbonization of all society. We can't just handle the transportation end emission-free. We want to build our cars with neutral emissions as well." His message: If you want a zero-emission society, you need hydrogen – and a lot of it.

Like Japan's steel companies, Toyota is developing hydrogen-fueled blast furnaces for its factories. The country's energy expert also points to hydrogen's role as a portable, combustible energy storage medium. Operators of solar and wind power facilities can produce hydrogen with their excess electric current, which can be used in hard-to-electrify applications elsewhere – in trucks, ships, steel production and oil refineries, for example.

30,000

fuel cells annually is Toyota's goal for production capacity.

70 hydrogen buses are expected to be in operation at the Olympic Games.

The Search for Hydrogen Suppliers

But the real strength of Japan's strategy is that it has become a national movement, with political leaders and industry driving each other. The government is going all out to recruit hydrogen suppliers on a global scale. At the end of 2019, the first hydrogen transport tanker was built and launched by Kawasaki Heavy Industries.

For imports, the government has resorted to a strategy that has raised some eyebrows among climate activists. For example, starting this year, Japan is getting coal-generated hydrogen from Australia, and hydrogen produced from natural gas is due to be imported from Southeast Asia. It is only later that Saudi Arabia is expected to become a major supplier of "green" hydrogen produced from water with electrolysis, powered by electric current from renewable energy sources.

Japan Initially Resorting to Hydrogen from Coal

Japan's government is defending its use of coal and natural gas – along with its methods of carbon dioxide storage – as a key intermediate step toward a more rapid conversion to green hydrogen. The calculation: The more profitable the enterprise, the greater the incentive for governments, companies and investors to shift capital into innovations and to develop common rules and technological standards.

With the government's help, Japan's industrial sectors are now pressing ahead. In 2018, automakers teamed up with natural gas and oil companies, investors and other enterprises to form the "Japan H_2 Mobility" company to fund the construction of hydrogen filling stations. Toyota and Honda are also investing in new fuel cell vehicles. In 2019, Toyota introduced the second generation of its Mirai fuel cell vehicle and started selling fuel cell buses. The company also plans to increase its production capacity for fuel cells from a few thousand to 30,000 units per year over the next year or two.

Japan Inc. is already exporting its fuel cell technology. Toyota is offering many of its patents at no charge and selling its technology in the global market. The Portuguese bus manufacturer CaetanoBus is sourcing its fuel cell system from Japan. The technology company Panasonic is marketing its fuel cells for household use in Europe through an alliance with the German heating technology company Vaillant.

The Olympic Games as Jump-Start for a Hydrogen Society

The Olympic Games are supposed to give the country's hydrogen strategy an additional push, even domestically, as shown by two major projects launched by Tokyo's city administration. By the start of the games, the city's transportation agency intends to ramp up the number of hydrogen buses leased from Toyota from 15 to 70. With their blue exteriors and the words "Fuel Cell Bus" emblazoned on them, the buses are a clear advertisement for the integration of hydrogen into the Tokyo cityscape.

The other project is the first of its kind. After the games, the Olympic Village will be converted into a city neighborhood with about 5,600 apartments. Takeshi Ikawa, Tokyo's director of new development, pointed proudly to a line in the construction plan. "The first municipal hydrogen line in Japan will run here," he said.

The pipes will start at a hydrogen filling station north of the district, where hydrogen is separated from natural gas. From there, it will take a subterranean course over a few hundred meters to two fuel cell parks with an output of nearly 40 kilowatts. They are designed to supply a local shopping center and public facilities with electricity and hot water. Panasonic is also equipping 4,000 condos with small fuel cells. Ikawa said the objective is clear: With this new city district, Tokyo intends to show the world what a megacity might look like with sustainable climate policies. ◎

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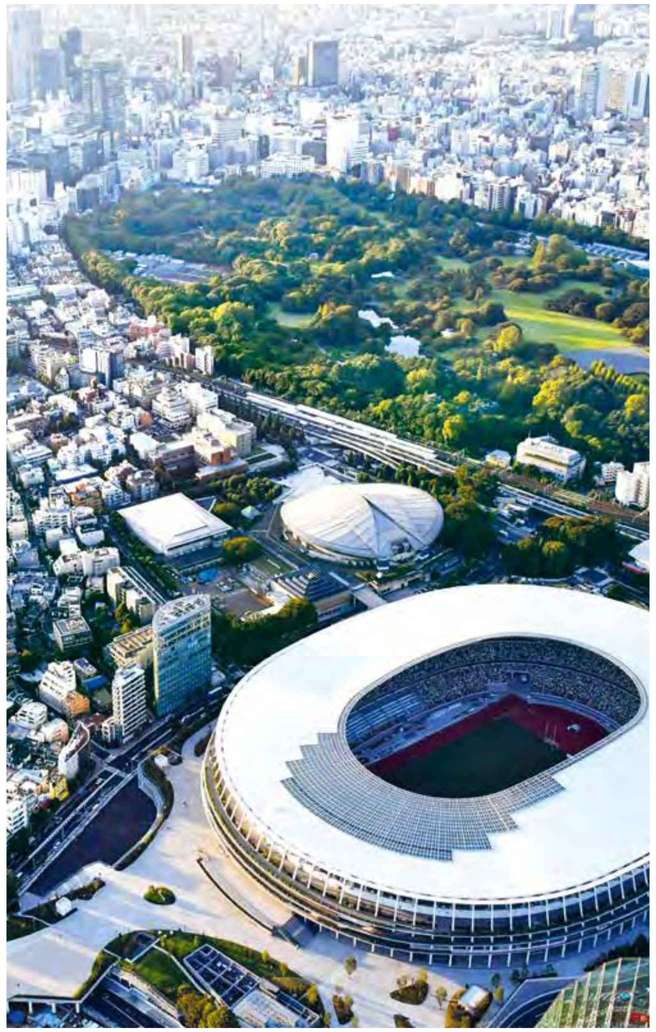

1_The athletes in the Olympic Village are expected to move around in battery-electric, autonomous vehicles, not with fuel cell propulsion.

2_Hydrogen buses like this one will be used in Tokyo during the Olympic Games.

3_The beating heart of the Tokyo Games can be found here: in the new national stadium.

What Is Driving Other Countries

Alternative powertrains are on the march around the world – but every country is different. Two FST employees, one from China and the other from Sweden, discuss the use of alternative drives in everyday life.

DEREK WONG, SHANGHAI
Sales Director of NOK Freudenberg China Automotive Industry

In just three years, the importance of electric mobility has grown immensely in China. Today, electric cars and charging stations are seen everywhere. There are two main reasons for this: License plate fees, which are very high in China, had been waived for electric cars for quite a while. But the incentive has not been offered recently, and the interest in buying an electric car has fallen off since July 2019.

But the market is still hotly contested. Virtually all of the leading international automakers have a presence in China to promote their electric cars. There are also local manufacturers such as an NIO that focus solely on electric cars and combine appealing design with innovative ideas.

Transportation brokering is other reason for the vehicles' popularity. In China, the main company is Didi, which is comparable to Uber in other countries. Many city dwellers buy an electric car and offer it as a shared vehicle using the Didi platform. It is an approach that combines two megatrends, electric and shared mobility. Transportation brokering is especially popular in large cities. I use driving-service apps every day so I don't have to look for a parking space downtown.

Electric cars with a range of just 400 kilometers (250 miles) are not a problem. In China, they are only used in major cities. "Shared" electric bicycles work very well in urban centers, too. You can use cashless payments for the transactions. Frankly, I haven't handled cash for months. People here are generally very open to new technologies and innovations. Fuel cells are the exception. The large tanks seem to scare people off. They apparently have safety concerns in mind.

JONAS HANSSON,
STOCKHOLM
Key Account Manager
Automotive Sales, Freudenberg Sealing Technologies

The government is still very committed to the issue. There are discounts on electric cars, and the number of charging stations is expected to double."

We now see electric cars everywhere in Stockholm. In just one year, their number has almost doubled to nearly 90,000 battery-powered vehicles. A full 8 percent of all the cars in Sweden are powered electrically. In Malmö, Göteborg and Stockholm, the number of charging stations is striking.

But the situation is entirely different outside Sweden's major cities. I happen to come from a rural region. Diesels still reign supreme there. We are a thinly populated country. Many commuters travel as much as 150 kilometers (93 miles) to work every day. And people are skeptical as to whether batteries can actually handle these distances during a cold winter. Facts are little help here. Indeed, in Northern Sweden, where people drive long distances, pure battery vehicles will not meet the needs and expectations.

In any case, the government is still very committed to the issue. There are discounts on electric cars, and the number of charging stations is expected to double. Sustainability, energy and climate are also hot topics in Sweden. You are surely at least somewhat familiar with a Swede named Greta. The diesel scandal in particular has sparked debates in this country over vehicle powertrains.

But it's also clear that Sweden can hardly manage this kind of future-oriented topic by itself. We need the support of other Europeans. We also haven't made much progress in fuel cells. There are only five hydrogen filling stations in Sweden.

Alternative powertrain systems are the future, but infrastructure will be the crucial issue. A great deal will depend on it.

Before the Long Slumber

Torpedo on four wheels: In 1899, “La Jamais Contente” exceeded 100 km/h with battery drive.

The question remained unanswered over the first quarter century of the auto industry: Which powertrain system would prevail? But then innovation, an oil boom and an automotive pioneer sped up the decision-making process.

In 1894, a French magazine offered to test the reliability of “horseless carriages.” It attracted 102 applicants for the 130-kilometer (81-mile) drive from Paris to Rouen. The scope of their creations was reflected in their powertrains, which included everything from gasoline engines to hydraulic systems, all the way to compressed-air, steam and electric contrivances. It was an indication that the competition for the title of the “most promising powertrain” was far from settled, even if it was only steam- and gasoline-powered cars that ultimately tackled the challenge.

A Speedy Electric Runabout

The “Motorcar Number 1” produced by Carl Benz in 1886 has been considered the pioneer in the development of the automobile. The car looked like a three-wheeled carriage and drew power from a combustion engine. In fact, an electric vehicle debuted in Paris five years earlier. Developed by physicist Gustave Trouvé, it relied on chargeable lead acid batteries and traveled at a speed of 12 kilometers (7 miles) per hour. Eighteen years later, an electric car driven by the Belgian Camille Jenatzy sped far faster down a road at the gates of Paris. Called the “La Jamais Contente,” the vehicle accelerated to a record speed of more than 105 kilometers (65 miles) per hour on April 29, 1899.

Three Types Stand Out

During this same era, Ferdinand Porsche produced an electric vehicle before he designed history’s first hybrid car. At the 1900 Paris Exposition, he introduced his so-called Lohner-Porsche, which weighed a staggering 1.2 tons and featured both an electric wheel-hub drive and an internal combustion engine. The wheat was just separating from the chaff at this point. The cars of the future were expected to be powered either by steam, gasoline or electricity. In 1897, Adolph Klose, President of the Central European Motorcar Association, was convinced of this. “The first category [steam] is likely to come into consideration mainly for cars on rails and for heavy road vehicles, while petroleum-fueled motor vehicles will circulate through large swaths of the country, and the smooth asphalt surfaces of large cities will be enlivened by cars powered with onboard electricity.” His prediction was not all that daring. What he described was already a reality in the United States, at least. In 1900, 1,688 steam-powered cars were produced there, along with 1,575 electric cars and 929 gasoline-fueled vehicles. They roughly split the market between them.

City Cars with Electric Power

The electric drive was concentrated in the cities. The vast majority of New York taxis used it. The same was true for its many buses. As the electrification of cities progressed, the opportunities to charge batteries expanded. Electric cars even found favor with women. They ran smoothly and quietly, and were clean. The steam- and gasoline-powered cars were another story. They were dirty and hard to steer. They were also difficult to start. Steam power required long warm-up periods to reach the proper driving temperature, and gasoline engines had to be cranked by hand.

Internal Combustion Engines Prevail

The fact that electric mobility was left behind is in part due to the invention of the electric starter, which greatly simplified the ignition process for combustion engines. Their range meanwhile continued to be unmatched. Political decisions did the rest. In the German Empire in 1906, the military was making decisions on truck subsidies. It decided to focus on long-range internal combustion engines that were equipped with uniform pedal arrangements and gear shifting so drivers would not have to continually adjust to different controls. Numerous breweries bought trucks suited to their operations. Meanwhile, the price for gasoline-powered vehicles declined with the mass production of the Ford Model T, even as the emerging oil boom in Texas cut the cost of fuel. Gasoline became available on a mass scale. Filling stations popped up like mushrooms. Electric powertrains lagged behind. Then they fell into a long slumber. ◎

E-Bikes in the Fast Lane

What is predicted for cars has already come a long way with bicycles: rapid growth in electrification. E-bikes are the latest trend.

It looks like a normal bicycle at first glance. E-bikes have been loaded with more and more technology.

Motors like these provide enormous assistance during pedaling.

At first glance, Victoria Pendleton would seem an unlikely advocate for electric bikes. After all, the 39-year-old Brit won Olympic Gold in 2008 and 2012 at the cycling track. She first mounted one of these advanced electric bicycles during a vacation in California. When her uncle invited her to try out one of his e-bikes, she hesitated. “I felt like it would be cheating at first,” she said. But when they took off on a ride together, she discovered she enjoyed it. Headwinds were no problem for the battery-supported pedaling. She didn’t work up a sweat, and she overtook bicyclists wearing sports gear. She was soon a convert to e-biking, to the point of designing one herself.

E-Bikes Stimulate Saturated Market

There is no question that e-bikes are enjoying a surge in popularity worldwide. For the bicycle sector, they appear to be what smartphones were for the mobile phone market several years ago: a shot of adrenaline for a saturated market. Electric bikes may have been derided as a vehicle for seniors at the start, but they have long been considered an option for anyone. Electric bikes have wide appeal to riders of every stripe, from children and commuters to athletes and retirees. The most sought after electric models are city, trekking and mountain bikes. But even cargo-hauling bicycles have their fans.

A Business Worth Billions

The picture from the sales figures is clear: While 4.2 million bicycles and 110,000 electric bikes were sold in Germany in 2008, the figures were 3.2 million for conventional bikes and nearly a million for electrified bikes a decade later. As electric bikes cost significantly more, the average sales price for the vehicles in Germany rose from 446 to 756 euros in the same period. This drove revenues skyward. In the United States, the total number of electric bicycles sold increased eightfold between 2014 and 2018. The sale of electric bikes has now become a business worth billions. Deloitte expects to see the sale of 130 million electric bikes around the world between 2020 and 2023.

Features Found in Cars

What has made e-bikes such a success? One factor may certainly be an increase in environmental consciousness, but it is more than that. A survey conducted by the automotive supplier Bosch points to the increase in riding pleasures thanks to help from the motor. Health aspects are also often cited. One-third of the respondents could also see themselves commuting to work on one of these high-tech vehicles at some point. The technology in them is becoming more and more sophisticated. Along with improved motors in the bottom bracket or in the wheel hubs, the standard features include high-performance lithium ion batteries and sensor systems to control output. Sophisticated wheel and disc brakes provide reliable braking at increased speeds. There have also been technical advances such as ABS and automatic transmissions that were exclusively seen in automobiles until now. A display or smartphone on the handlebars provides all the key data – speed, current route, battery charge, pedaling frequency and fitness data. The e-bike has become the rider’s fully networked companion, whether cycling on mountainous terrain, commuting to work or zipping around a gridlocked city. ◎

E-Bike? Pedelec?

When people talk about e-bikes, many of them – including us – are referring to pedelecs (pedal electric cycles). In pedelecs, the electric motor supports the rider’s pedaling. The assistance shuts off at 25 km/h (16 mph) when pure muscle power takes over. “Speed pedelecs” support pedaling up to 45 km/h (28 mph), which qualifies them as a small motorbike. Strictly speaking, full-fledged e-bikes are electric motorcycles since pedaling is not required.

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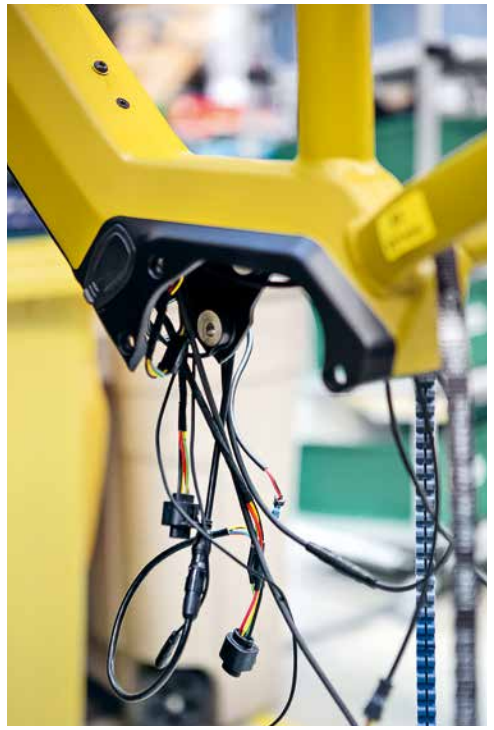

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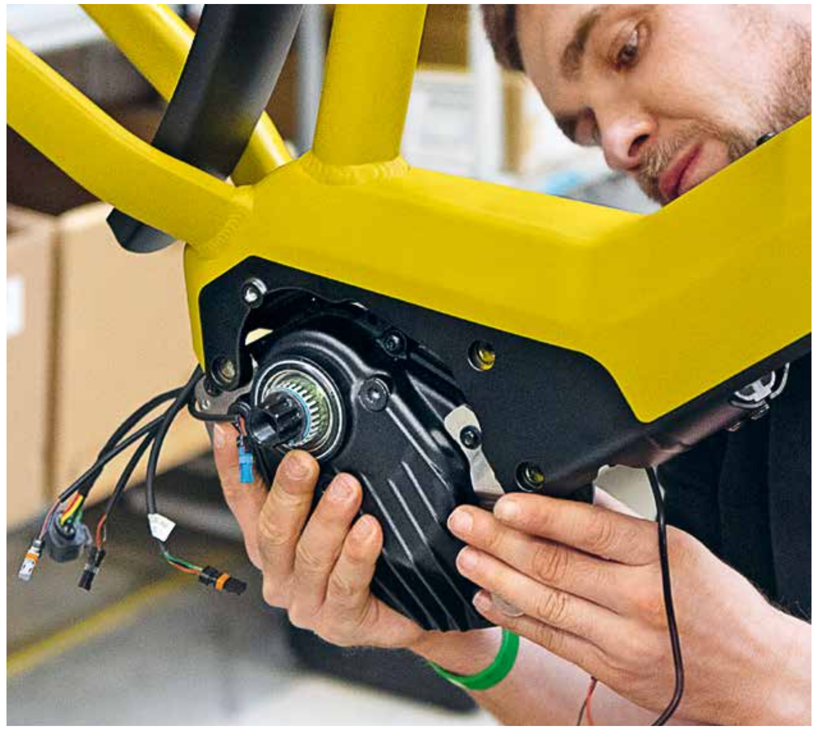

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1_Lithium ion batteries are also in demand for e-bikes.

2_This e-bike is still waiting for its propulsion system …

3_… and here it is already installed.

4_The production trend for e-bikes only knows one direction: up!

Dr. Sandra Wolf,
CEO Riese & Müller

FROM REAL LIFE …

Riese & Müller has produced e-bikes since 2012, even though specialized dealers thought its new focus was lunacy at the time. Yet the number of its employees has increased from 35 to 550.

It was 27 years ago that engineers Markus Riese and Heiko Müller founded the bicycle company bearing their names in Darmstadt, near Frankfurt. The first product was the Birdy folding bicycle, which they developed themselves. The inspiration for the name was the riding experience that its full suspension created. The kicker was the fact that the suspension points could be used to fold up the vehicle. Thanks to its space-saving design, the Birdy became an everyday companion that could be brought onto buses and trains.

Everything in One Basket

The Birdy is Riese & Müller's warhorse. Although modified multiple times, the folding bicycle has been sold continuously right down to the present. The fact that the bike is viewed as an everyday companion and a pioneer in daily mobility is still important to Riese, Müller and Dr. Sandra Wolf, who is now on the executive team. That's why the bicycle maker is moving in new directions and has radically reshaped its lineup. Since 2012, it has been electrifying its products and now sells premium e-bikes. At the start, this would have led to some head-shaking. Niche products of that kind seemed to mainly target seniors. But the company's new orientation has been paying off. The number of employees at Riese & Müller has risen from 35 to 550 since the changeover, and its revenue rose 38 percent to 145 million euros during the last fiscal year. The company recently moved into a new company headquarters, which was sustainably designed from the ground up and where high-end bicycles are assembled.

The Transition Comes Naturally

Wolf sees climate change as one of the drivers of the considerable demand for electric bicycles. "Our customers want to take countermeasures by switching to bikes," she said. It's no surprise that Riese & Müller have scored big in markets that, at least in urban environments, are in the process of moving beyond the automobile. They include the German-speaking countries, the Benelux states and Scandinavia. "Early on, we anticipated that electric bikes would be important for urban mobility," Wolf said. "And this change develops further if the benefits come naturally." Electric bikes are facilitating the transition from cars to bicycles. The motor can be switched on to improve the driving experience. Commuters don't have to work up a sweat. They can meanwhile say goodbye to traffic jams on the way to and from work, not to mention the search for a parking spot.

E-Bikes Support the Mobility Transition

Wolf believes the e-bike can promote the mobility transition. "It has a kind of crazy momentum. A lightness and pleasure defines the e-bike ride on a micro level. That's priceless," she said. That's why she considers electric bikes to be an important part of the mobility mix of local public transit, cars and bicyclists. And if cars give up the streets and roads, cities will become more livable, among other things. But cars still play a role for Riese & Müller's customers to some degree. Wolf says many of them have the same expectations of their e-bikes that they have of an automobile. "That is why we think in terms of 'extreme premium.' But not to manufacture a luxury product, but rather something tremendously reliable." It's an approach that Riese & Müller has scrupulously taken so far. ◎

ESSENTIAL – THE ELECTRICAL OUTLET

Electricity comes from electrical outlets. Everyone knows that. But this wasn't always the case. When electricity became available to private households, it was exclusively used for lighting. Lamps were wired directly to the electrical grid. The first large electrical appliances obtained their electric current through lamp sockets. For example, vacuum cleaners were connected to lamps. In apartments, the cost of electricity was calculated based on the number of lamp connections. The use of specially designed electrical outlets, eventually with grounded contacts, represented a quantum leap in convenience and safety around the 1930s. But there was a catch: Different countries developed their own designs. Today, there are more than a dozen different plugs throughout the world. This didn't matter a century ago. No one was thinking about travelers who had to connect their smartphones or electric toothbrushes to a source of current. Notwithstanding the national differences, inductive charging or USB connections could soon bring an end to this drawback. But the next problem is already here. Manufacturers are developing different connectors for electric cars. History is repeating itself. ◎

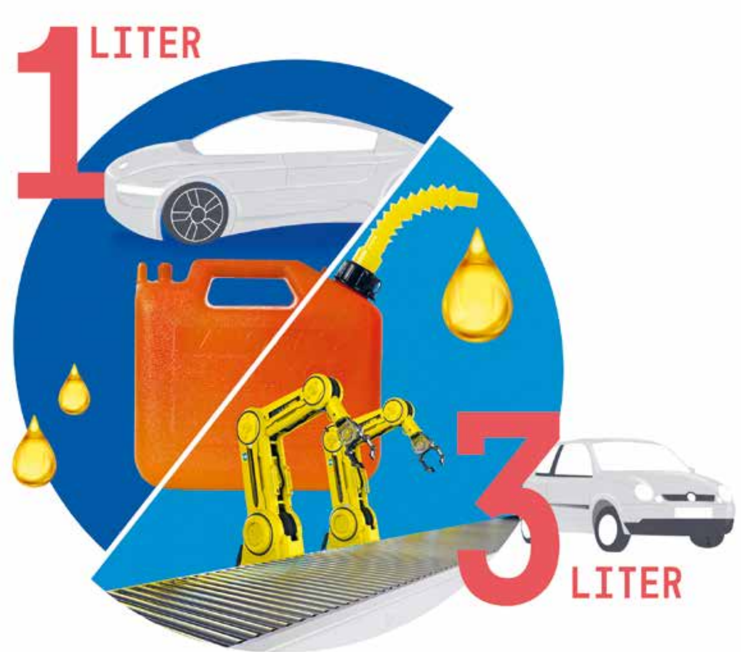
Left by the Way-side

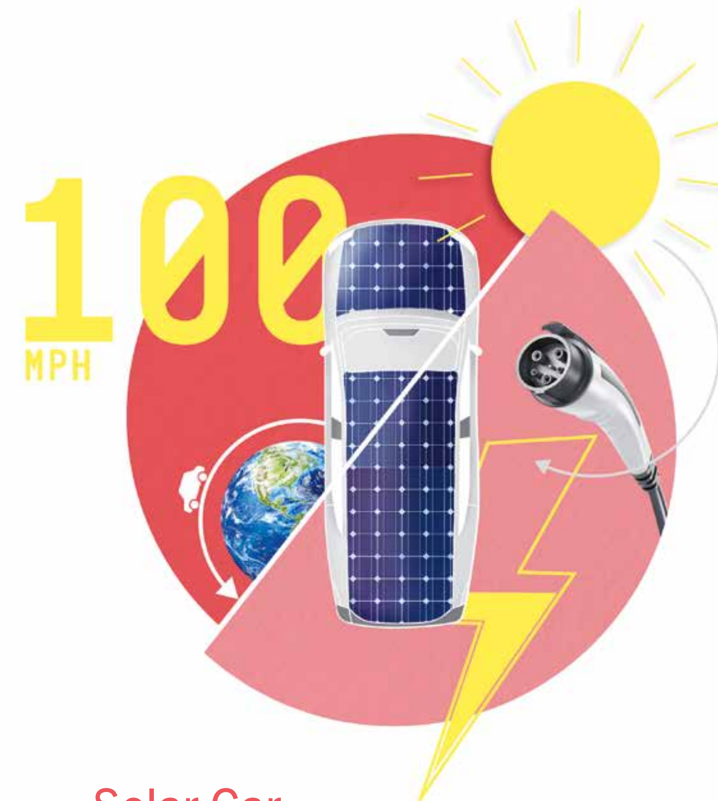
They had the potential to be the repositories of hope for eco-friendly mobility. But how did they actually turn out?

Three-liter Car

Sounds Promising
The "car of the future" was supposed to consume less fuel decades ago. The oil crisis of the 1970s showed industrial nations how dependent they were on the lubricant of the global economy. The environmental movement, which emerged later, demanded a reduction in emissions. The world seemed ready for a so-called low-energy vehicle. Volkswagen drove these considerations to new heights in 2002. Then-CEO Ferdinand Piëch demonstrated the suitability of a one-liter car for the road when he drove a prototype 230 kilometers (143 miles) to the company's annual meeting. Was this the path to a new era of auto mobility?

Really?
No! VW built 200 units of a successor to the one-liter prototype between 2014 and 2016, but it halted the project just like it did the three-liter car previously. The mini-compact Lupo featured a streamlined aluminum body, but was only built from 1999 to 2005. Consumers found the car to be too small and expensive and its look unappealing. Sales of just 27,000 units testify to that. Even a three-liter version of the larger Audi A2, which reached the market in the same timeframe, made little headway. Just 6,500 units were built. The three-liter car with an internal combustion engine remained a footnote in the industry's history, to say nothing of the one-liter car. ◎





Solar Car

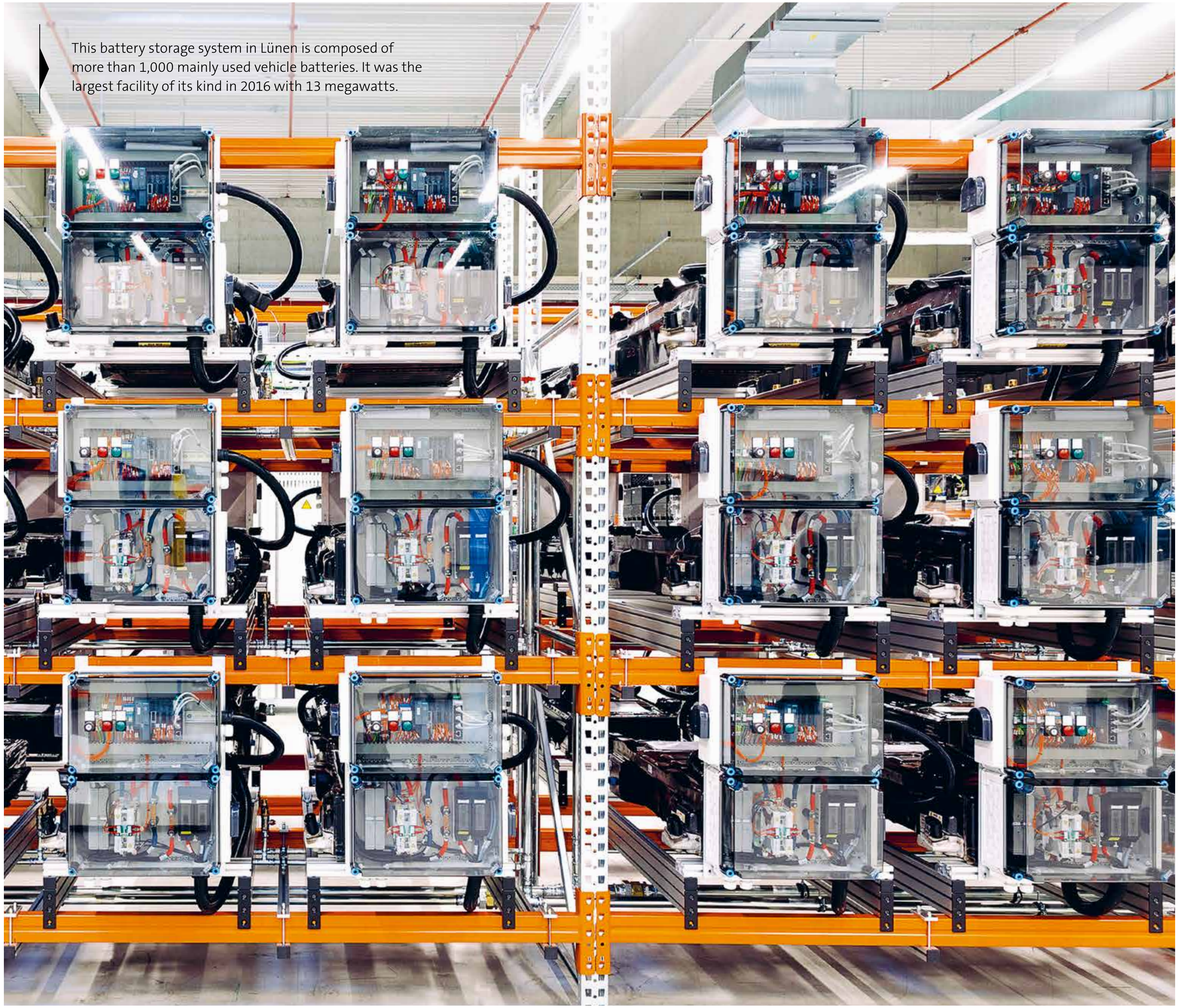
Sounds Promising
If solar cells have made it possible to navigate in space, why not use them for mobility back home on earth? Solar vehicles have many advantages: Their powertrains produce no emissions at all. They don't require a charging infrastructure, and the fuel beaming down from the heavens is free. A car drove the first miles using solar energy in 1958. Since then, scientists have tinkered with ambitious solutions. In the World Solar Challenge, for example, futuristic "solarmobiles" hurtled across Australia at 100 km/h (62 mph). The first solar cars have now made it around the world. Are they now among the alternatives to take seriously?

Really?
Not at all! At least not as pure solarmobiles. The idea of boosting electric cars to greater ranges now seems a bit more realistic. Their bodies would be covered with solar cells. Short stretches should even be possible exclusively with solar power, assuming that the car is exposed to enough sunlight ahead of time. These ideas have been discussed in the high-end sector, but haven't made it past the business-simulation stage. All-solar electric cars look like large soapbox racers and aren't ready for series production. They also pose safety hazards due to their extremely light weight. Heavy loads are not in the cards either, and their ranges remain an issue. And a great deal of energy is lost during the conversion of sunlight into electricity. ◎

Autogas

Sounds Promising
Gas is a true oldie when it comes to fuels. In the case of gas propulsion, a distinction is made between natural gas and autogas, which is liquefied under high pressure. In many places, the latter is marketed under the abbreviation LPG (liquefied propane gas). Long-range taxis and buses are among the beneficiaries of gas-fueled powertrains, not least of all because the prices of these fuels are generally much lower than those for diesel and gasoline. Many countries also have a comprehensive network of filling stations offering these varieties of gas. They both emit lower levels of nitrogen oxides and CO_2 than gasoline and diesel do. Are they potential big sellers?

Really?
Not at all! Sure, there are countries where gas propulsion is comparatively popular. South Korea, Turkey, Russia, Poland and Italy accounted for nearly half of the autogas consumption worldwide in 2017. But on the global level, gas registered only in the low single-digit percentages. It is marginal in the U.S. In Germany, electric vehicles recently overtook their natural gas counterparts. The number of autogas vehicles has fallen 20 percent in the last five years. Why? The connections for fill-ups are not uniform internationally. Moreover, gas-fueled vehicles require more maintenance, and there are significantly fewer models in series production. Conversions are only amortized over relatively long periods of time. ◎



This battery storage system in Lünen is composed of more than 1,000 mainly used vehicle batteries. It was the largest facility of its kind in 2016 with 13 megawatts.

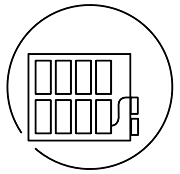
Nowhere Near the End

The used-up batteries of electric vehicles don't have to be recycled or discarded. Due to their remaining storage capacity, they are an attractive option for a second life in a stationary energy storage system.

In 2019, there were 5.6 million electric vehicles worldwide. If the International Energy Agency (IEA) is to be believed, there will be 125 million electrically powered vehicles in ten years. The quantity of used electric batteries will climb as the number of vehicles rises. Based on this forecast, a scrap problem for electric cars is looming. After all, the recycling processes for these technologies are far from impressive. They are both laborious and energy-intensive. But there's a way to approach the millions and millions of used powertrain batteries as an opportunity.

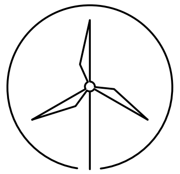
After 10 Years Still Not Ready for the Scrapheap

And that's exactly what the early players are doing right now. A lithium ion battery will propel an electric vehicle for about a decade. During this time, its storage capacity will gradually diminish to around 80 percent. That increasingly seems unsatisfactory for demands of transportation. But it would still come under consideration for use in a stationary storage system, perhaps for a period of ten to twelve years.



2,000

batteries are planned to be included in a storage system in Germany and France.



700

batteries store wind energy for use in manufacturing operations at the BMW plant in Leipzig.

The Japanese solar park Hikari-no-Mori turned to this approach back in 2013, relying on sixteen used lithium ion batteries as an energy storage system. The batteries came from Nissan Leafs and have added to the stability of its network as buffer storage. If an energy bottleneck looms, the stored solar electricity is released into the grid. By contrast, if the situation involves peak loads, the energy is parked there. This kind of reuse of electric batteries improves their environmental impact. At its Leipzig factory, BMW is using up to 700 batteries from its i3 model as an energy storage system. The wind energy to power its manufacturing operations is retained temporarily inside the system, and, when necessary, fed into the public grid. For its part, Audi has reassembled used electric batteries to propel industrial trucks on the shop floor, saving money in the process.

Energy Storage System at a Soccer Stadium

Meanwhile, a project in the Netherlands is attracting attention. New and used battery cells from Nissan have been assembled into a huge 3-megawatt battery at the Johan Cruijff ArenA, the highly advanced home stadium of the Ajax Amsterdam soccer club. The storage serves as an emergency supply and reduces the use of the usual diesel generators. The system is capable of providing the stadium, which holds 55,000 spectators, with energy for at least one hour. Aside from supplying electricity for events, the storage system retains energy from a solar cell system on its roof and delivers it to the commercial grid when it is needed, generating income.

“The Mobility House,” a Munich-based technology company with additional operations in Switzerland and California, provides the operation of the novel energy storage system in the Amsterdam stadium with its intelligent charging and energy solutions. The Munich firm works with other automakers that are looking for a connection to the energy market. Collaborating with Daimler AG, the company is establishing a battery storage system for stabilizing the electricity grid on the grounds of a former coal-fired power plant. But in that case, it is turning to around 2,000 brand-new battery modules. The rationale for this 9-megawatt storage system is different. The new modules not only store electricity – they are also a “living” source of replacement parts. If a defective battery has to be replaced in a Smart car, Daimler can help itself to modules in the battery storage system. Teaming up with Renault and other companies, “The Mobility House” has announced the construction of stationary storage systems in France and Germany. Together, they are expected to achieve a capacity of 60 megawatt hours. The standardized system, which is stored in containers, consists of 2,000 batteries. It is designed to temporarily store enough energy to meet the daily needs of 5,000 households.

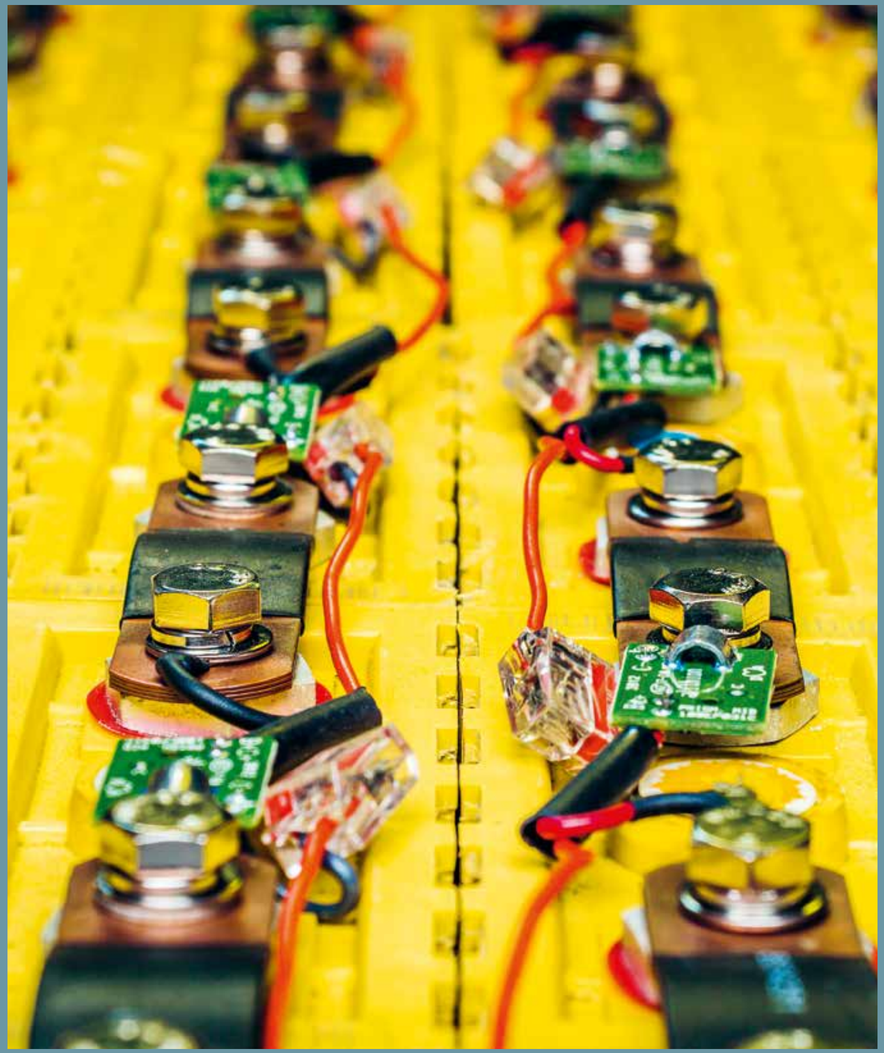
Second Life as a Flexible Power Bank

By contrast, Volkswagen is working hard on the reuse of used lithium ion batteries in electrical recharging systems. What were once propulsion batteries are helping out their still-functioning counterparts by serving as a “power bank.” The series production of the charging stations is expected to get rolling this year, either for grid connections or for mobile operations, perhaps at a music festival or similar events. The charging stations are scalable for any purpose. As soon as the energy in the mobile stations is depleted, the batteries are replaced and recharged in a service park. They are only recycled when they are no longer suited for this mission.

The second life of electric batteries doesn’t just have the potential to make electric mobility more sustainable – it can also promote the energy transition. ◎

A CLOSER LOOK AT THE NUMBERS

17 Tons of CO_2



Electric cars are considered to be a way to cope with rising greenhouse gas emissions. After all, they don’t emit carbon dioxide. But that’s just half the story. Cars with battery propulsion all need to be charged with electric current at some point. If the electricity doesn’t come from renewable sources, the benefits to the environment suffer. Furthermore, the CO_2 resulting from the manufacture of the battery has to be taken into consideration. One statistic has stubbornly persisted in the discussion: 17 tons. But what should we make of that figure? Very little, it turns out. The Swedish journalist who published it used Tesla’s 100 kW battery, its most powerful option, as the basis for the calculation, not the average battery. Besides, the crucial aspect is the source of the energy used to make the battery anyway. The energy mix varies from country to country. Tesla touts its use of green energy at its Gigafactory. In 2016, the Korean cell maker LG Chem indicated that 3.2 tons of CO_2 are released during the construction of a battery with a 24 kW capacity. Notwithstanding the information from LG Chem, the misleading figure of 17 tons has taken on a life of its own in the emotional debate over the environmental credentials of electric cars. ◎

Fast Forward

A growing number of large cities want to switch to public buses with battery-electric powertrains. The Hamburg-Holstein Transit Company is one of the pioneers in Germany. A visit to an electric bus depot shows that the charging infra-structure must be taken into account right from the start.

Mountain goats: The VHH has been testing its battery-electric buses since 2014.

Building conversion: New plant space enables work on the roof.

Erwin regularly works late into the night. Yet his next shift often begins before sunrise, and he can only get a little rest at noon from time to time. This arduous shift work does not violate occupational safety laws since Erwin is a transit bus. The vehicle, measuring a full 12 meters (13 yards) in length, just joined the Hamburg-Holstein Transit Company in February. It was four years ago that VHH Managing Director Toralf Müller announced that the company would only buy emission-free buses beginning in 2020. That time has come, and the first 16 electric buses are standing in the Bergedorf depot, on the far east side of Hamburg. Their names, which were selected in an employee competition, all begin with the letter "E."

The electric buses have to prove themselves in normal transit use right from the start. The operations involve "round trips," predetermined daily travel from the departure to the return to the depot. A bus can be used on various lines. A typical round trip for an urban public bus covers about 200 kilometers (roughly 124 miles). The battery for an electric bus must be able to last that long unless it can be recharged en route. Müller won't even consider the idea of special treatment, such as different trips and routes, for his electric buses. "We demand the same flexibility from our electric buses that we get from vehicles with diesel engines," he said. Right from the beginning, he ruled out charging batteries en route, at the terminus of a line, for instance. That would have restricted the use of electric buses to particular lines or would have been very expensive.

Reducing Peak Loads

The charging can only take place at the bus depot. Even there, things have to move fairly smoothly because the battery modules on individual buses, which are built into the rear and the roof, hold a total of 243 kilowatt hours of energy. The charging capacity, which is limited by the maximum current strength, is 150 kilowatts. By comparison, the installed load for a standard townhouse is only 50 kilowatts. If you take the roughly 120 buses that will have to connect with the grid every night at the Bergedorf depot, you end up with a peak output of 18 megawatts, which is about the capacity for a small city district. Even if the VHH depot were adjacent to an electrical substation, it would be enormously expensive to provide the peak output on demand. That's why Hendrik Wüst, who is responsible for the charging infrastructure, and his team are working on smart charging management. In the first phase of the expansion, the charging capacity as well as the start and end of the charging process can only be programmed in advance. Later Wüst and his staff will be able to determine load profiles and take external data – for example, the existing supply of green energy – into account.

"Not every bus leaves the depot at the same time and, depending on the schedule, the battery need not be completely charged in every case," Wüst explained. "Our calculations show that we can reduce peak loads by around 50 percent with a smart charging strategy." A battery storage system with a capacity of around 500 kilowatts is still in the testing phase. Electric current from the grid can be buffered there. This makes it possible to draw electricity when it's more abundant than usual – and therefore less expensive. It is interesting that the lithium ion batteries in the storage system had a prior life in MAN transit buses.

The charging process itself is as mundane as it is for an electric car. After he is done with his trip, the driver takes the CCS plug from the charging station, puts it in the charge socket and secures the plug connection. The charging takes place with direct current at about 750 volts. It is transformed and rectified in two container-sized facilities, each of which provide 64 charging points using a line set in the ground during the final expansion stage. The entire electric infrastructure takes up a bit of space, although that's not a major issue in the Bergedorf industrial district. But the VHH has a dozen or more other depots in the greater Hamburg area, and conditions are significantly tighter in some of them. "Controlled charging can help to limit the need for space," Wüst said. Another measure is proving useful: The VHH has turned to a Polish manufacturer for double charging stations, which can split the output: If only one bus is connected to the network, the full 150 kilowatts are available. If there are two, they share the output.

Climbing onto the Roof

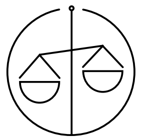
Electric buses basically require less maintenance than their diesel counterparts. There is no motor oil or fuel filter that has to be changed. And since the electric motor largely handles the braking process, the brakes wear less. Nonetheless, the VHH has invested in a modern maintenance facility. Mike Ehmke, who is responsible for the technology of VHH's electric buses, explained why it is needed. "When it comes to electric buses, a large portion of the energy supply system is on the roof, so we wanted to create workplaces where the maintenance staff has safe access to it." So a second work level has been constructed in the space. Its individual sections can be brought close to the bus's roof so there is no gap at any of the four sides.

The VHH has used electric and hybrid buses in tests on individual lines for years, but they still have much to prove at this point. What is the true level of availability? What are the energy needs in practice? They were precisely computed for each line in advance with the help of Helmut Schmidt University. How quickly is battery technology advancing? The VHH wants to complete the conversion of its entire fleet by the end of the decade. "With today's battery technology, we can cover about 50 percent of the round trips," Müller said. And the rest? He pointed to the most important lesson of the conversion: "We have to tackle the changes actively and leave no stone unturned." ⊚

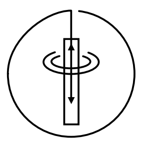
> We have to tackle the changes actively and leave no stone unturned."
>
> Toralf Müller,
> VHH Managing Director

February 2020

Integrated Advantage



80 %
less weight



35 %
less friction

Those are the benefits of a plastic sliding bearing integrated into a Freudenberg Sealing Technologies seal. The unit has been tested successfully in the sensor housing for an electromechanical steering system for cars. To make it as light, durable and affordable as possible, the seal and the bearing had to be precisely coordinated. The seal's reduced friction improved steering, and the increased rigidity of the integrated plastic bearing increased driving comfort. The unit can be produced at will as a customer-specific development for series production. ◎

October 2019

Benefits for Shock Absorbers

A seal developed by Freudenberg Sealing Technologies for single-tube shock absorbers has gone into series production for a well-known automaker. The innovation is based on a new design concept, with a cone-shaped construction inside the shock absorber that is much simpler than the structure of conventional seals. This helps to reduce the total number of components and makes installation easier. In addition, the friction inside the shock absorber decreases – as does wear and tear. In customer tests, the shock absorber is shown to be highly responsive to bumps and jolts, improving vehicle handling. ◎

January 2020

Robust Long-range Forecasts

Wide-ranging calculations are carried out to produce durable, static seals for large installations such as wind turbines. They include the Arrhenius equation, which is used to forecast temperature-dependent aging. But until now, the component often ended up larger than necessary. Freudenberg Sealing Technologies has developed a sophisticated technique – which has been successfully tested under real-life conditions – that considers how materials change at the molecular level. The result: greater forecasting reliability with reduced material use. ◎

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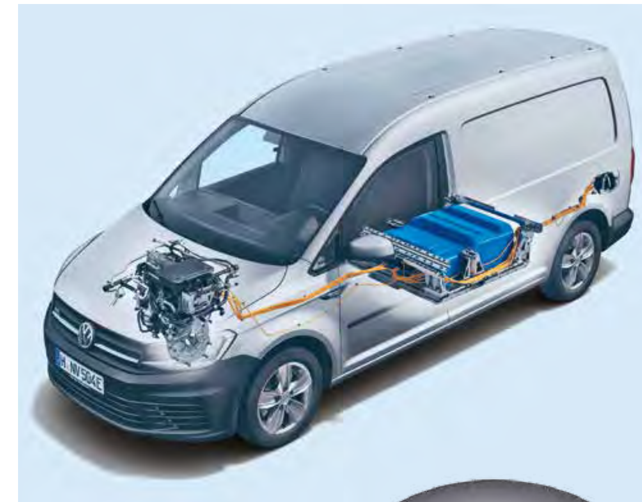
March 2020

Breathing Battery

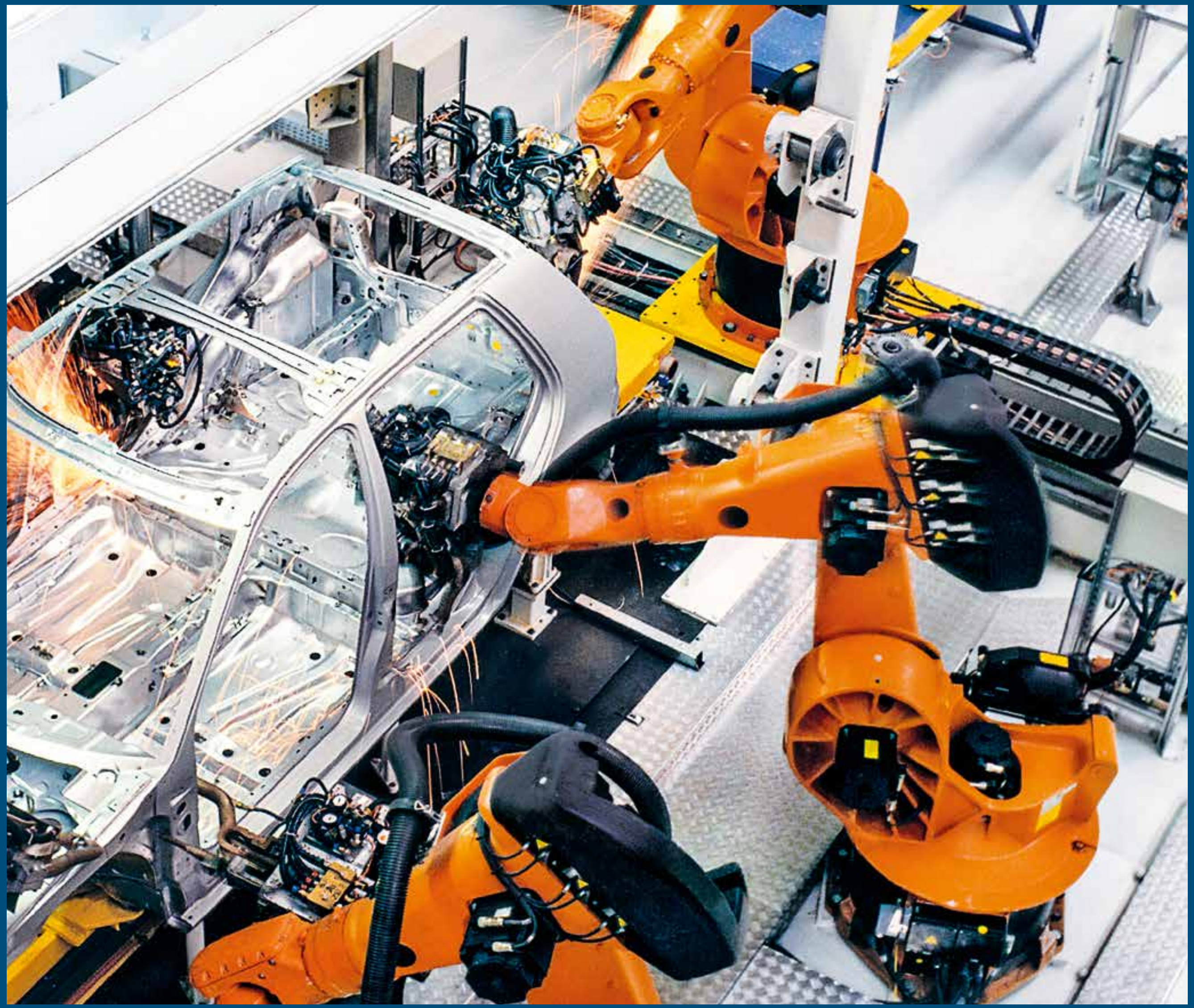


Venting during normal operation, de-gassing in an emergency: Those are the two key requirements that an electric car's battery system must meet. Freudenberg Sealing Technologies has combined both functions in its DIAvent product. It relies on two nonwovens with different characteristics. A water-repellent nonwoven on the exterior enables both an exchange of air and impermeability to water to a certain degree. If the water pressure increases, a swelling effect of a second nonwoven layer makes sure that water does not enter the housing. In an emergency, a screen valve, which encloses the nonwoven like a ring, allows the de-gassing. Then it closes, permitting the safe removal of the damaged battery. An extensive range of tests shows that DIAvent meets all the parameters for pressure equalization, sealing against spray and emergency de-gassing. DIAvent has been installed in two vehicle models (the ABT e-Caddy and the ABT e-Transporter) from the ABT e-line, the premium partner of Volkswagen Commercial Vehicles. ABT worked closely with Freudenberg Sealing Technologies on the development. DIAvent went into series production after just one year. ◎

November 2019

Emission-free Mobility

XALT Energy, a U.S.-based enterprise of Freudenberg Sealing Technologies, specializes in the production of high-quality, robust lithium ion batteries for urban buses and commercial vehicles. XALT Energy now furnishes powertrains for the first-ever fully electric long-distance buses, which private and public transportation companies are testing in the U.S. It is working with bus maker Motor Coach Industries (MCI). MCI President Ian Smart said he is convinced that his company, in concert with XALT, is capable of delivering a battery-electric bus that offers the same or better performance than current diesel models. In October 2019, XALT Energy's solution proved to be ideal for long distances during a maiden road trip from San Francisco to Sacramento. FlixBus, Europe's largest provider of long-distance bus trips, has announced that it is testing the powertrain in a long-distance bus network that it has launched in the United States. ◎



Before and after: Industrial robots can recuperate energy with industrial robots

The Direct Answer

The factories of the future could be operated completely with direct current. A major research project coordinated by the Fraunhofer Institute for Manufacturing Engineering and Automation in Stuttgart is laying the foundation for this.

The lab is not particularly large. But a half-dozen control panels with thick orange cables visible through their glass-enclosed fronts send a message: There are powerful current flows here. But what may seem completely unexciting to a layperson could help to change the direction of electric energy supplies for industry. "For example, we are simulating a welding robot that is operated with direct current," explained Timm Kuhlmann, who is on the scientific staff of the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA). So far, the energy supply for robots – as is the case for other industrial equipment – has been alternating current.

That has been the standard since Thomas Edison and George Westinghouse fought bitterly over the design of the American electrical grid at the end of the 19th century. Westinghouse, who preferred alternating current, ultimately prevailed over Edison, who advocated direct current. But direct current might be able to establish itself as the better alternative in the future, at least inside today's factories. Kuhlmann coordinates the "DC-Industry 2" project, which has attracted more than 30 industrial companies and five research institutes as participants. The basic feasibility of using direct current in industry was confirmed in an earlier project. Now the idea is to provide scientific support to companies with the help of plans for a real-life production hall.

Free of Fluctuations

There are good reasons to make the switch to direct current. The first and perhaps most important one involves the conversion of an entire electrical system to climate-neutral technologies. Unlike conventional power plants, solar and wind energy facilities do not generate electricity continually. If supply and demand are not a 100-percent match, the frequency and thus the voltage of the grid fluctuate – mostly without being noticed but enough that they can impair sensitive production processes. "With a local direct-current network, a factory can be completely decoupled from these fluctuations – easily and efficiently," said Alexander Sauer, who has been one of the two directors of Fraunhofer IPA since the start of the year. There is another advantage: More and more companies are covering a portion of their electrical needs on their own, for example, with solar facilities on roofs. However, the semiconductors in solar modules always produce direct current. So far, this electric flow has had to be converted into alternating current using inverters so it can be used in factories. "You can save money by cutting out a lot of inverters," Sauer explained.

Today's power electronics have significantly reduced the once relatively high costs of components needed to switch and protect direct current, he said. There will be more opportunities to develop industry-specific components. So far, scientists are

Not so obvious: Only experts can tell whether the motors are AC or DC.

1882

The world's first electric grid in Manhattan operated on direct current.

mainly getting by with components from the railway industry. The key component for a factory's local direct-current network is the "active front-end" that is used to rectify and transform alternating current at the connection to the grid – for the entire factory or at least one manufacturing hall.

The direct-current network running in the background operates on around 650 volts. There are still no industrial standards for the new world of electric current, but the foundations worked out in the "DC-Industry 2" project are expected to aid the German Commission for Electrical, Electronic and Information Technologies (DKE), which is responsible for defining them. Greater energy efficiency results from the reduced number of conversions during operation. Today's inverters operate with very high efficiency, but a few percentage points are still lost when there are multiple back-and-forth conversions. The gain in efficiency for a typical industrial robot amounts to about 10 percent. The energy needed for braking can be used in adjacent equipment without any losses.

A 6 percent increase in energy efficiency was shown for a machine tool used for wood processing. If an industrial installation is integrated into a local smart grid, the use of direct current offers another benefit. While alternating current requires additional voltage sensors whose signals are transported within milliseconds over a glass fiber or 5G network, the direct current itself can serve as the control signal for machines. "You cut out both the sensor system as well as the overall real-time communication infrastructure," Sauer explained.

Edison Strikes Back

Built by Thomas Edison in Manhattan in 1882, the world's first electric grid relied on direct current. The technology might be making a comeback some 150 years later. "Perhaps we will be converting our entire electrical supply system in 20 or 30 years," Sauer said. "In principle, the advantages that we are showing in factories can be carried over to buildings," especially since a growing number of end-devices, ranging from LED lights to laptops, are designed for direct current. ◎

Outstanding Communication

We cover current, entertaining and astonishing topics for you with the same passion that drives our development of high-performance products. With some success, as these awards for our company magazine Essential demonstrate.

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Videographer Awards 2019 – Gold
"Digitalization" trailer in the Category Video Production / Video (Other)

Videographer Awards 2019 – Gold
"Thirst" trailer in the Category Video Production / Video (Other)

Videographer Awards 2018 – Silver
"Rethinking" trailer in the Category Video Production / Marketing (Product)

Fox Awards 2019 – Gold
Category Industry, Technology, Production / External Communication

Fox Awards Visuals 2019 – Gold
Category Industry, Technology, Production / External Communication

Fox Awards 2018 – Gold
Category Industry, Technology, Production / External Communication

Fox Awards Visuals 2018 – Silver
Category Industry, Technology, Production / External Communication

Galaxy Awards 2019 – Gold
Category Corporate Magazines

BCM Awards 2019 – Silver
Category Magazine B2B Commerce / Transportation / Logistics

BCM Awards 2018 – Silver
Category Magazine Cover

Communicator Awards 2019 – Silver
Category Marketing / Promotion – Magazine-Corporate

Communicator Awards 2018 – Silver
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Communicator Awards 2018 – Silver
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Mercury Awards 2018 / 2019 – Gold
Category Customer Publications B2B Customer Magazine

Internationaler Deutscher PR-Preis 2019 – Shortlist
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