tomorrow

EXPERIENCING TECHNOLOGY WITH SCHAEFFLER

Clean energy

Rethinking and
redefining energy

Energy chain

The interaction between
source, storage and consumer

Issue 1/2017 · Energy

SCHAEFFLER

En|er|gy - ['enərdʒi]

Measure of the ability of a body or system to do work or produce a change, expressed usually in joules or kilowatt hours (kWh). No activity is possible without energy and its total amount in the universe is fixed. In other words, it cannot be created or destroyed but can only be changed from one type to another.

THE TWO BASIC TYPES OF ENERGY ARE
(1) Potential
Energy associated with the nature, position or state (such as chemical energy, electrical energy, nuclear energy).

(2) Kinetic
Energy associated with motion (such as a moving car or a spinning wheel).

Source: BD BusinessDictionary

DEAR **READER,**

We are living in exciting times. The speed at which existing technologies continue to develop or new ones emerge is high. The sectors in which Schaeffler operates as a globally active integrated automotive and industrial supplier are so energized that their pulsations can virtually be felt.

The focal topic of the current issue of our technology magazine "tomorrow," to which I cordially welcome you, is "energy" which – no doubt – is a field with many facets. If we follow Albert Einstein, this topic can be summarized in two letters and a superscript number: energy equals mc^2. This law of nature and the man who discovered it while elaborating his theory of relativity is obviously not to be missed by a magazine dedicated to the topic of energy. When asked about how he came up with his famous theory of relativity, Einstein responded: "A brilliant light dawned on me." A cerebral energy discharge, an ingenious idea or a stroke of genius. What would humanity be without it?

In 1949, Georg Schaeffler had such an ingenious idea as well. The result: the cage-guided INA roller bearing – an important foundation of today's Schaeffler Group and a milestone of industrialization. Our company's founder, Georg Schaeffler, who died in 1996, would have been 100 years old this year: an appropriate occasion to look back on the life of this energetic entrepreneur in this issue of our magazine. Georg Schaeffler was driven by a zest for discovering new things and saw change as an opportunity.

Both of these traits have become firmly embedded in the DNA of the company that bears his name. While reading this magazine you will repeatedly come across Schaeffler innovations that help generate and use energy efficiently – be it bearings for wind turbines and solar power, system solutions for the mobility for tomorrow and Industry 4.0 or new surface technologies. In its development projects, Schaeffler frequently looks at nature as well. Based on six fascinating examples from fauna, "tomorrow," starting on Page 34, shows how efficiently animals manage available energy resources and what technology developers can learn from this.

Talking about "nature:" It is an inexhaustible source of energy, Iceland being a perfect case in point. The seething volcanic island in the North Atlantic completely covers its heat requirement using CO_2-neutral hydropower and geothermal energy. More on this can be found starting on Page 14. In other places, the power of the Sun is utilized which, thanks to technological progress, can be tapped with increasing effectiveness. Scientists, for example, have already been able to use solar energy to produce high-energy fuels from carbon dioxide and water. Although the amounts obtained this way are still small this, too, could soon change. Or might cold fusion and antimatter be the energy sources of the future? "tomorrow" explores this question starting on Page 70.

As said in the beginning, "energy" is a field with many facets and I hope that your curiosity has now been sparked enough to join us in embarking on a number of exciting and informative expeditions.

Klaus Rosenfeld
Chief Executive Officer

global

A glimpse of the world

in motion

Innovations in the course of time

here and now

Living with progress

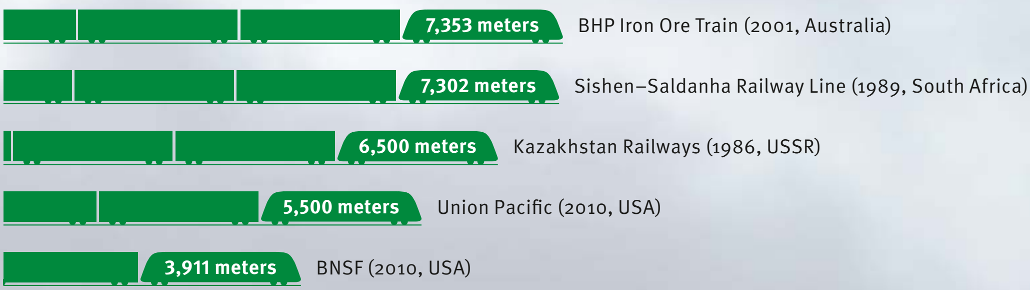
outlook

Technology for tomorrow

LOAD AS **FUEL**

A 750 meter long "string of beads" made up of 68 freight cars laden with 6,800 metric tons of ore – the trains of the Swedish mining company LKAB are giants in the field of rail cargo, hauled by twelve-axle Bombardier IORE 118 twin locomotives. With 2 x 5.4 megawatts of output they rank among the world's most powerful electric locomotives. Now that's awesome, but even more impressive is the fact that the Swedish iron ore trains practically operate like a perpetual motion machine. From the mines in the northern Swedish mountains to the shipping points in the harbors of Narvik (Norway) and Luleå (Sweden) the heavily laden trains coast downhill most of the time. The braking energy generated in the process is stored in batteries. The resulting energy budget is impressive. A fifth of the recuperated electric power is enough to take the trains to the harbors. Subsequently, the locomotives use the remaining 80 percent to haul the empty freight cars back to the mines. In the U.S., there are plans for using circulating trains for grid-scale energy storage, conceptually similar to pumped-storage hydroelectric systems. More on this starting on page 88.

THE LONGEST FREIGHT TRAINS



For comparison: the longest passenger train

Source: Wikipedia

global

A glimpse of the world

» *When first invented, the locomotive was an iron monster. What is it today for the villager except a humble friend who calls every evening at six?*

Antoine de Saint-Exupéry

360° ENERGY

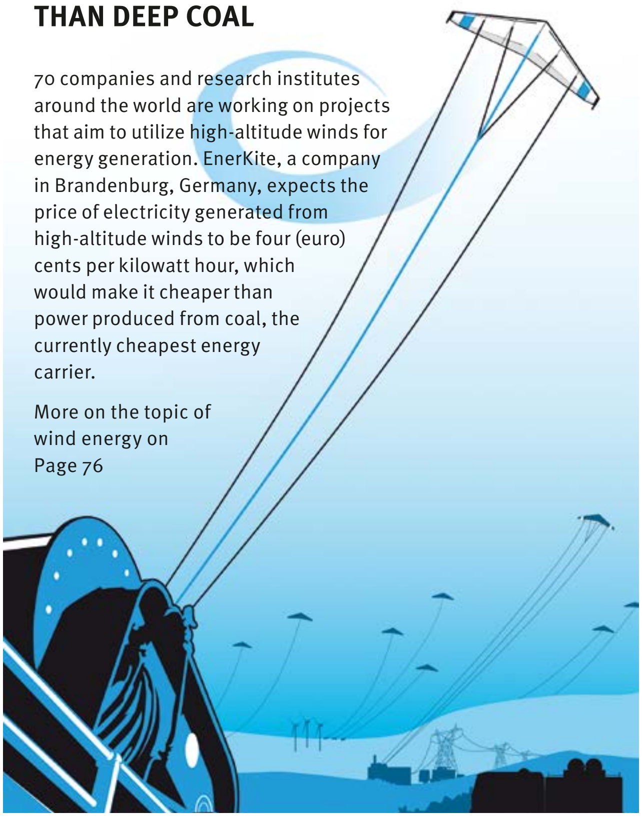
Facts, figures, oddities – a panorama of the world of energy.

by Carsten Paulun

HIGH WINDS CHEAPER THAN DEEP COAL

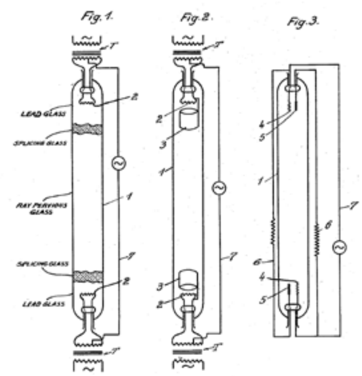
70 companies and research institutes around the world are working on projects that aim to utilize high-altitude winds for energy generation. EnerKite, a company in Brandenburg, Germany, expects the price of electricity generated from high-altitude winds to be four (euro) cents per kilowatt hour, which would make it cheaper than power produced from coal, the currently cheapest energy carrier.

More on the topic of wind energy on Page 76



Only 3 copper atoms are the diameter dimensions of the thinnest power supply line's core, sheathed by an ultra-thin sulfur-diamond layer. The intriguing aspect is that, like tiny Lego bricks, the molecules independently position themselves in the appropriate configuration to grow toward the cable, which itself is not discernible by the naked eye. Naturally, these micro-conductors are intended for use in applications where space is at a premium, such as cell phones.

Source: Stanford University



PAVING THE WAY FOR THE ENERGY-SAVING LAMP

1926 marks a major milestone on the road toward energy saving lamps. The idea of the German inventor Edmund Germer to fill its glass jacket under higher pressure and to coat it inside with a fluorescent substance that transforms ultraviolet radiation into light revolutionizes the gas discharge lamp. The first rudimentary form of today's energy saving lamp is born. The concept of fluorescent lamps (pictured) for which Germer filed a patent application is bought by General Electric. The first major production of energy saving lamps for domestic uses is launched in 1938.

75 %

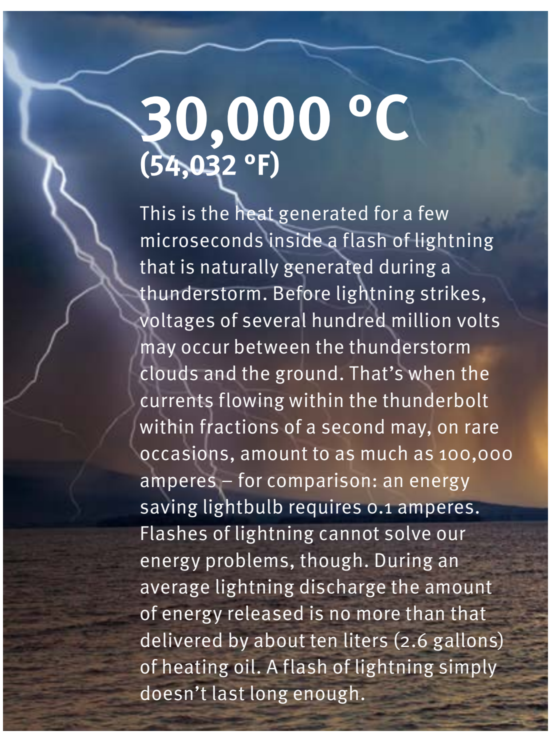
of the energy used for cooking can be saved by using a lid. For those who'd like to save even more, a pressure cooker is the way to go. It saves another 50 percent.

56 kWh

of energy are available to a Formula E driver per race, which corresponds to the amount of energy of 20,000 AA batteries or the electricity consumption of a two-person household in six days. More about energy in motorsport on Page 60.

38 MILLION YEARS

This is how long all currently operated nuclear reactors would have to run at full capacity in order to achieve the same energy turnover as the Sun does per second. This makes the Sun the absolute star among Earth's energy suppliers, although only a fraction of the solar energy reaches our planet. *More on the topic of solar energy starting on Page 24.*



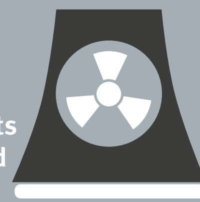
30,000 °C

(54,032 °F)

This is the heat generated for a few microseconds inside a flash of lightning that is naturally generated during a thunderstorm. Before lightning strikes, voltages of several hundred million volts may occur between the thunderstorm clouds and the ground. That's when the currents flowing within the thunderbolt within fractions of a second may, on rare occasions, amount to as much as 100,000 amperes – for comparison: an energy saving lightbulb requires 0.1 amperes. Flashes of lightning cannot solve our energy problems, though. During an average lightning discharge the amount of energy released is no more than that delivered by about ten liters (2.6 gallons) of heating oil. A flash of lightning simply doesn't last long enough.

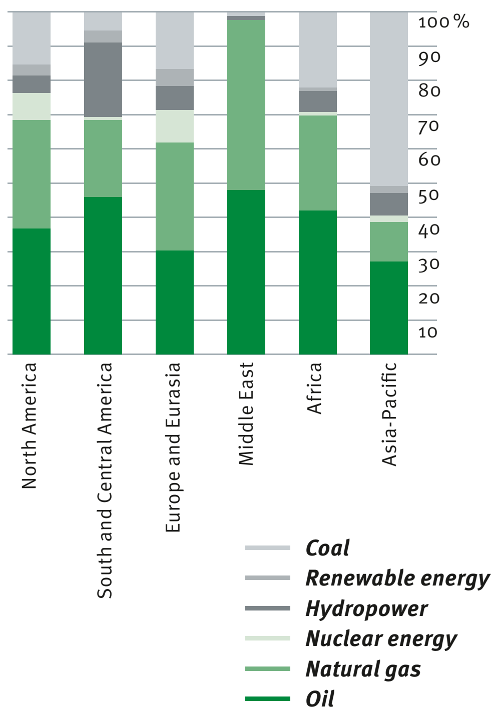
450

nuclear power plants supply grids around the globe



Source: atw – International Journal for Nuclear Power, (31/12/2016)

THE GLOBAL ENERGY MIX



582

PERCENT TOO MUCH

Many digital electricity meters indicate excessive consumption, according to research by the University of Twente in the Netherlands. According to these findings, more than half of the electricity meters investigated indicated levels that were by far higher than they should have been, in some cases by as much as 582 percent! The researchers provided the reason for this as well. Modern energy saving domestic appliances don't draw power in wave-like ways but abruptly. Meters, however, are unable to process this abruptness and, as a result, provide wrong measurements.

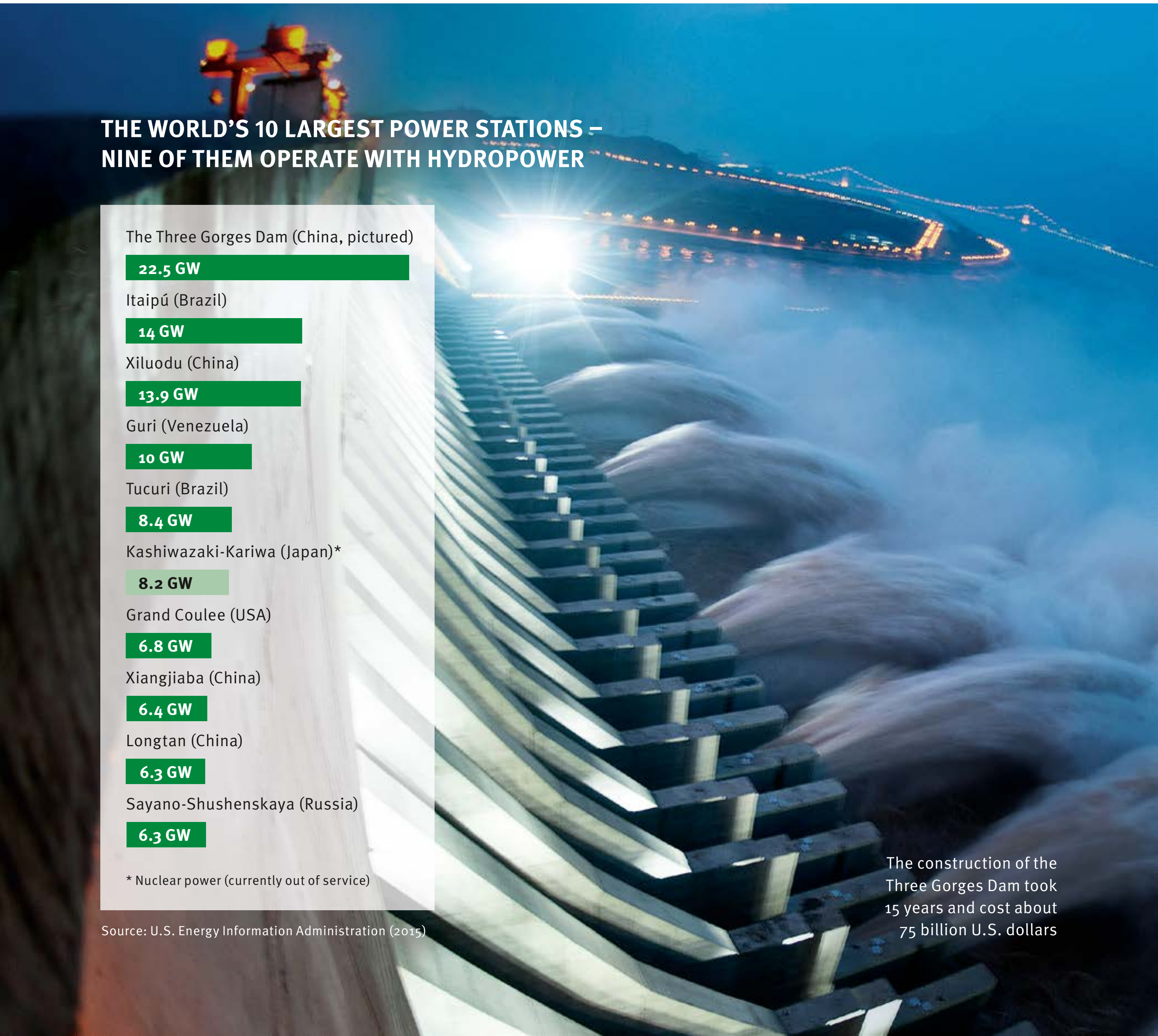
8 YEARS, 7 MONTHS AND 6 DAYS OF SCREAMING GENERATES ENOUGH SOUND ENERGY TO HEAT A CUP OF COFFEE.

HEATING EN PASSANT

250,000 people heat a renovated building in Stockholm with their body heat. They're the daily visitors of the central train station of Scandinavia's major transportation hub. Combined, they produce about 25 megawatts of heat, which is conducted to a 13-story office building across the street. This not only reduces CO_2 but also cuts energy costs by about a quarter. Paris uses the thermal discharge of people at train stations as well, heating 17 apartments with the waste heat from a single metro station.

800 volts

can be generated by an electric eel. The South American sweet water fish has up to 6,000 electrocytes which, combined, produce a current of one ampere for about two milliseconds. The electric eel uses this current for defense as well as for attacking its prey. The electric shock can even be hazardous for humans because it may lead to muscular spasms and respiratory arrest.



THE WORLD'S 10 LARGEST POWER STATIONS – NINE OF THEM OPERATE WITH HYDROPOWER

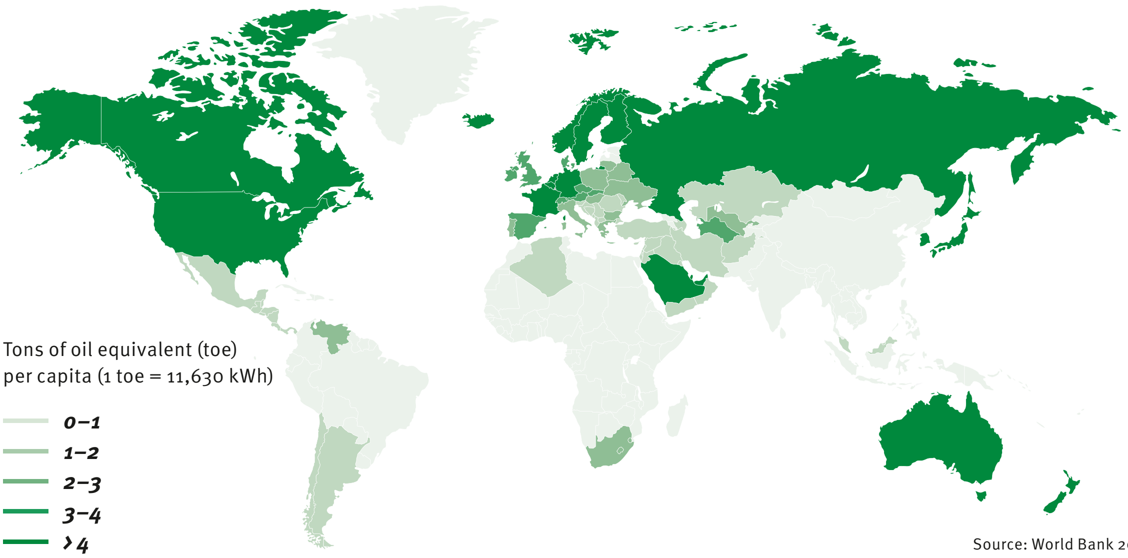
The Three Gorges Dam (China, pictured)	22.5 GW
Itaipú (Brazil)	14 GW
Xiluodu (China)	13.9 GW
Guri (Venezuela)	10 GW
Tucuri (Brazil)	8.4 GW
Kashiwazaki-Kariwa (Japan)*	8.2 GW
Grand Coulee (USA)	6.8 GW
Xiangjiaba (China)	6.4 GW
Longtan (China)	6.3 GW
Sayano-Shushenskaya (Russia)	6.3 GW

* Nuclear power (currently out of service)

Source: U.S. Energy Information Administration (2015)

The construction of the Three Gorges Dam took 15 years and cost about 75 billion U.S. dollars

ANNUAL WORLDWIDE PER CAPITA ENERGY CONSUMPTION



Source: World Bank 2013

2,000 TIMES

the amount of light emitted by wax candles is generated by fireflies from the same amount of energy. Even modern LED lamps require 7.5 times more energy for the amount of light a firefly generates.

660 kcal

is the energy contained in 100 grams of Brazil nuts, which makes them the powerhouse among foodstuffs. For comparison: 100 grams of sugar "only" has 405 kcal.

FOR ONE KILOWATT ENERGY AUTOGAS (LPG) EMITS 128.1 GRAMS OF CO_2, NATURAL GAS (CNG) 249.1 GRAMS, GASOLINE 261.8 GRAMS AND DIESEL 269.4 GRAMS

564 MILLION METRIC TONS SAVED

China reduced its black coal mining activities between 2013 and 2016 by 4.9 % per year on average. While this doesn't sound like much, the resulting amount that has stayed underground is huge because China with a world market share of about 50 % in coal mining and consumption is the number one coal country by far. The aggregated 564 million metric tons nearly equate to the annual amount mined by India, the third-largest coal nation.

Source: National Bureau of Statistic of China

Facebook status updates made from a smartphone consume **100 times less energy** than those made from a desktop PC. And 100 million users surfing the internet using their smartphones instead of their home computers cuts annual greenhouse gas emissions by the amount emitted by 430,000 cars during the same period.

Source: Nokia

600 million

people were without electricity in northern and eastern India on July 31, 2012. 20 of 28 Indian states were affected by the largest power outage in history. The cause was grid overload.

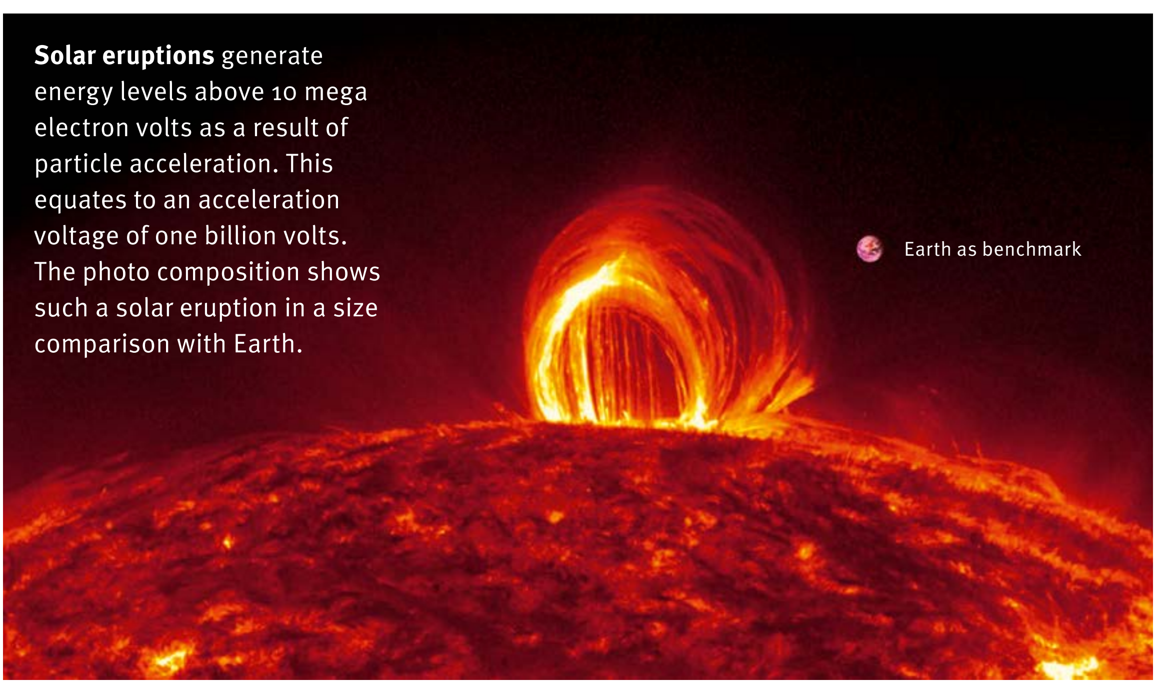
KNOWLEDGE SAVES ENERGY

Googling 100 times consumes about as much energy as a 60-watt lightbulb does in half an hour. The reason is that Google's data centers are energy guzzlers, accounting for about 0.013 % of the global energy requirement, according to Google.

ETERNAL LIGHT

The world's longest-burning light bulb shines in the Livermore fire department in the U.S. state of California – consistently since 1901, except for a few incidents like power outages that weren't the bulb's fault. The "Centennial Bulb" has been watched by webcams (centennialbulb.org) for a few years. Unlike the bulb, they already had to be replaced three times.

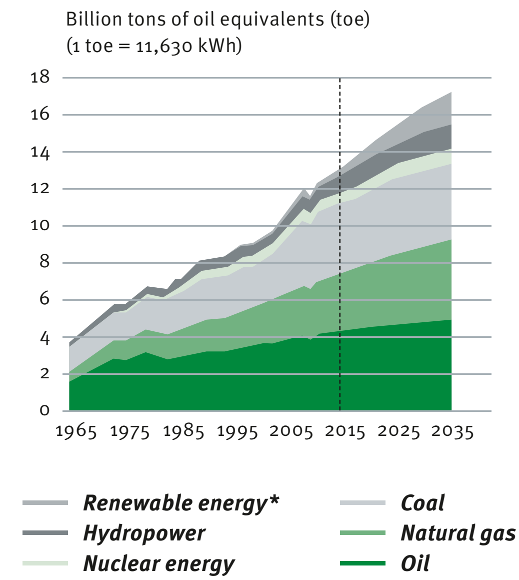
Solar eruptions generate energy levels above 10 mega electron volts as a result of particle acceleration. This equates to an acceleration voltage of one billion volts. The photo composition shows such a solar eruption in a size comparison with Earth.



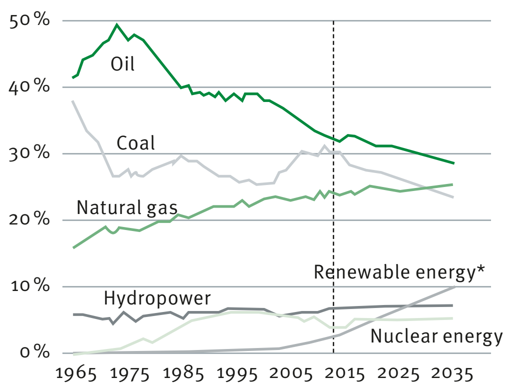
1,000,000,000,000,000

$1 QUADRILLION IS THE PROJECTED COST OF THE CONVERSION TO RENEWABLE ENERGIES BY 2030.

PRIMARY ENERGY CONSUMPTION BY ENERGY CARRIERS



PERCENTAGES OF PRIMARY ENERGY



* Renewable energies include wind and solar power, geothermal energy, biomass and biofuels

Source: BP P.L.C. 2017

» *Energy cannot be generated but only transformed from one form into another*

Law of energy conservation according to Julius Robert von Mayer, James Prescott Joule and Hermann Ludwig Ferdinand von Helmholtz

€ 400 million

in Germany alone could be saved by energy-efficient street lighting, according to estimates by the NRW Energy Agency. Street lights in 50 percent of German communities use technology from the 1960s.

THE AUTHOR

Facts and figures are second nature to our author ***Carsten Paulun*** *(50). Math and physics were even his major "Abitur" (high school graduation exam or A-levels) subjects. At the moment, he spends every free minute on his smartphone checking the hourly yield of the solar power system he just bought. According to his calculations, it will have paid itself off after 11.27 years. If the weather does its part ...*

HARNESSING NATURE'S FORCES

Iceland intends to become the "green battery" of Europe. The island in the North Atlantic Ocean covers its heating and electricity requirements from geothermal and hydropower sources. Excess electric power is made available at low rates, for instance as an incentive to attract energy-intensive industries to the volcanic island.

by Carsten Paulun

It was love that motivated Katja Laun to move from the middle of Germany to Iceland. She and her husband, Freyr, run the Uppsalir guesthouse, 15 kilometers south of Akureyri, a town that with a population of just under 20,000 is the biggest one outside the Reykjavík metropolitan area. "I wanted to get away from industrialization, consumerism and the hectic pace in Germany, although life here isn't easy and, above all, expensive, especially ever since the 2008 financial crisis," says the German expat. Iceland's three biggest banks were placed under government control, the Icelandic crown lost nearly 70 percent in value vis-à-vis the euro, and prices exploded. "There's just one thing that's really cheap here: energy. Be it electric power or heat – there's an abundance of both," says Katja Laun. Not surprisingly, given that Katja, Freyr and about 340,000 other Icelanders live on the biggest volcanic island on Earth.

Heated streets

All it takes to tap into nature's forces is to stick one's finger into the ground. This can be taken quite literally. Iceland is located on the Mid-Atlantic Ridge, which puts it on the North American and Eurasian Plates. Both plates are drifting apart – by about two centimeters per

99 %

of the Earth's inner mass is more than 1,000 degrees centigrade hot, while temperatures in the Earth's core are as high as 6,000 degrees – all in all, more than enough energy to supply the whole world with electricity and heat – at least theoretically. But even practically this renewable energy source is increasingly being tapped.

The world-famous Blue Lagoon is one of Iceland's major tourist attractions – although it is actually just a "by-product" of the nearby Svartsengi geothermal power station

year – resulting in volcanic activity that heats the Earth underneath Iceland. Some 130 volcanoes, numerous geysers and steaming water springs provide visible evidence of this sheer endless energy.

The Icelanders soon made use of these springs. Even in the days of the early settlers around 800, houses and barns were heated by the steam from the Earth and bread was baked in the lava soil. Today, in Reykjavík, the world's northernmost capital, and in Akureyri, the streets and sidewalks are kept free from snow and ice in winter by geothermal energy.

The first district heating system was built as far back as in 1950. Today, there are more than 30 geothermal power stations, including a few privately operated ones. 90 percent of all Icelandic buildings are heated using geothermal heat and the rest with electricity. Heating by means of gas, coal or oil has ceased to exist in Iceland.

All geothermal power stations combined have a capacity of 2,699 megawatts and deliver 12.7 TWh per year, as much as three to four medium-sized nuclear power plants, according to the International Geothermal Association (IGA). The world's largest geothermal power station, Hellisheiði in the south of Iceland, can produce 300 megawatts of electricity and 130 megawatts of district heat – enough to supply up to 200,000 households.

The second energy source: hydropower

Besides geothermal energy, hydropower is Iceland's second import source of renewable energy. 49 hydropower stations have a total capacity of about 2,000 megawatts, feeding the grid with 12.9 TWh of electricity. This equates to 72.9 percent of the country's total electricity requirement, according to the national energy authority, Orkustofnun.

In total, Iceland produces 100 percent of its electric power and heat requirements in CO_2-neutral ways, which makes the country a role model in Europe and the world – not only environmentally but also economically, as Iceland quotes Western Europe's lowest electricity prices. Private households pay only 13 cents per kilowatt hour. For industry customers, electricity – like almost anywhere in the world – is even cheaper: they are charged less than three (!) cents per kilowatt hour.

ELECTRICITY FROM GEOTHERMAL ENERGY – THE TOP 10 COUNTRIES

Country	*Installed capacity [MW]*	*Annual capacity [GWh]*	*Number of power stations*	*Increase since 2010 (installed capacity)*
USA	3,450	16,600	209	11 %
Philippines	1,870	9,646	56	–2 %
Indonesia	1,340	9,600	22	12 %
Mexico	1,017	6,071	37	6 %
New Zealand	1,005	7,000	43	32 %
Italy	916	5,660	33	9 %
Iceland	665	5,245	25	16 %
Kenia	594	2,848	10	194 %
Japan	519	2,687	20	–3 %
Turkey	397	3,127	4	336%

HEAT FROM GEOTHERMAL ENERGY – THE TOP 10 COUNTRIES

Country	*Installed capacity [GWh]*	*Annual capacity [GWh]*	*Increase since 2010 (installed capacity)*
China	17,870	48,434	100 %
USA	17,415	21,047	38 %
Sweden	5,600	14,423	25 %
Turkey	2,886	12,536	38 %
Germany	2,848	5,425	14 %
France	2,346	4,407	74 %
Japan	2,186	7,258	4 %
Iceland	2,040	7,422	11 %
Switzerland	1,733	3,228	63 %
Finland	1,560	5,000	81 %

Source: International Geothermal Association (as of 2015)

16.6 %

of the global electricity is produced by hydropower (72.2 % in Iceland), thus clearly ranking ahead of other renewables such as wind (3.1 %), biogenic materials (1.8 %), solar power (0.9 %) and geothermal energy (<0.4 %).

Source: World Energy Council (as of 2014)

Already a classic: the Ljósafoss hydropower station commissioned in 1937

Room for more: a mere two wind turbines are currently operated by the national Icelandic energy utility Landsvirkjun

This powerful selling point is intended to attract energy-intensive industries such as aluminum smelting, which by now accounts for more than 50 percent of the total electricity consumption. But international data centers have been moving to Iceland as well. In addition to cheap and, above all CO_2-neutral, electricity, Iceland has a well-educated workforce of techies. And there's yet another benefit offered by Mother Nature: at an average annual temperature of seven degrees centigrade, free cooling of the sensitive electronics is part of the package. In addition, the Icelandic power grid is one of the world's most stable ones.

As industrial operations keep growing, so does Iceland's hunger for energy. As a result, the existing geothermal and hydropower stations have to be expanded or new ones built – which normally entails interventions in the island's sensitive natural environment. The Kárahnjúkar hydropower project commissioned in 2006 is a case in point. Europe's highest dam wall (nearly 200 meters) was erected, and a high plateau flooded – in order to supply electricity to an aluminum smelting plant. Accordingly, the project met with high – but ultimately fruitless – resistance.

Wind energy might be a solution. Currently, not even a handful of wind turbines are rotating in Iceland. In the sparsely populated north east, a constant wind blows – a good location for new wind farms that could produce several terrawatts of electricity.

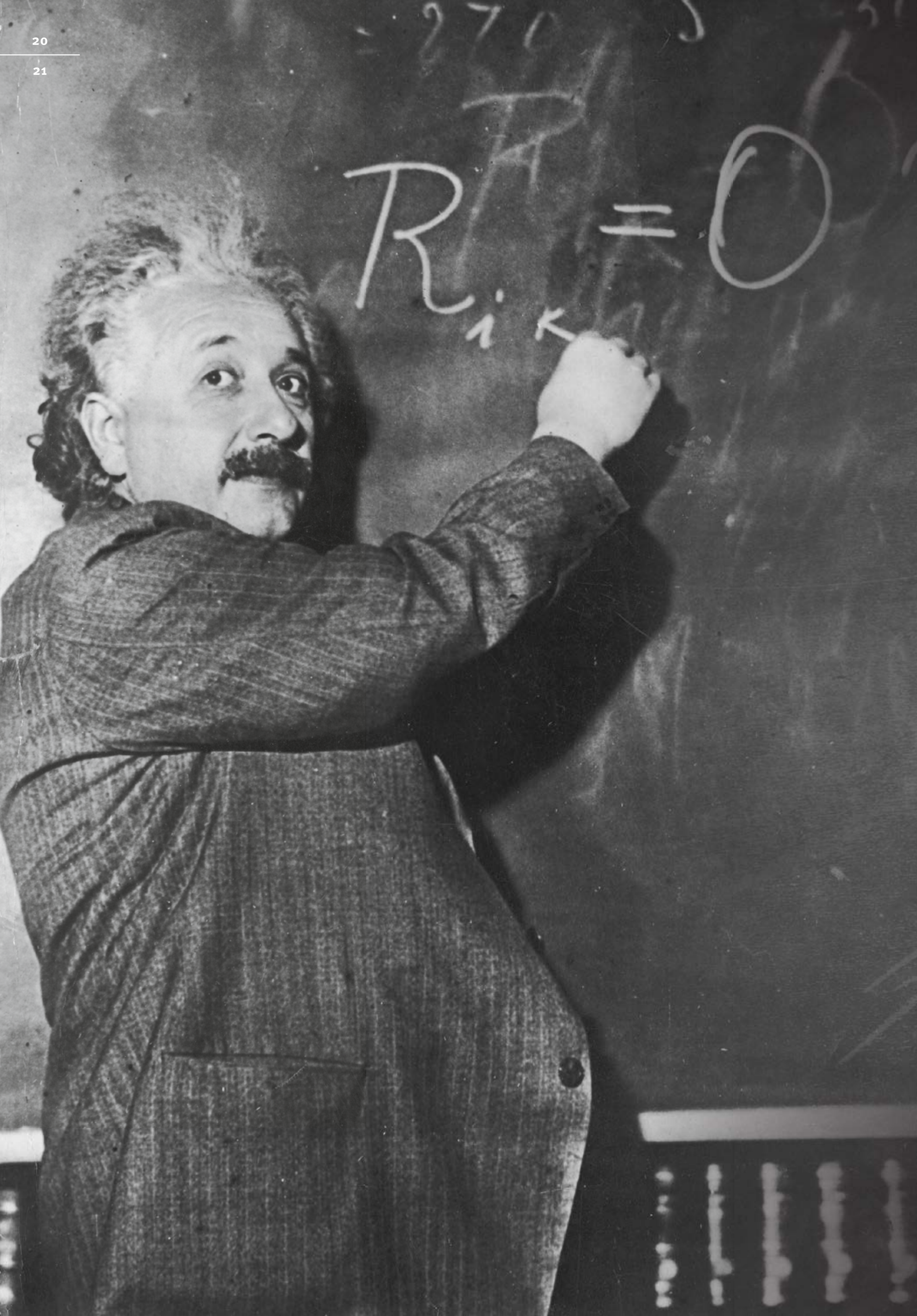
Targeting a 100-percent increase

Iceland's electricity production from hydropower, wind power and thermal energy is intended to double from the current 18 to 36 terrawatt hours per year. The reason is that Iceland – according to the wish of its government – should profit from the global hunger for electricity and export its electricity from climate-neutral production, preferably to Europe. To support this endeavor, plans for the world's longest submarine power cable were launched in 2011. The "IceLink" is to run from Iceland to Scotland covering a 1,170-kilometer distance. Starting in 2024, more than five terrawatt hours of electricity per year are to be sold to Europe via this "power highway." In the light of electricity prices increasing by about three percent per year, this is certainly not a bad business case.

The main reason why Iceland is "only" covering 80 percent (the EU's average is below 15 percent) of its total energy demand by renewables is the use of fossil fuel for transportation. Ambitious Iceland is addressing this issue by another project, which aims to intensify the utilization of hydrogen particular in transportation. The production of hydrogen is particularly energy-intensive, but Iceland has an abundance of climate-friendly energy that can be used for this purpose. The hydrogen produced this way is to replace gasoline and diesel fuel on the road as well as in the fishing industry. Conventional e-mobility is intended to receive a boost as well, for instance by an increase in charging stations. By 2050, Iceland plans to completely do without fossil fuels – as befits a European battery that is green through and through. Expat Katja Laun and her husband Freyr will probably approve of this plan.

THE AUTHOR

*Water, beaches, nature in its purest form – Iceland has plenty of all this. **Carsten Paulun** (50), the technology & car editor of "Bild"/"Bild am Sonntag" for many years, now working as a freelancer, has visited the island in the North Atlantic three times. He was not only fascinated by its rough beauty but also by nature's incredible forces that can be felt practically everywhere on the island.*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THE PHILOSOPHER'S STONE OF ENERGY

Energy equals mass multiplied by the speed of light squared. This physics equation marks a breakthrough, as well-known as the man who first wrote it down 112 years ago: Albert Einstein.

by Wolfgang Stegers

When Albert Einstein in 1905 postulates his formula E=mc² it joins René Descartes' cognition: "I think, therefore I am," or Euler's Identity, which is regarded as one of the most beautiful mathematical formulas of all, in the world's history books. But only E=mc² makes it into graffiti on rail track installations or restroom doors, is printed on postage stamps or converted into a fashion label. In 1999, Time Magazine names the scientist who has acquired cult status the most important person of the 20th century to whom, in commemoration of his "annus mirabilis" a hundred years ago and the 50th anniversary of his death in 2005, a commemorative year is dedicated.

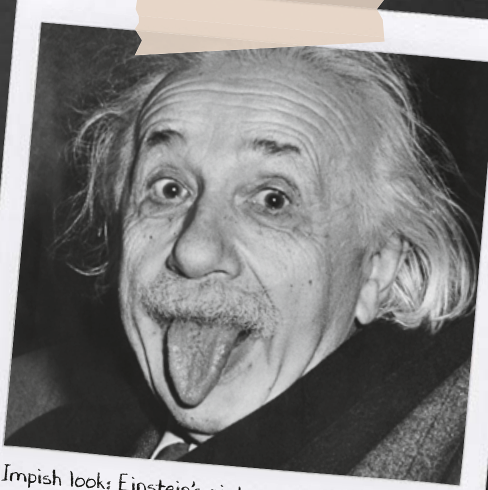
1905 is Albert Einstein's miracle year. The 26-year-old has been working at the Swiss Patent Office in Bern for three years, a nine-to-five job. After hours, Einstein becomes an "inventor" himself, and a prolific one at that. No less than four pioneering papers he publishes in 1905, all of them representing incisive steps in advancing the science of physics.

His first paper reaches the editors of the "Annals of Physics" in Berlin, one of the world's oldest scientific journals, on March 17, 1905. In it, Einstein claims that light consists of particles, so-called photons. With that, Einstein creates an important foundation for the theory of quantum mechanics.

On May 11, he ups the ante. In the second paper he sends to the German capital city, Einstein provides the first coherent explanation of Brownian motion and thus becomes a co-initiator of statistical mechanics.

On June 30, the editors of the "Annals of Physics" receive mail from Bern again. Under the heading "On the Electrodynamics of Moving Bodies," Einstein postulates the Special Theory of Relativity, which refutes the existence of an ether pervading the entire universe, revolutionizes the idea of space and time, and defines the speed of light as the absolute maximum of speed.

In an addendum dated September 27, titled "Is the Inertia of a Body Dependent upon its Energy Content?" the formula that would subsequently acquire world fame is described for the first time – as a footnote. Einstein had previously submitted the paper as a dissertation at Zurich University.



Impish look: Einstein's picture was taken so often that occasionally he'd say "model" when asked what his profession was

Bam! A young family man, who had quit school at one time in his youth, now working as an "assistant examiner – level III" at the Patent Office in Bern and completely unknown to the scientific world to date, changes the world within the space of one year. The physicist, philosopher and peace researcher Carl Friedrich von Weizsäcker wrote in this context: "1905, an explosion of genius. Four publications on four different subjects, each of which, as one says today, would be worthy of winning the Nobel Prize."

Enormous energies

$E=mc^2$ – although actually being a mere marginal note – is a special discovery: so simple, so clear, yet all-encompassing. Each of the three letters symbolizes a specific physical quantity. The lower case "c" stands for "celeritas," the speed of light, the lower case "m" for mass, measured in kilograms. If the speed of light, "c," is multiplied by itself and then with mass, "m," the result is energy, "E." The enormous magnitude of the speed of light traveling at 300,000 kilometers (approx. 186,282 miles) per second presages that the resulting energy has to be enormous.

A genius's personal life: with one of the two daughters from his wife's first marriage on his lap and while pursuing his pastime of sailing

Three thousandths of one gram (0.03 oz) of mass suffices to allow a 100-watt lightbulb to burn for a hundred years. According to the equation, a body or object is light or heat at the same time as well. This equivalence becomes tragically obvious to hundreds of thousands of people in 1945. When the two atomic bombs are dropped on Hiroshima and Nagasaki, the splitting of atoms releases gigantic amounts of energy, destroying these two Japanese cities.

Driven by the concern that Nazi Germany might be able to seize world domination with an atomic bomb of its own, Einstein, who is of Jewish origin and has emigrated to the United States, writes a letter to U.S. President Franklin D. Roosevelt as early as in 1939 that provides initial impetus to the American nuclear arms project – not an easy step for Einstein who is a professed pacifist. Later he refers to this letter as "the one great mistake in my life."

Moving on from this dark chapter to something more enlightening that can be explained by $E=mc^2$ as well. The warming rays of the Sun result from nuclear reactions during the fusion of hydrogen to form helium and other elements. Here, the Sun as a nuclear reactor transforms four million metric tons (4.4 million short tons) per second into radiation. The quest for technology enabling the generation of such amounts of energy on Earth for peaceful purposes and without harmful side effects is still being pursued.

How the physicist turned into a pop star

Why Einstein of all people is catapulted into a popularity orbit like no other scientist before him and – perhaps with the exception of Stephen Hawking – no other one after him, mystified Einstein himself. "Why is it that nobody understands me and everybody likes me," Einstein asks himself again and again. And it's not uncommon for him to express that this puts him on edge: "With me every peep becomes a trumpet solo."

A spectacle of nature puts him in the limelight. During a total eclipse of the Sun on May 29, 1919, two expeditions led by the British astronomer Arthur Stanley Eddington take pictures of constellations that actually should not have been visible because they're located behind the Sun. This provides proof of what Einstein predicted in his General Theory of Relativity published in 1915, i.e. that celestial bodies due to their mass and energy bend the space that surrounds them, like a heavy ball placed into a taught sheet. Rays of light that move through such bent space will follow the curvature as well. That's why the hidden constellations

$E = mc^2$

IQ meeting: Einstein (1) among others, with Max Planck (2), Marie Curie (3), Hendrik Antoon Lorentz (4), Erwin Schrödinger (5), Werner Heisenberg (6) and Niels Bohr (7)

can be photographed. While the scientific details escape many people at the time (just like today), they do realize that there's someone among them who had predicted this spectacle and other wondrous phenomena: Albert Einstein. Suddenly, the whole world starts talking about him and his work. Einstein mania is particularly wide-spread in the United States, much to his chagrin: "Currently, every coachman and every waiter is debating whether relativity theory is correct [...] Since the light deflection results became public, such a cult has been made out of me that I feel like a pagan idol."

Interpersonal gravitation

As popular as Einstein has suddenly become, his fame, as he says himself, has little effect on his personal life, which he describes as "amazingly uneventful." The man who will go on to adjust the world's view of physics is born in Ulm, Germany, in 1879. His parents, Hermann and Pauline Einstein, are middle-class citizens of the Jewish faith, not very observant, but rather free-spirited, well-read, liberal and forward-thinking people. Their son utters his first words only at the age of three, but immediately forming them into full sentences. Social interaction does not come easy to him either. But – throughout his life – he's driven by a childlike curiosity, by an irresistible urge to "understand the secrets of nature," as he'll later put it himself. At the age of eleven, Albert Einstein strikes a friendship with Max Talmud, a medical student ten years his senior. Talmud: "The flight of his mathematical genius soon became so high that I was no longer able to follow it." But the highflyer sees his wings clipped by the military discipline of his high school in Munich. Albert quits school, applies to study at the Zurich Polytechnic but fails the entrance exam due to linguistic deficits. A detour via a cantonal school in Aarau ultimately paves his way to an enrolment at the Polytech. He has no interest in the gregarious lifestyle of his fellow students. Instead of spending his time in pubs, Einstein, with his thirst for knowledge, attends extracurricular lectures, but meets a woman nonetheless. Mileva Maric, to the chagrin of Einstein's parents, is a bookworm just like their son. In spite of their disenchantment, he marries his "smart wench" in 1903. A year later, their son, Hans Albert, is born, followed by a second boy in 1910, Eduard. Correspondence discovered in 1987 hints at the birth of a premarital daughter in 1902, whose fate has remained obscure to this day. There has also been plenty of discussion to this day about the share his mathematically talented wife had in Einstein's pioneering work. The fact that the plural "we" is not uncommonly found in his papers is fertile soil for this speculation.

In spite of the enthusiasm for science the spouses share, their marriage doesn't last. When Einstein is awarded the Nobel Prize for physics in 1921, the two have long been divorced. One reason that put the end to their marriage was Einstein's affair with his cousin, Elsa, whom he marries in 1919. In 1933, they emigrate to the United States where Elsa, in 1936, dies in Princeton that has become home to them. Although Einstein lovingly cares for his ill spouse, the preceding years of their marriage are difficult because the nerdy physicist – who'd have thought – feels attracted by the gravitational force of females in rather unchaste ways. In 1952, he's offered the presidency of Israel. He declines, saying, among other things, that he lacked "natural aptitude and experience" to deal with people. Three years later, Einstein dies. His ashes are scattered. The involuntary pop star does not want a tombstone that might become a place of pilgrimage.

THE AUTHOR

Albert Einstein and no end in sight. Even as an editor for the "P.M." science magazine ***Wolfgang Stegers*** *wrote about the enigmatic scientist and his ingenious ideas. With good reason: issues showing Einstein's distinctive face on the cover were always bestsellers at the kiosk.*

POWER GALORE

The Sun is the most efficient energy source we can use. But it took a long time before we began to utilize it for large-scale electricity and heat production. And even today the immense future potential of photovoltaics and solar thermal energy is still underestimated.

by Kay Dohnke

7.4 SECONDS

This little bit of solar radiation suffices to cover the world's energy demand for a whole day. *And if we could store the solar energy received on a full day, we'd have enough energy for 32 years. These numbers alone clearly show that we don't have a global energy problem. We only have a problem transforming the abundance of the Sun's energy into electricity and heat, and making intelligent use of it. And solar energy is just one of several renewable energy sources available to us.*

But at least, in order to use renewable energy sources, the technology is getting better and better – even though we got off to a slow start. ***In 1839, Alexandre Edmond Becquerel discovered that solar radiation can be directly transformed into electric current.*** *But it took until 1893 for the first functional photovoltaic cell to be designed and it was only in the 1980s that the global success story of solar power generation began. Today, blue solar panels are commonplace in both urban and rural areas in many countries.*

Photovoltaics accounts for the lion's share of solar energy. Solar cells installed on flat panels transform diverse sectors of the solar radiation spectrum – primarily from the visible and low infrared range – directly into electric power, which is either immediately consumed or fed into the grid. Silicon-based modules can be produced in large volumes at low cost and require almost no maintenance, but ***their efficiency is only about 20 percent.*** *Surprisingly, the more the Sun heats a solar panel, the lower the electric power it yields.*

300 KW

This was the capacity of Europe's largest solar station in 1983. *It was not located in the sunny south as might be suspected, but on the North Sea island Pellworm. And 229 is the total capacity of the global solar power stations in 2016 – albeit in gigawatts. This equates to 229 million kilowatts, in other words nearly 765,000 times the amount of electricity that used to be generated on the island in the North Sea. Pellworm Park had the size of two soccer fields, while the largest solar power station currently planned in North-West China with a capacity of two gigawatts will require 4,600 hectares (11,367 acres) of land for six million solar panels – more space than all of Pellworm (3,744 hectares/9253 acres) has to offer, which illustrates a* ***clean energy production technology's march of triumph.***

As capacity keeps increasing, the space on which photovoltaics can be economically used automatically grows. Modern solar panels with their high efficiency can ***generate electricity even in places where this would have been inefficient with previously existing panels.*** *And the technical range for solar cells is large. Scientists are working on solid-state dye-sensitized solar cells, flexible solar cell sheets or transparent panels that can be installed on building surfaces and windows. Elon Musk' company, Tesla, in addition to exclusive electric cars and batteries, will soon be launching solar rooftop tiles. What looks like normal shingles is actually a rooftop made up of many small power generators.* ***Solar power generation is well on its way toward making itself invisible.*** *Indispensable it has already become.*

THE 10 LARGEST SOLAR POWER STATIONS

There is hardly another field of technology in which announcements of new records follow each other in equally quick succession as solar power generation. In spring of 2017, the ten plants below were the most powerful ones in the world. The values refer to maximum rated capacity (target value: final capacity following current, near-complete extension).

1 Longyangxia Dam Solar Park, Qinghai/China **850 MW**
2 Kamuthi, Tamil Nadu/India **648 MW**
3 Solar Star I and II, California/USA **579 MW**
4 Huanghe Golmud Solar Park, Qinghai/China (target value) **560 MW**
5 Desert Sunlight Solar Farm, California/USA **550 MW**
6 Topaz Solar Farm, California/USA **550 MW**
7 Charanka Solar Park, Gujarat/India (target value) **500 MW**
8 Copper Mountain Solar Facility, Nevada/USA **458 MW**
9 Ivanpah Solar Power Facility, California/USA **392 MW**
10 Agua Caliente Solar Project, Arizona/USA **392 MW**

RECORD POWER PLANTS CURRENTLY UNDER CONSTRUCTION OR IN THE PLANNING STAGE

Ningxia Solar Project, China **2,000 MW**

Ouarzazate, Morocco (partly in operation, partly under construction) **580 MW**

4.4 PERCENT

A meager share: solar thermal power plants accounted for a mere 4.4 percent of the 229 gigawatts of solar capacity existing in 2016. *The reasons are easy to explain. Photovoltaics is a prime example of how economic conditions influence the future of environmental technologies. The rapid drop in prices for solar panels combined with government subsidies and feed-in compensations promoted the burgeoning of photovoltaics. All of a sudden, a large number of real estate owners were able to convert their environmental consciousness into cash. The result was a massive, politically intended and government-subsidized, increase in photovoltaic systems in many countries. On the downside, investments in clearly more efficient solar thermal power did not materialize.*

1,200 DEGREES

1,200 °C (2,192 °F) is the maximum temperature that can be achieved with the second form of efficient solar technology. *In the case of solar thermal systems, the heat of the sunlight is concentrated by optical amplifiers many times over. A spectacular sight is the solar power towers with their tops equipped with hundreds of mirrors that concentrate the light. These movable mirrors can generate high and ultra-high temperatures many hours of the day. Subsequently, evaporating fluids power turbines to produce electricity or are used for heating, solar cooling or drinking water treatment.*

Other types of solar power plants operate with parabolic trough mirrors or dish-like mirror systems. Such large-scale plants are costly and require a lot of maintenance but achieve ***efficiencies of up to 85 percent.*** *Base load power is a special advantage of solar thermal power plants. Heat generated during the day is stored in molten salt batteries and used to generate electricity at night. The Gemasolar solar power tower plant in Andalucía commissioned in 2011, for instance, not only has a capacity of 19.9 megawatts but is able to store the solar heat concentrated up to a temperature of* ***565 °C*** *(1,049 °F) in a molten salt battery for up to 15 hours.*

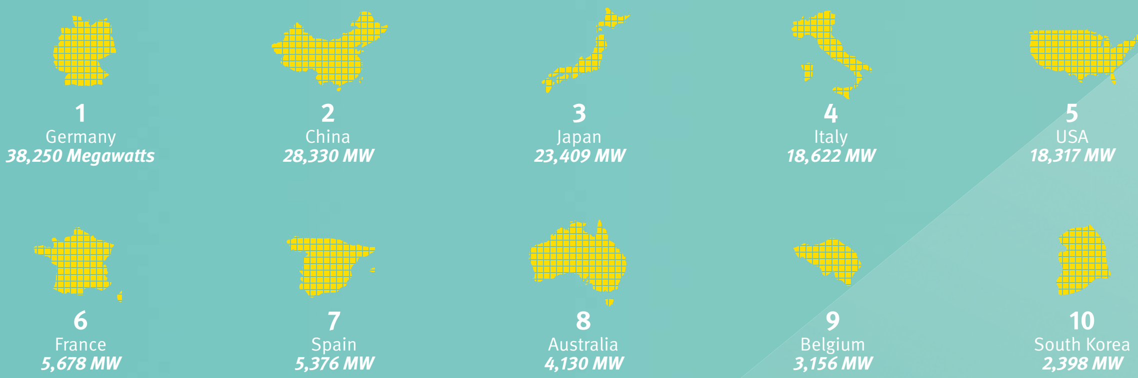
46 PERCENT

This is the efficiency of the most powerful solar cell in existence to date, *which researchers of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, developed together with French partners in 2014. The quadruple solar cell is able to transform the photons in the wave length range between 200 and 1750 nm into electrical energy. In addition, the sunlight is focused in a small area by means of special lenses, the record lens having achieved a 508-fold concentration of the light received. Multi-layer lenses that use various wavelength ranges of sunlight are currently the* ***key to enhancing efficiency*** *in photovoltaics. However, the wide-spread silicon cells with an efficiency of only about 20 percent can be produced at clearly lower costs than high-tech record lenses and are therefore more profitable at the moment.*

SOLAR LAND BRANDENBURG

Germany is the world's "biggest" solar country (see next page). Seven of the ten major solar power stations there are located in Brandenburg. Combined, they have a capacity of 895.4 MW (equating to that of a medium-size nuclear power plant). 246 MW of this is delivered by Germany's number one, the Senftenberg solar complex.

THE **TOP 10 SOLAR COUNTRIES**



Source: International Energy Agency

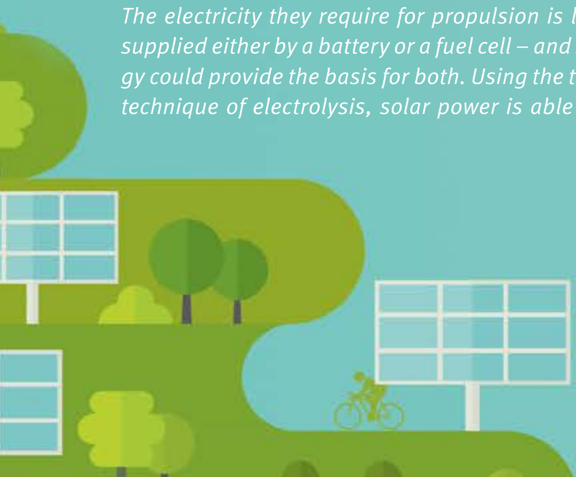
1.3 MILLION

This is the number of electric vehicles registered around the world in 2016, and all are capable of being operated with solar and wind energy. *1.3 million – in the light of 1.2 billion cars existing worldwide, this number appears as small as the Pellworm solar complex does in retrospect. However, this is another field where practically the sky's the limit when it comes to the concepts pursued by the developers. Overhead line systems for buses and trucks, and quick-charging stations are already being operated in the field. The march toward e-mobility is taking place on a global scale. In Asia, various concepts for electric pedicabs are competing with each other in the quest for reducing emissions from public transportation in metropolises. In China, several manufacturers have been stepping up their production of electric vehicles in order to control smog in the mega cities. Futures studies predict that by 2035 up to 150 million electric vehicles will be on the world's roads.*

The electricity they require for propulsion is likely to be supplied either by a battery or a fuel cell – and solar energy could provide the basis for both. Using the time-tested technique of electrolysis, solar power is able to decompose water into hydrogen and oxygen. This "power-to-gas" process is already in use. The hydrogen produced this way is transformed by fuel cells into the drive power for electric motors. Dutch researchers have developed a solar cell made of gallium phosphide that can even produce hydrogen directly.

As electricity produced from renewable sources – "power-to-gas" works with wind power as well – is available in abundance, cars with fuel cell powertrains could continue to run even after the end of oil. And if hydrogen is methanized with carbon dioxide the result is synthetic natural gas – which can be used for climate-neutral operation of converted IC engines, as only the amount of carbon dioxide is emitted that has previously been added in the manufacturing process.

But this doesn't exhaust the Sun's potential yet. By transforming its energy in specific ways even conventional IC engines can be fueled by solar energy. In the "power-to-liquids" process, carbon dioxide and water, by means of solar power, initially react to form a synthetic gas from which gasoline, diesel or kerosene can subsequently be produced. While this technology consumes a lot of energy it does produce very clean fuels. A technology developed in Switzerland circumvents the use of solar electric power by utilizing the immense solar heat for a synthetization process based on the principle of a solar power plant. By means of a special catalyst this process, as well, produces hydrocarbons from carbon dioxide and water as the basis for environmentally neutral liquid fuels.



THE AUTHOR

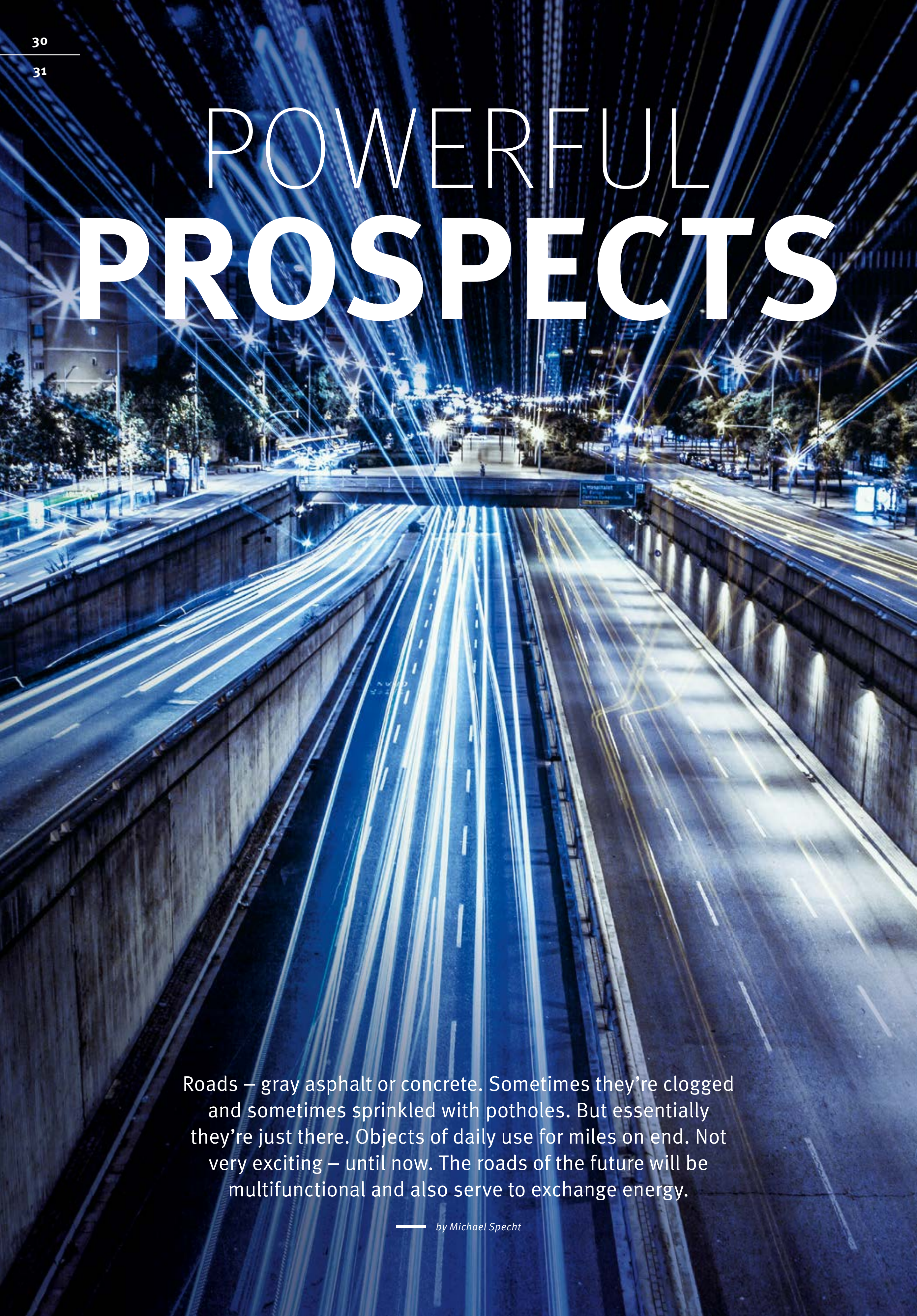
*Witnessing the conflicts over the Brokdorf nuclear power plant in the Germany of the seventies and now feeling indifferent to the energy turnaround? "An absolute no-go!" says **freelance journalist Kay Dohnke**, who was born in nearby Itzehoe and is happy that working on renewable energies provides him with a range of equally sustainable and forward-thinking topics.*

ALWAYS **FOLLOWING THE SUN**

In many solar power stations, bearings and technologies from Schaeffler are used. A look at the Spanish Andasol plant shows the advantages they offer.

1,248 plain bearing rod ends have been installed there for the purpose of supporting and positioning several hundred hydraulically adjustable parabolic troughs and ensuring that they continuously follow the Sun. Plain bearings are optimally suited for the slow, precise swivel movements. They absorb high loads and are suitable for both high unilateral and alternating loads, for instance when the direction of the wind changes. As a result, the 150 meter long collector chains can be adjusted precisely to within a tenth of a millimeter, enabling the troughs to follow the Sun on its daily path from east to west. The hydraulic rod ends are fitted with manganese phosphate coated radial spherical plain bearings with steel/steel sliding contact surfaces. This special surface treatment protects the material against wear and reduces friction. The inner ring of the spherical plain bearing with a width of 70 millimeters has a cylindrical bore diameter of 110 diameters and a spherical outer slideway, while the 160-millimeter outer ring has a cylindrical outer surface and a concave inner slideway with a diameter of 140 mm. Schaeffler's products for Andasol are completed by 7,488 environmentally friendly plain bearing strips from its portfolio of metal-polymer composite plain bearings. Mounted in the supports between the individual segments of the 150 meter long collector chains, they ensure smooth slewing movements while the troughs track the Sun.

The Andasol solar power station



POWERFUL PROSPECTS

Roads – gray asphalt or concrete. Sometimes they're clogged and sometimes sprinkled with potholes. But essentially they're just there. Objects of daily use for miles on end. Not very exciting – until now. The roads of the future will be multifunctional and also serve to exchange energy.

by Michael Specht

Roads are an important piece of the puzzle on the path to mobility for tomorrow – for truck traffic, to name just one example. Nobody in their right mind would think of putting a battery-powered freight or passenger train on a track. Logically, trains are supplied with power from overhead lines – permanently and with high efficiency. So why not "fuel" trucks this way too? It would allow them to travel even long distances on highways quietly and with zero emissions.

A smart name for this already exists. It's called an eHighway. A real-world route exists as well. In Sweden, north of Stockholm, a pilot project has been underway on a public highway since June 2016. On a dedicated section of the highway, diesel-hybrid trucks can plug into an overhead line and then be operated in fully electric mode. The project is jointly run by Scania and Siemens and could reduce emissions caused by the combustion of fuel by 80 to 90 percent, according to Scania.

Even Chancellor Angela Merkel was impressed by the energy highway during a visit with Swedish Prime Minister Stefan Löfven. The two heads of government agreed to enter into a so-called investment partnership during a meeting in Stockholm. Initially planned in Germany are two test routes, one on A1 between Reinfeld and Lübeck, and the other one between Frankfurt Airport and Darmstadt. "The objective is to make road transportation of goods more climate-friendly in every respect," says State Secretary Jochen Flasbarth from the German Federal Environmental Ministry.

Local public transportation systems are equally predestined for drawing power from an overhead line. Trolley buses with their current collectors that resemble fishing rods can still be seen in many cities. And every child is familiar with streetcars or trams. They run in Munich and Melbourne as well as in San Francisco or Stuttgart. In many cases, though, such as Hamburg, overzealous politicians in the 70s had rail and overhead power line systems removed in favor of diesel buses. Thinking since then has become more rational again. The city of Hamburg has plans on the shelf for returning to the environmentally friendly streetcar system.

Charge me quickly

As a viable future alternative to the former trolley buses, Siemens has developed the pantograph. This is what the corporation calls its quick-charging system that can be installed on a mast or the canopy of a bus stop shelter. The idea behind the pantograph is to recharge the battery, for instance at a bus terminal, up to a level that allows an electric bus to travel the distance to the next charging station. For fully automatic charging, the bus is driven under a charging station that precisely

» Mobility will continue to evolve from the classic vehicle the way we know it today. Likewise, the road and its direct environment will be seeing a continuing evolution. Overhead lines for trucks or inductive charging while the vehicle is in use are two interesting approaches, as the electric motor has won through in all areas of personal mobility where electrical energy is not being stored but fed to vehicles. Car2X communication with roadside infrastructure is another interesting field for Schaeffler to explore with respect to the utilization of its products. And so are, for example, the fields of Condition Monitoring and Predictive Maintenance in which we are very well positioned in the Industry and Rail sectors

Prof. Peter Gutzmer, Schaeffler AG's Chief Technology Officer

Two possibilities of range-independent electrification of trucks and buses: power rails (above) and overhead lines. Both are currently being tested in Sweden

€ 75,000

in fuel costs can be saved by a Swedish 60-ton truck if it travels a 200,000-km (124,274-mile) distance on an electric highway.

Source: Siemens (calculation based on current electricity and fuel costs)

80 cm

between vehicles traveling in a convoy at 100 km/h (62 mph) are enough if they are interconnected in a 5G network. Human response time in vehicles networked this way is reduced from 5.5 seconds to 2 milliseconds.

Source: Huawei

lowers the pantograph onto the contact rails. Buses providing regular service have been using this system for testing purposes in Dresden since November 2014.

Battery-electric buses with additional power supply from an overhead line would provide another advantage, as urban intersections would not have to be completely equipped with overhead lines like in the old days. As a result, there would be no need for complex "cable spaghetti" because the bus can travel the short stretch across the intersection on battery power and subsequently connect itself with the overhead line again.

What works from the top down should also work from the bottom up, similar to a Carrera model race track. This concept, at least, is being investigated by Volvo. Together with rail specialist Alstom, the Swedish truck maker is testing road-integrated power rails on a twelve-kilometer section from Stockholm Airport to the Rosersberg logistics center. "The lines are sectioned so that live current is only delivered to a collector mounted at the rear of, or under, the truck if an appropriate signal is detected," says Mats Alaküla from Volvo.

Charge me, but don't touch me

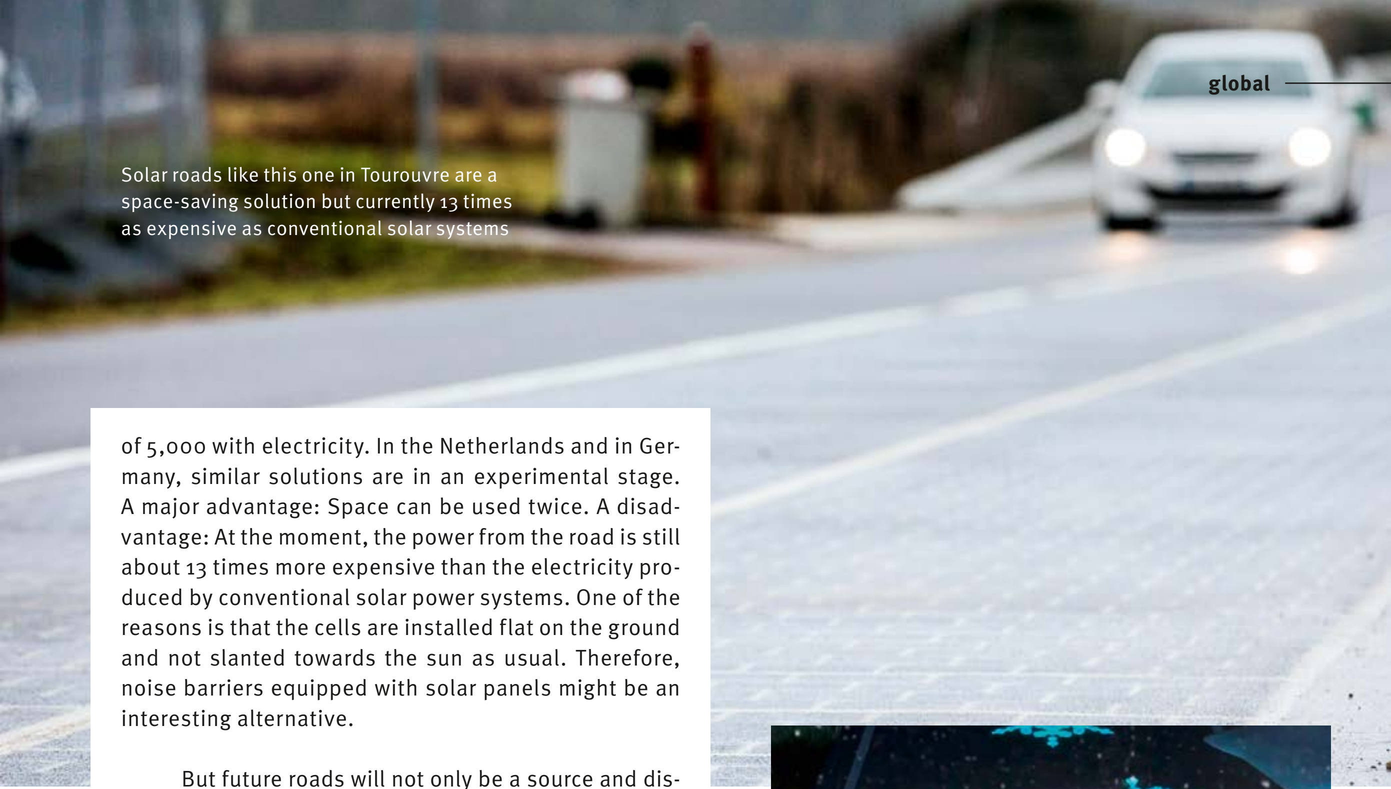
The road no doubt offers further opportunities to supply energy, including wireless ones. For years, induction loops in the surface of streets or roads have been used for switching traffic lights, lifting toll bars or triggering speed cameras. In parking bays, induction loops could be installed underneath the asphalt. Nissan, the world's major manufacturer of electric cars, even predicts that there will be charging zones in which autonomous vehicles look for induction parking bays themselves, charge their batteries, and subsequently move on to a regular parking space so that others can pull into the charging bay.

Statically, inductive charging already works today, for instance in Formula E, where the safety vehicles from BMW use "Halo" inductive charging technology from Qualcomm for wireless charging. But what about dynamic charging? Why not use induction to continually supply electric vehicles with power while they are moving? In Israel, start-up ElectRoad is operating a test road for this purpose. A research team at Stanford University in California is working on such an inductive system as well, saying that it would allow clearly smaller and lighter batteries to be installed in the car. Only three percent of the energy transferred by their highway-integrated wireless charging equipment would be lost, according to the researchers. As a positive side effect, autonomous assistance systems could use road-integrated wires for orientation. Technology like this could also be used by companies for on-site transportation and similar purposes as digitalization keeps increasing on the way to Industry 4.0 and smart factories.

Power right from the road

The electric power needed for advanced technologies might be produced by the roads themselves if a project in Tourouvre, France, catches on. There, a 1,000 meter long road section has been paved with solar cells. The electricity they generate (max. 1.500 kWh/767 kWh on average) at least suffices to supply the street lights of the small town with its population

In the case of the SRS system from Alstom, which has already proven viable for streetcar systems, it takes only 20 seconds to sufficiently charge the battery for the bus to reach the next stop



Solar roads like this one in Tourouvre are a space-saving solution but currently 13 times as expensive as conventional solar systems

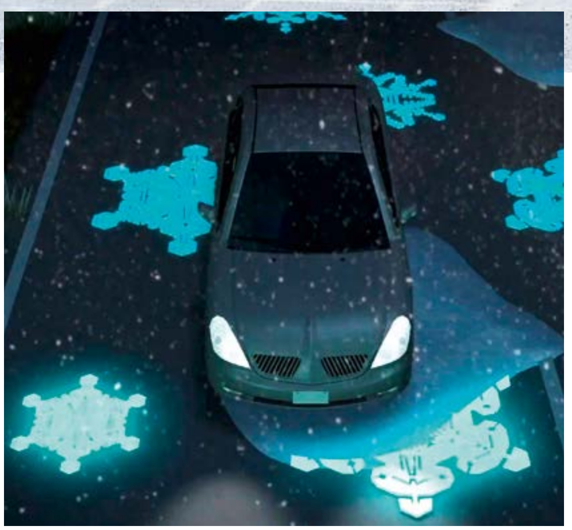
of 5,000 with electricity. In the Netherlands and in Germany, similar solutions are in an experimental stage. A major advantage: Space can be used twice. A disadvantage: At the moment, the power from the road is still about 13 times more expensive than the electricity produced by conventional solar power systems. One of the reasons is that the cells are installed flat on the ground and not slanted towards the sun as usual. Therefore, noise barriers equipped with solar panels might be an interesting alternative.

But future roads will not only be a source and dispenser of energy but, equipped with integrated or adjacent sensors, an important source of information for modern traffic control using car-to-infrastructure-communication (Car2X) as well. In March 2017, the German state of Lower Saxony and the German Aeronautics and Space Research Center (DLR) jointly started installing devices on about 280 kilometers of road with which Car2X technologies can be developed further. “Through Car2X, for instance, vehicles receive information about the condition of the road: Is it icy? What places pose a risk of hydroplaning?” explains Prof. Karsten Lemmer, Chair of Energy and Transportation at DLR. “Drivers can adjust their driving style accordingly and future assistance systems can help them do so.”

Designer Daan Roosegaarde has developed his own vision of a “smart highway” – using relatively simple means. For example, the Dutchman would like to spray thermal paints on the road that in freezing temperatures would flash in the form of large ice crystals to warn drivers of black ice, while illuminating paints that store solar energy could make unlit roads brighter.

And what would it be like if there was no need to warn cars of upcoming potholes anymore because they no longer existed? This, for instance, is a vision Henk Jonkers from Delft University of Technology in the Netherlands is working on. Jonkers is a microbiologist and has developed “bio concrete” with self-healing powers. If water enters the concrete structure though a “wound” integrated bacteria will wake up, propagate and help form limestone that closes the “wound.”

No matter what developments we are going to see – in the years ahead, the topic of roads will become more exciting than ever before.



Vision: thermal paints can warn drivers of black ice

THE AUTHOR

Michael Specht *(60) has been a motor journalist for 30 years with a bias toward electric mobility. His personal era of IC engines ended three years ago. Now, a BMW i3 is parked in his garage. The freelance author is still thrilled by silent acceleration and says: “If you’ve ever owned an electric car you’ll never go back to pistons, cylinders and oil.”*

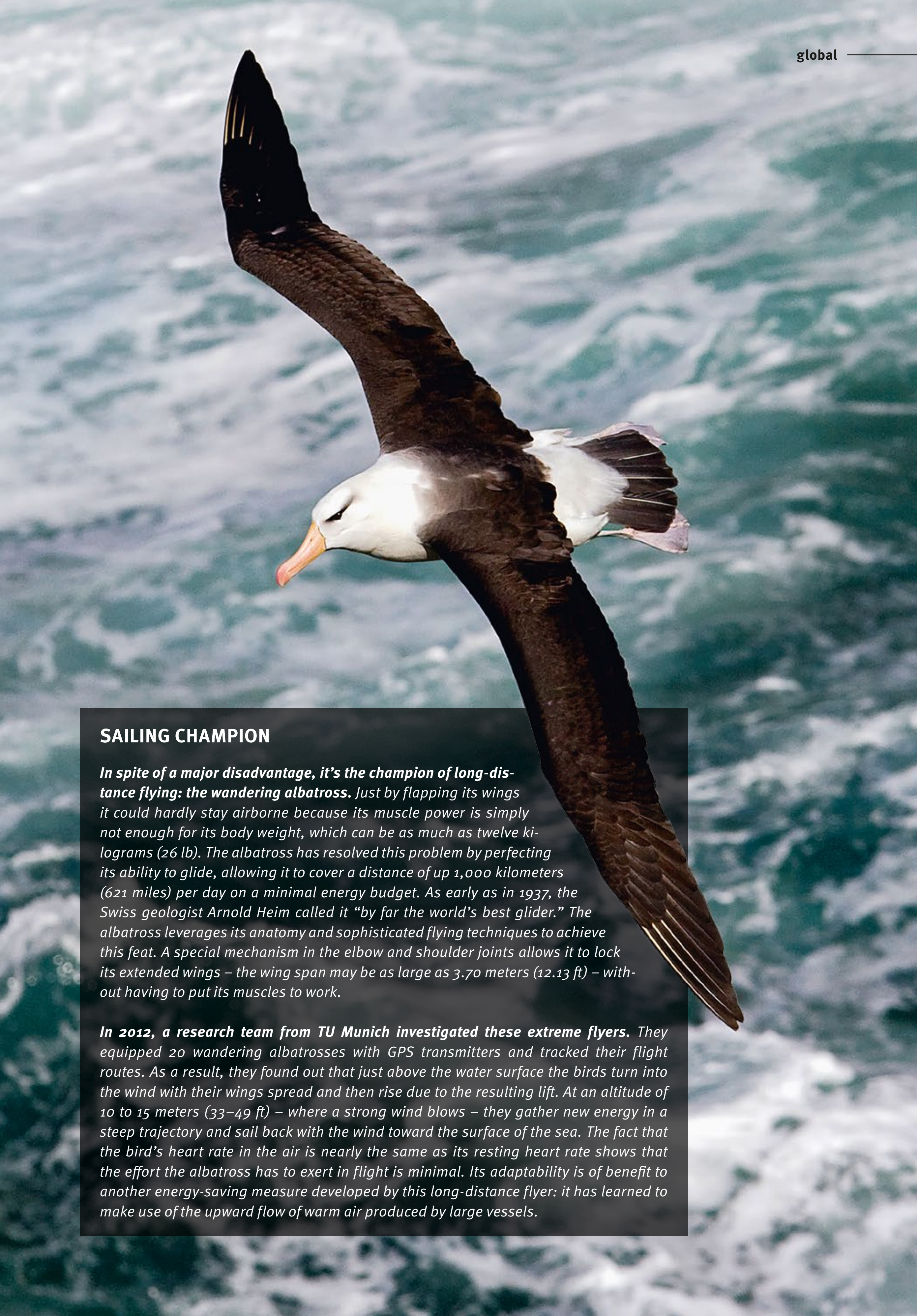
NATURALLY EFFICIENT

In the animal kingdom, a great diversity of strategies for an energy-efficient way of life has developed in the course of evolution. “tomorrow” presents fauna’s efficiency kings.

by Lars Krone

SUCTION POWER

Although almost 99 percent of what they’re made up of is water, there’s more to jellyfish than meets the eye. *U.S. researchers have found out that the slippery sea creatures have developed one of the most efficient propulsion systems in the animal world. For a long time, it was assumed that jellyfish primarily push against the water behind them for propulsion. But current research by a team from Stanford University in California has yielded new findings. “Our experiments show that jellyfish actually suck water toward themselves to move forward instead of pushing against the water behind them, as had been previously supposed,” writes biophysicist John Dabiri. As the jelly’s umbrella-shaped plume collapses, water ahead of the animal is pulled aft, propelling the jellyfish forward, by 45 percent more compared with only pushing against the water behind them. The fact that muscle mass accounts for only about one percent of a jelly’s body weight – compared to fish where the ratio is about 50 – shows the efficiency of this form of propulsion. The research team drew another interesting conclusion. The energy saved in propulsion is invested in growth. As a result, jellyfish can grow to a diameter of more than two meters (6.5 ft), which clearly makes it easier for them to catch prey.*



SAILING CHAMPION

In spite of a major disadvantage, it's the champion of long-distance flying: the wandering albatross. *Just by flapping its wings it could hardly stay airborne because its muscle power is simply not enough for its body weight, which can be as much as twelve kilograms (26 lb). The albatross has resolved this problem by perfecting its ability to glide, allowing it to cover a distance of up 1,000 kilometers (621 miles) per day on a minimal energy budget. As early as in 1937, the Swiss geologist Arnold Heim called it "by far the world's best glider." The albatross leverages its anatomy and sophisticated flying techniques to achieve this feat. A special mechanism in the elbow and shoulder joints allows it to lock its extended wings – the wing span may be as large as 3.70 meters (12.13 ft) – without having to put its muscles to work.*

In 2012, a research team from TU Munich investigated these extreme flyers. *They equipped 20 wandering albatrosses with GPS transmitters and tracked their flight routes. As a result, they found out that just above the water surface the birds turn into the wind with their wings spread and then rise due to the resulting lift. At an altitude of 10 to 15 meters (33–49 ft) – where a strong wind blows – they gather new energy in a steep trajectory and sail back with the wind toward the surface of the sea. The fact that the bird's heart rate in the air is nearly the same as its resting heart rate shows that the effort the albatross has to exert in flight is minimal. Its adaptability is of benefit to another energy-saving measure developed by this long-distance flyer: it has learned to make use of the upward flow of warm air produced by large vessels.*

TIME FOR A BREAK

Flat-out during the day and half-dead at night – the life of hummingbirds alternates between two extremes. *These pip-squeaks weighing no more than two to 20 grams (0.07 to 0.70 oz) have extreme maneuvering skills – even hovering and flying backward is no problem – and they achieve speeds of more than 100 km/h (62.13 mph). Their secret lies in hovering by moving their wingtips up to 90 times per second in a figure-eight pattern with the eight lying on its side – an absolute record in the birds' world. Some hummingbird species have heart rates of 1,200 per minute. For all this, the birds need an immense amount of energy: 250 calories per hour – as much as a man weighing 70 kilos (154 lb). To cover its energy needs, a hummingbird has to empty between one and two thousand flowers per day. The amount of nectar absorbed this way equates to more than half of their body weight. During their twelve-hour sleep at night, they reduce their physical functions by 90 percent and go into a hibernation-like state called torpor. While in torpor, bee hummingbirds whose habitat is Cuba for instance lower their body temperature from 40 °C to 18 °C (104 °F to 64.4 °F).*

LIFE IN SLOW MOTION

"Sloths lead their lives in energy-saving mode," *says Prof. Dr. Martin S. Fischer, Chair of Systematic Zoology and Evolutionary Biology at University of Jena, Germany. Due to their laid-back lifestyle that has them near-exclusively living in trees, these unusual animals are still baffling researchers in many respects. They sleep about 16 hours per day and move very little. And even in climbing, efficiency plays a major role, as Fischer's colleague at University of Jena, Dr. John Nyakatura, explains in a research paper. In the evolution of sloths, he says, "a dislocation of certain muscular contact points occurred which enabled them to keep their own body weight with a minimum of energy input."*

Their diet explains why such low energy consumption is essential to their survival. *Sloths have specialized in eating low-energy leaves. To extract a maximum of nutrients from them, sloths have the slowest metabolism of all mammals. It may take them up to a month to completely digest a single meal. To enable them to ingest other nutrients without expending a major effort, sloths have developed an unusual symbiosis with algae and moths living in their thick coat of fur. The algae with their shimmering green not only enhance the sloths' camouflage but also provide additional nutrients. To ingest the nutrients of the algae, the sloths lick them while grooming their fur coats. To some extent, the algae are even directly absorbed through the skin. The moths provide nutrients to the algae through their feces and in turn deposit their eggs in the feces of the sloths.*

IN FULL SWING

They're the giants of the treetops. *With a height of up to 1.50 meters (4.9 ft), orangutans are the world's largest tree-dwellers. Their diet is austere, the menu primarily consisting of low-calorie fruits, so saving energy is important. Orangutans spend the major part of the day snoozing for hours on end. As a result, in relation to their height, these anthropoid apes taking in 1,200 to 2,000 calories per day consume less energy than most mammals. But their strenuous climbing in search of food continually takes the primates to their energy limits. How they manage their energy budget was investigated by British scientist Dr. Lewis Halsey from the University of Roehampton. His research was focused on finding out how orangutans get from tree to tree. They have three options available to them. First: climb down, run to the next tree and climb up again. Second: jump from tree to tree. And the third and most efficient one: sway a branch until you're able to reach the branch of another tree. Halsey found out that swaying is most efficient. Only young animals jump because they lack the strength to bend stiff branches. So, the larger and heavier they are, the more efficiently orangutans can move around. The arboreal apes instinctively adapt their movements to keep from incurring an energy deficit. Halsey: "One thing that's even more strenuous than climbing up a tree is pulling oneself up a vine the way Tarzan used to in the movies."*

FORMED TO PERFECTION

How foolish of Mother Nature: penguins are birds but they can't fly. *On land, they're incredibly clumsy but in water, they're in their element. The perfection with which they swim even eclipses that of most fish – their main food. Under water, penguins achieve speeds of more than 40 km/h (24.85 mph) although the effort they exert is minimal. The energy in one liter (0.26 gal) of gasoline would allow a penguin to swim a distance of 1,500 kilometers (932 miles). One reason that enables them to do so is the highly streamlined shape of their bodies. "The wave-shaped front of the body with a concave-convex transition between the beak, head and torso is particularly conspicuous," explains bionics expert Stefan Löffler in his doctoral thesis. In addition, "all torsos have a near-circular frontal area and the length-thickness ratios (4:1) of their bodies are within the range of volume-optimized laminar spindles." Flow around the penguins' body shape is nearly ideal, in other words with zero loss. There are no major separations and turbulences. Plus, penguins use another trick: the air stored in their plumage escapes in the form of small bubbles when they dive. This micro-bubble effect reduces drag even further.*

THE AUTHOR

He grew up with dogs, cats and chickens in rural Westphalia. Now ***Lars Krone*** *(39) lives in Hamburg – without any animals whatsoever. Today, he nurtures his passion for nature primarily during seaside vacations.*

"**NATURE** IS AN OUTSTANDING PROVIDER OF IDEAS"

In bionics, scientists use nature as a role model for new technology. In an interview, Prof. Dr.-Ing. Tim Hosenfeldt, Senior Vice President, Corporate Innovation, talks about its significance for Schaeffler.

As an engineer, what fascinates you about nature?
It is very exciting to watch how nature optimally adapts to the conditions and requirements of its environment. In doing so, it uses the available energy as resource-efficiently as possible. There are many challenges or problems we are facing today where a look at nature would be useful. In many cases, nature has already developed something that has become a successful evolution and that we can adapt.

Can you name some examples?
A very interesting aspect, for example, is structural mechanics and lightweight design – both in flora and fauna. For instance, in highly stressed places, the fibers of trees grow in a special direction for greater stability. With birds on the other hand, lightweight design is the appropriate solution for energy-efficient flight. Particularly fascinating as well are nature's self-healing powers. That is what we would obviously like to develop for materials as well. But the field of surface design can be mentioned in this context too. By using the lotus effect, surfaces can easily be kept clean. And providing ships with a so-called shark skin can reduce friction, which lowers their energy consumption.

What role does bionics play at Schaeffler?
In our "mobility for tomorrow" strategy, for instance, lightweight design is an important factor. In this context, nature has created many role models that show how resource-efficient lightweight design can work. This has resulted in new possibilities in engineering design and manufacturing. Lightweight design, for example, is applied in our drawn roller bearings. Another positive example is the development of a CVT (continually variable transmission) for which, as far back as 15 years ago, we took advantage of the laws of nature in optimizing the strength of link-chain plates.

What departments at Schaeffler are involved in bionics?
We foster a company-wide exchange about key topics of the future. This obviously includes bionics. Our Forum of Inspiration that serves to exchange ideas about future projects and developments and our Technology Dialog where we lay the foundations for the most important developments of the next five to ten years are important platforms. But we also engage in exchanges with external partners from the research community, industry and with startups as well.

Will bionics be playing an even greater role in the future? Talking about energy efficiency …
Definitely so. The continually growing demand for electric vehicles is a case in point. Due to the heavy batteries, lightweight design is a very important factor in terms of energy efficiency. Generally, the rule applies that the lighter the vehicles become, the lower will be their energy consumption. Nature is an outstanding provider of ideas for innovative lightweight design. We want to counteract global warming by reducing CO_2 emissions and using fewer fossil fuels. In this context, we are involved in the field of renewable energy generation, as well as in projects that look at possibilities of chemically storing this energy the way nature does – which is in gaseous or liquid form as methane or as synthetic fuel. Artificial intelligence and self-learning systems will be playing a greater role in the context of increasing automated mobility. These systems learn based on data from which they generate knowledge – and they do so in the spirit of our vision for a world that will be cleaner, safer and more intelligent.

BIONIC EXAMPLE

Due to its hybrid plastic-metal design, the weight of a wheel bearing, compared with the conventional design (left), was reduced by 440 grams (15.5 oz) in predevelopment. The utilization of bionic structures with a topology optimization of the plastic component reduces the load of the material by 20 to 30 percent.

» *There is no easy way from the Earth to the stars*
Lucius Annaeus Seneca

in motion

Innovations in the course of time

CELESTIAL **FORCES**

The five "Saturn V" F-1 rocket engines rest at Kennedy Space Center in Florida, "stiff and still": every one of them 5.6 m (18 ft) tall and weighing 9.1 t (20,180 lb). In spite of having been out of service for more than 40 years, they continue to rank among the world's most powerful engines. Converted to horsepower, each delivers 32 million HP, although thrust, which in this case is 6.67 MN each, is the more decisive criterion for a rocket engine. It doesn't take a lot of imagination to picture the awesome energies unleashed by five of these F-1s when they were ignited to launch a Saturn rocket. The five turbo fuel pumps, each delivering 54,900 horsepower, would press 15 t (33,069 lb) of a kerosene and liquid oxygen mixture into the combustion chambers in which temperatures would rise to over 3,000 °C (5,432 °F). The amount of energy released just during lift-off of the 2,938 t (6,478,000 lb) "Saturn V," the rocket that was used to propel "Apollo 11" to the Moon and for other missions, could have supplied all of New York City with electricity for 75 minutes. NASA is currently developing the "Space Launch System" as the successor of the "Saturn V" heavy-lift rocket that is to set new records in terms of thrust and payload and use RS-25 engines of the discontinued Space Shuttle program. The fuel pumps for them, by the way, are equipped with bearings supplied by the Aerospace Division of the Schaeffler Group.

THE MOST POWERFUL ROCKET ENGINES (THEIR ROCKETS AND FIRST LAUNCHES)

SRBs (Space Shuttle Booster, 1983), USA	12.5 MN*
RD-170 (Energija, 1987), USSR	7.26 MN
F-1 (Saturn V, 1967), USA	6.67 MN
UA 1207 (Titan IV,1989), USA	6.40 MN
P230 (Ariane 5, 1996), EU	5.86 MN
RD-264 (R-36M, 1973), USSR	4.16 MN
RD-180 (Atlas III and V, 2000), Russia	3.83 MN
RS-68a (Delta IV Heavy, 2004), USA	3.14 MN
YF-21C (Long March 2C, 1982), China	2.96 MN
SRB-A3 (H-IIB, 2009), Japan	2.15 MN

* thrust in meganewtons at sea level

Source: wikipedia.org

ENERGY
THE ENGINE OF PROGRESS

The development of humanity is inseparably tied to the amount of energy we're able to generate and consume. A brief history of human energy consumption in eight chapters.

by Christian Heinrich

TIME JOURNEY TO THE SOURCES OF ENERGY

4.5 billion years ago

Scientists assume that Earth's most important energy source is 4.57 billion years old: **the Sun.** The star is expected to "burn" for another 5 billion years. In the Sun's core, 5 million metric tons (5.5 short tons) of hydrogen are converted into helium per second, producing core temperatures of an incredible 15 million °C (27 million °F) (rocket combustion chamber 4,200 °C/7,592 °F).

1.5 million years ago

Thunderbolts and volcanic eruptions bring **fire** to Earth. When exactly early humans began to make fire usable for their purposes is hotly debated among scientists. A relatively safe assumption is that Homo erectus in Africa used fire pits approx. 1.5 million years BC. And even before Homo sapiens succeeds in kindling its own fire (approx. 32,000 BC), the hot flames are used for tempering purposes (approx. 70,000 BC).

1 STEPS TOWARD CIVILIZATION
USE OF FIRE AND THE FIRST ENERGY CRISIS: WOOD BECOMES A SCARCE RESOURCE

About 1.5 million years ago, Homo erectus discovers how useful fire can be. *But only 32,000 years ago, Homo sapiens invents the "lighter" when causing sparks to fly by striking stones against each other. Being able to kindle fire themselves enables humans to spread to colder regions such as Northern Europe or even Siberia. Subsequently, the "invention" of agriculture allows wandering hunters and gatherers to settle down because food as an energy source is now always within reach. The next step follows when animals are domesticated as both a source of food and tractive force. Thanks to the ingenious principle of the wheel, humans are able to cover long distances and begin to haul more and more goods – bartering begins to flourish. At the same time, energy is invested in homes. Wooden and stone houses provide shelter from the elements. Fire does its part in banishing the cold, plus it provides the light required to conquer the night. Fire makes progress of another kind possible as well. Its heat is used for smelting iron, which provides humans with more iron tools and components, from scythes to spokes in horse-drawn carts to machines such as wind and water mills. All this saves energy in other areas and creates new sources of it as well. However, wood, the main fuel of fire, is becoming scarcer and scarcer, not least because it is an important construction material – up to 3,000 oak trees have to be felled for one ocean-going ship. Indications are that this situation cannot continue ...*

THE ERA OF WHALING

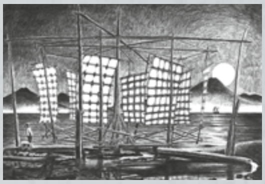
From the 17th until the 20th century, almost every house and many streets in Europe's major cities are illuminated by lamps burning whale oil. *It is obtained by boiling chopped blubber and the huge demand for it makes whaling a profitable business. Around 1840, 900 whaling ships are out on the world's oceans, killing up to 10,000 whales in high-yielding years. Due to the first successful refinement of petroleum, which has similar properties as whale oil, in 1855, whaling nearly ceases in the following years. Only the use of whale oil to produce margarine and nitroglycerin causes demand to rise again and the hunt for these giants of the sea to start all over.*

12,000 years ago

Archaeological excavations suggest that humans used **animal oil** in lamps for illumination as far back as in the Middle Stone Age (10,000–8,300 BC). The Chinese are supposed to have been the first to use petroleum for this purpose around the time of Christ's birth.

4,000 years ago

The power of **water and wind** has been used by humans as an energy source for about 4,000 years, wind mills being assumed to be a little older than water mills. They're the first machines to move without the use of human or animal energy.

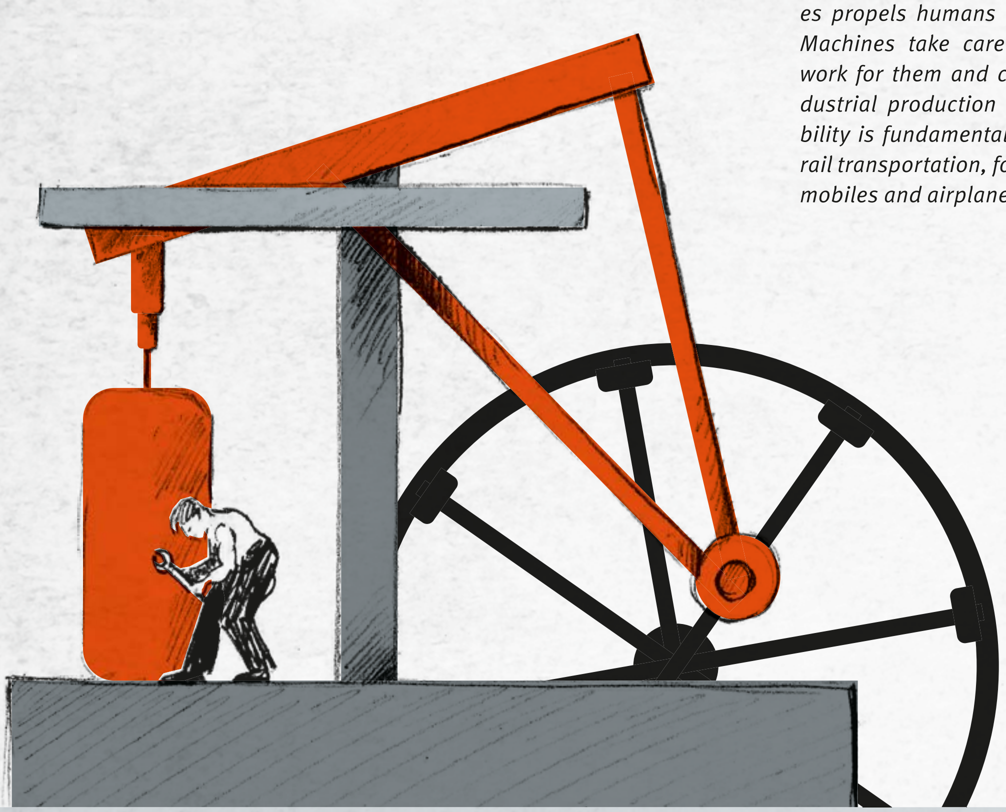


2 BLACK GOLD
THE STEAM ENGINE AND FOSSIL ENERGIES

In preindustrial times, the dirty, stinking coal is still a stopgap, serving as a substitute when wood and charcoal are in scarce supply. *But there's one invention that causes its use to explode starting in the 18th century: the steam engine. With it, heat can be converted into kinetic energy for the first time, which means that it can be used to drive anything that could previously only be moved by wind, water or muscle power. From the loom in textile manufacturing to the vehicle in the form of the steam locomotive, it fundamentally revolutionizes everyday life of humans. Coal proves to be a particularly ideal raw material for these purposes because its energy density is very high and it's easy to haul. Coal – like oil and gas which are increasingly used from the 20th century on – is one of the fossil energy sources that were formed in ancient geological times, in the case of coal from plant residues in a long process that took place 250 to 350 million years ago. The utilization of fossil energy sources propels humans into a new era. Machines take care of mechanical work for them and create novel, industrial production processes. Mobility is fundamentally expanded by rail transportation, followed by automobiles and airplanes.*

70 TIMES MORE ENERGY …

… than the basal metabolic rate is consumed on average by every human in industrial societies. *This explosion of energy consumption began with the industrial revolution defined by the invention of the steam engine. A major portion of energy is still being produced by fossil fuels today.*



Approx. 2,600 years ago

The Greek savant Thales rubs pieces of amber against each other in order to create **static electricity.** Amber in Greek is called "elektron." However, more than 1,000 years would pass before electricity was used. Or maybe not? With the "Baghdad Battery" (a ceramic pot with an iron rod and a copper cylinder) a voltage of 0.5 could be produced as far back as approx. 100 BC. However, whether or not the pot was actually used as a battery is a controversial question.

Approx. 2,000 years ago

Heron's engine (aka aeolipile) is considered to be one of the first **steam engines.** It's named after Heron of Alexandria, although the aeolipile is assumed to have already been known to priests in Ancient Egypt. In his writings "Pneumatika," Heron, in addition to his Heron's engine, describes thermal engines for practical usage in the form of automatic temple doors.

3 ELECTRIFIED AND NETWORKED

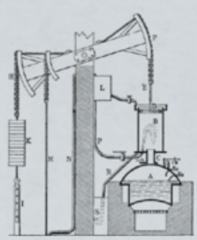
ELECTRICITY AS THE MOST VERSATILE ENERGY

Higher standard of living, higher productivity, more per capita energy consumption *in spite of less physical work – great! The industrial revolution has just been digested when the progress-hungry start looking at the next step from the corner of their eyes. Isn't the need to fill a steam engine with coal wherever energy is required enormously cumbersome? So, the fact that the next quantum leap is on the agenda in the second half of the 19th century comes in handy. The conversion of steam – as well as hydropower by the way – into electricity and its transportation via cables solves a lot of problems. Electricity can be generated in central power stations and then distributed. It causes zero emissions – at least at the points of consumption – and meets practically any requirement, from heating to mechanical driving to lighting, at the push of a button. In addition, new inventions soon make electricity indispensable, be it for telephones, radios or washing machines. The only catch is that as the number of users and uses increases, so does energy consumption. In 1950, only ten percent of fossil fuels are used to generate electricity – 50 years later, the percentage will have increased to 40.*

1713

In England, **coke** is produced for the first time from coking coals. At 1,000 °C (1,832 °F) in the absence of air, the volatile components of coal are extracted, resulting in fusion of the solid carbon and the residual ash. The fuel value of coke (23– 31 MJ/kg or 20-31MJ/2.2 lb) is approximately four times as high as that of raw coal (heating oil approx. 43 MJ/kg or 43 MJ/2.2 lb). Coke would remain the world's most important energy source until after World War II.

1769



The Briton James Watt files the patent for **steam engines,** albeit, he has not invented them because as far back as in 1712 Thomas Newcomen designs the first usable steam engine. Its efficiency, though, was only 0.5 %, while Watt's engine achieved 3 %.

4 MIGHTY DANGEROUS
THE ELEMENTAL FORCE OF NUCLEAR POWER PLANTS

Soon, fossil fuels and hydropower alone are hardly able to cover the demand for energy and electricity. *In addition, the fact that the decades-long burning of coal has been leaving unpleasant marks in the atmosphere as well becomes obvious. At least in terms of air quality, a new technology promises to deliver clean energy: nuclear fission in which atomic nuclei are split and the energy released in the process is converted into electricity in a power station. In 1954, the first civilian nuclear power plant is commissioned in Russia and 35 years later, 438 reactor blocks produce electricity from nuclear energy around the globe. Not least the Chernobyl nuclear catastrophe in 1986 and the Fukushima meltdown in 2011 show that this is not a viable future for energy generation. Neither has the problem of the resultant nuclear waste been resolved (see below).*

DANGEROUS LEGACY

By the end of 2010, some 300,000 metric tons (330,693 short tons) of highly radioactive waste have accumulated worldwide, *requiring safe storage for at least several hundred thousand years due to long its half-life. However, a permanent repository for highly radioactive waste does not exist yet anywhere in the world, as no location has met the exacting storage requirements to date. As a result, we're faced with an unsolved problem that is quite literally carrying increasingly heavy weight, as 12,000 metric tons (13,277 short tons) are added year after year.*

1859

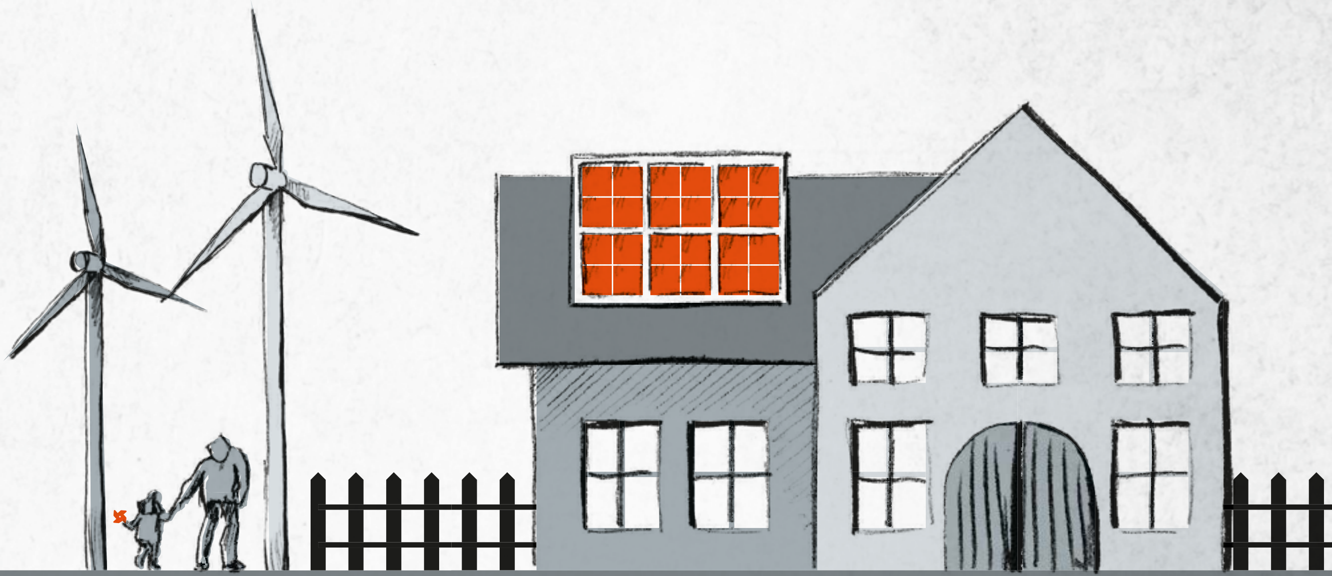
In the German town of Wietze the first modern-day **crude oil drilling** project is successful on July 1. Just a few weeks later, Edwin L. Drake in Pennsylvania (USA) discovers an ample deposit. Oil expert William Brice would later refer to this Sunday afternoon on the banks of Oil Creek near Titusville as providing the spark that catapulted the petroleum industry into the future.

1867

Werner von Siemens presents the **dynamo-electric principle.** Using the generators on which it is based, the supply of electric power can be intensified and accelerated compared to the previous commonly used batteries. The resulting electrification for the first time gives a wide berth to separating the electrical load from the primary source. Inventions like the transformer, lightbulb and electric train follow in rapid succession.

5 BACK TO WIND AND SUN
THE RISE OF RENEWABLE ENERGIES

Never before have humans produced and consumed as much energy as today. *So, what will the future hold? There are three things which are becoming increasingly clear. First: Energy consumption will continue to increase. The internet alone consumes about ten terawatt hours per year, which is a third more than the annual basal metabolic rate of all humans combined. Second: The central energy carriers of the past decades and centuries, fossil fuels and nuclear energy, have no future – being either too dirty or too dangerous. Third: Consequently, the future of energy will arguably be in the field of renewables, primarily wind and solar power. Both emanate from the Sun, as wind is the result of temperature differences in the air. So, humans are turning back to where they began. However, in view of today's technology, this doesn't mark a step backward but a step forward.*



THE AUTHOR

Freelance journalist ***Christian Heinrich*** *is currently training for a marathon. Ever since his research for this article, the thought of the luxury he's indulging in occasionally crosses his mind while running — a human from the Early Stone Age would hardly have taken on such an exertion of physical effort, considering that it offers no prospect of finding new food.*

1951

On December 20, electric current produced by **nuclear power** flows through a line for the first time. It's supplied by the U.S. research reactor EBR-I and causes four lightbulbs to illuminate. The world's first large-scale nuclear power plant is the Obninsk reactor near Moscow commissioned in 1954.

2009

In Oslo (N), the world's first **osmotic power station** is commissioned. It uses the difference in salt content between fresh water and sea water to extract energy and produce electricity. Worldwide, this technology could be used to generate 625 TWh of energy (3 % of the global electricity demand). Over the long run, pioneering Norway is planning to cover 10 % of its electricity requirement by osmosis.

ENERGY **PERSONIFIED**

CEO, family man, driving force – Dr. Georg Schaeffler would have been 100 years old this year. A portrait of a man brimming with vigor.

by Wiebke Brauer

It is Sunday, June 20, 1948. On the preceding Friday, radio stations had announced that the Currency Reform would come into effect on that day. The Deutsche Mark will change everything, the days of bartering will come to an end, and the German economy will be rebuilt: from nothing. Georg Schaeffler has to start from scratch, too. He assembles his workforce made up of some 70 people. "Workers, I have exactly as much as you do," Schaeffler says to them. "I'm getting 40 deutschmarks. So, what are we going to do? I'm back to square one, just like you. I expect your decision." After discussing the question, the workers tell their boss: "We'll carry on. Pay us when you have some money again. It'll all sort itself out."

Perhaps this is the day when the company becomes inspired by a special spirit. A spirit marked by willingness to take risks – and by huge confidence in the man standing in front of his workforce. The workers' confidence will pay off, as just a day later, on June 21, 1948, a new company is founded, Industriewerk Schaeffler oHG, and the success story begins, driven by untiring faith in change and the new things it will bring.

Ever-new things to do

Schaeffler's life is not only defined by exceptional vigor. It also reflects German history of the 20th century. Georg Schaeffler was born on January 4, 1917 in Lothringia, where his family was running a farming business. After World War I, the family moves to the Saarland. In 1938, Georg Schaeffler starts studying business administration in Cologne and, following the outbreak of World War II, is drafted into the military. During a stay at a field hospital in 1944, he finishes his "Diploma" degree program. His plan to subsequently study engineering is frustrated by the turmoil of war.

A flash of genius behind the wheel

Previously, in 1939, the family had acquired a textile company that also produced needle bearings during the war and relocated its headquarters several times. In 1946, their search for a lot with direct railroad siding takes brothers Wilhelm and Georg Schaeffler to Herzogenaurach. The company produces wooden articles like ladders and buttons, soon adding metal products such as universal joint bearings and needle bearings to its range. The acronym INA for "Industrie-Nadellager" (industrial needle bearings) dates back to those days. When employees later ask him what the acronym stands for, Georg Schaeffler answers: "Immer neue Aufgaben" (roughly translated: "Ever-new things to do").

Schaeffler is a man with a propensity for perfecting things. As early as in 1949 he has already long been thinking about how to improve the conventional needle bearing. While on the road in his car, he has the decisive

Georg Schaeffler died in 1996 – but lives on through the Schaeffler Group which he and his brother founded

One for all: Georg Schaeffler introduces company child care facilities, vacation homes, insurance policies with low rates and company sports teams for his employees

In 1982, Minister-President Franz Josef Strauß presents Georg Schaeffler with the Bavarian Order of Merit

idea: The needles have to individually run parallel to the axis in a cage. In later years, Schaeffler himself will tell the story: “We produced the first needle cage on a day that was followed by our company’s carnival celebration the same night. That afternoon, I was still testing the cage with a stethoscope.” The design engineers of Mercedes-Benz and Adler-Motorradbau are thrilled and immediately agree to install the new product in their vehicles. These two large orders are received on the same day in February 1951, followed by orders from Borgward and Auto-Union.

And business continues to pick up. Until 1953, he and his older brother Wilhelm (1908–1981) take turns touring West Germany every week. The heads of development and engineering departments need to be personally sold on the benefits of the new products. Schaeffler: “I traveled the whole country in an old Mercedes – with ten spare tires in the trunk because you constantly had punctures due to the poor road conditions. I knew Germany like the back of my hand.”

The breakthrough invention of the INA needle cage is followed by many others, for instance in the field of engine components. In between – following the founding of LuK – the development and production of clutches and transmission systems are added. In the course of his productive life, Dr. Georg Schaeffler files a total of 70 patent applications for his inventions, the last one in July 1996. Its title: “Cup-shaped valve tappet.”

“The company was his life, his calling and his hobby on 365 days of the year,” Maria-Elisabeth Schaeffler-Thumann said in her speech on the occasion of her husband’s 100th birthday. The couple was married for 33 years – “challenging” is the word she uses to describe life as the spouse of this untiring man.

Technical genius and social commitment

In the years between 1960 and 1970 alone, the number of employees doubles around the globe from 5,700 to 10,700 while in Herzogenaurach the workforce increases by nearly 50 percent from 2,325 to 3,400. In the 1950s to the 1960s, Schaeffler takes care of his workers’ housing needs, provides pensions and a

Georg Schaeffler untiringly motivates his employees to turn on their "biocomputers"

company supermarket. A company child care facility is established, as well as vacation homes, insurance policies with low rates and company sports teams. The opportunity to have a brief chat with "Georg" in passing no longer presents itself to everyone like it used to, as the busy CEO now hardly has any time for this anymore.

»The company was his life, his calling and his hobby on 365 days of the year

Maria-Elisabeth Schaeffler-Thumann

In 1963, Georg Schaeffler and Maria-Elisabeth, nee Kurssa, get married. Their happy marriage lasted for 33 years, until his death

On August 2, 1996, Dr. Schaeffler passes away at the age 79, bequeathing to his wife and son a prospering company with some 20,000 employees, their number since having grown to about 87,000. On the occasion of the memorial service, Georg Friedrich Wilhelm Schaeffler says this about his father: "There is one thing we all have in common. The memory of his technical genius, his ability to see new opportunities, to see the bigger picture, in a nutshell – to use his own words – to think outside the box. I am sure that we will remember his ability to motivate people, not only to contribute their capacity for work but their capacity to think and to use their brains or, as he would put it, their biocomputers."

THE AUTHOR

*Hamburg journalist **Wiebke Brauer** has always had an interest in German history and now understands even better what the German "economic miracle" primarily consisted of: hard work.*

TOP TRUMPS

For 130 years engineers have been investing enormous energy in the development of the automobile. Increasingly faster, safer, comfortable and efficient – passenger cars have been approaching perfection step by step. 14 representative milestones on four wheels mark the development path from past to present.

by Roland Löwisch

PAGE FOLDS OUT ▶

A1 1886 D

Cubic capacity .... 984 cc
Engine .... single cylinder
Power output .... 0.75–0.88 HP
Output per liter .... 0.82 HP/liter
Vmax .... 16 km/h
0–100 km/h .... not possible
Weight ... 265 kg (approx. 330 kg/HP)
Consumption .... 10 l/100 km

BENZ PATENT-MOTORWAGEN TYPE 1

KEY INNOVATIONS The world's first automobile; lightweight, fast-running single-cylinder four-stroke engine; first balancer weights on the crankshaft of an IC engine; new drive system and chassis designed from scratch

THE CAR AND ITS HISTORY Carl Benz tested his invention of a "vehicle with gas engine operation" as thoroughly and as long as possible before finally holding patent number 37435 in his hands on January 29, 1886 – proving that this was the world's first automobile and a product fit for everyday use. He had designed it in 1885 not only incorporating an engine into a carriage, but reinventing everything else around it as well: an automobile of the kind that is still being built today – with an engine, an ignition and cooling system, a transmission, wheels and brakes. Only the steering system posed too great a challenge for him – which is why the car has three wheels. With 0.82 HP per liter, specific output as a measure of engine power, owing to the times, was still relatively modest.

PANHARD P2D

KEY INNOVATIONS Introduction of standard design (front engine, rear-wheel drive); first car built in low-volume production

THE CAR AND ITS HISTORY Following various changes in ownership of a former manufacturing company for woodworking machines, Panhard & Levassor was established in Paris in 1886. In 1890, they built France's first automobile, the P2D, as a prototype. Assisting the company in this endeavor was the friendship with Gottlieb Daimler who allowed Panhard to build Daimler's V engine under a licensing agreement starting in 1890. The first P2D actually became true mid-engine cars, which allowed for four full-size passenger seats, albeit with the occupants sitting back to back ("dos-a-dos"). In 1891, the engine – that grew to 1,290 cc and delivered up to 3.3 HP in the course of time – moved forward. Even today, the "standard car design" of the engine, radiator and transmission sitting at the front and rear-wheel drive is still based on this "Système Panhard."

A2 1890 F

Cubic capacity .... 921 cc
Engine V2
Power output .... 2 HP
Output per liter .... 2.19 HP/liter
Vmax .... 20 km/h
0–100 km/h .... not possible
Weight .... 420 kg (210 kg/HP)
Consumption .... unknown

A3 1901 USA

Cubic capacity .... 1,564 cc
Engine .... single cylinder
Power output .... 5.1 HP
Output per liter .... 3.27 HP/liter
Vmax .... 32 km/h
0–100 km/h .... not possible
Weight .... 500 kg (98 kg/HP)
Consumption .... unknown

OLDS CURVED DASH RUNABOUT

KEY INNOVATIONS First volume-production automobile; longitudinally mounted leaf springs also serving as side members and suspension

THE CAR AND ITS HISTORY Ransom Eli Olds began his engineering career at the end of the 19th century by experimenting with steam engines and electric motors. He came to the conclusion that the future would belong to IC engines and developed the Curved Dash Runabout that would later become the world's top-selling car in its day. In 1901 alone, Olds Engine Works built 425 of these cars, each selling for 650 dollars. The car's name was derived from its round, upwardly curved front which is nothing but a rolled wooden floor. By 1907, a total of about 11,000 cars were built, so Olds contributed to IC engines displacing steam-powered electric automobiles in a major way.

A4 | 1910 | A

Cubic capacity	5,714 cc
Engine	R4
Power output	95 HP
Output per liter	16.62 HP/liter
Vmax	132 km/h
0–100 km/h	approx. 13.5s
Weight	1,207 kg (12.1 kg/HP)
Consumption	approx. 27.5 l/100 km

AUSTRO-DAIMLER 27/80 "PRINZ HEINRICH WAGEN"

KEY INNOVATIONS The world's first sports car; excellent specific power output; dual ignition; four-speed transmission; good aerodynamics thanks to V-shaped radiator and tapered-tail body style

THE CAR AND ITS HISTORY Prince Albert Wilhelm Heinrich of Prussia, the brother of the German emperor, was a true automobile fan. In 1907, he initiated a competition to "perfect" the touring car and to promote tourism. In addition, the special stages were supposed to convey a racing character. The regulations specified that only four-seat road-going cars with four- or six-cylinder engines could be used. Exactly the right challenge for Ferdinand Porsche who at that time was employed with Austro-Daimler and in 1910 designed an appropriate car with aerodynamic performance which he drove himself. The four-day tour covered a 2,000-kilometer distance from Berlin to Homburg in the Saarland. Porsche triumphed: three Austro-Daimlers on podium and the professor himself in position 1.

BUGATTI TYPE 41 "ROYALE"

KEY INNOVATIONS Monoblock engine; three valves; largest engine of all time in a road car; largest passenger car in automotive history

THE CAR AND ITS HISTORY Luxury, luxury, luxury – Ettore Bugatti was never a modest man. Consequently, he put what is arguably the heaviest and most luxurious passenger car of all time on wheels: the Bugatti Type 41 "Royale." Length of up 6.5 meters, wheelbase of 4.53 meters, engine 14.7 liters (prototype), followed by 12.7 liters (production). As was the custom in those days, Bugatti only supplied the "rolling chassis," but meticulously monitored what type of body the (obviously) finest metal tailors would bolt to it. The eight-cylinder unit derived from an aircraft engine did not require a cylinder head, which made it particularly durable. As innovative as the Type 41 was – it would ultimately prove too large and too expensive. So, the world economic crisis carried it off in 1929. Only six complete cars plus one chassis were produced.

B1 | 1926 | F

Cubic capacity	12,763 cc
Engine	R8
Power output	approx. 275 HP
Output per liter	21.57 HP/liter
Vmax	approx. 200 km/h
0–100 km/h	unknown
Weight	3,200 kg (11.6 kg/HP)
Consumption	55 l/100 km

B2 | 1935 | I

Cubic capacity	2,905 cc
Engine	R8, two compressors
Power output	180 HP
Output per liter	62.07 HP/liter
Vmax	185 km/h (short wheelbase)
0–100 km/h	unknown
Weight	1,150 kg (6.3 kg/HP)
Consumption	21.4 l/100 km

ALFA ROMEO 8C 2900B

KEY INNOVATIONS Racing technology in a road car such as a sheer racing engine; independent front suspension

THE CAR AND ITS HISTORY The Alfa Romeo 8C 2900 cars are regarded as technologically outstanding and visually fascinating automobiles not only with respect to their times – in a nutshell: They marked the pinnacle of pre-war automotive engineering, based on sheer racing technology. Transferred to this day and age, an 8C 2900 today would be a Formula 1 race car sporting one of the most beautiful bodies with road approval, which explains its high output per liter. The proportions of the Alfa are perfect and the round Veglia instruments for the tachometer and speedometer are reminiscent of Art Deco elements. Only a few of these cars – with a short (2,800 mm) or long (3,000 mm) wheelbase according to the customer's preference and intended use – were built: between 30 and 36 depending on the source.

B3 1948 USA

Cubic capacity ... 5,473 cc
Engine ... 6-cylinder boxer
Power output ... 166 HP
Output per liter ... 30.33 HP/liter
Vmax ... 191.5 km/h
0–100 km/h ... approx. 11.0s
Weight ... 1,921 kg (11.4 kg/HP)
Consumption ... 12.7 l/100 km

TUCKER '48 "TORPEDO"

KEY INNOVATIONS Rear engine, safety belts, directional third headlight ("Cyclops Eye"); independent front and rear suspension; collapsible steering column; safety windshield; door cutouts up to the roof for easier ingress; four-speed transmission with automatic pre-selection

THE CAR AND ITS HISTORY Preston Tucker – an engineer from Chicago – was a true visionary. He felt that all the cars on the market were not safe enough, so he designed his own with a length of more than 5.5 meters and named it '48 based on its model year (it was only called the "Torpedo" in advertising). The technology and safety features of this rear-engine car were outstanding, but his financial backers soon cut off his money supply – legend has it that established U.S. automakers had a hand in this to keep from having to offer all these new features soon themselves. That's why only 51 of these cars, including the prototype, were built – each selling for a certainly competitive price of 2,485 dollars.

CHRYSLER NEW YORKER FIREPOWER-V8 "HEMI"

KEY INNOVATIONS Engine with hemispherical combustion chambers; Hydraguide power steering

THE CAR AND ITS HISTORY "New Yorker" from 1939 to 1997 was typically the name given by the Chrysler brand to its top-of-the-line models – making it one of the model names used for the longest time in U.S. automotive history. In 1948, Chrysler launched an all-new "New Yorker" which in 1951, instead of the previous 5.3-liter eight-in-line unit, was equipped with an ultramodern 5.4-liter V8 – the so-called "hemi" (officially: Firepower V8). It had hemispherical combustion chambers. Their greatest advantages: high efficiency and high engine power with low compression. The main disadvantage: more expensive due to the more complex design.

B4 1951 USA

Cubic capacity ... 5,425 cc
Engine ... V8
Power output ... 182 HP
Output per liter ... 33.70 HP/liter
Vmax ... 158 km/h
0–100 km/h (62 mph) ... 16.4s
Weight ... 2.010 kg (11 kg/HP)
Consumption ... 22 l/100 km

C1 1965 GB

Cubic capacity ... 6,230 (later 6,750) cc
Engine ... V8
Power output ... 178 HP
Output per liter ... 28.71 HP/liter
Vmax ... approx. 190 km/h
0–100 km/h ... approx. 11.5s
Weight ... 2,062 kg (11.6 kg/HP)
Consumption ... 22 l/100 km

ROLLS-ROYCE SILVER SHADOW

KEY INNOVATIONS First RR featuring unibody construction (more compact exterior with a larger interior than predecessors) and disc brakes; front and rear independent suspension; hydraulic braking system (redundant for safety reasons) and hydro-pneumatic self-leveling

THE CAR AND ITS HISTORY By the mid-60s, Rolls-Royce was no longer able to ignore the signs of the time and was in urgent need of a successor for the baroque body styling of its traditional models. In parallel to the new Silver Shadow the near-identically constructed Bentley T-Series was produced. While the exterior dimensions shrunk, the interior provided more room to the passengers. For the hydro-pneumatic system, the Britons used an existing one built on licenses from Citroën. The Silver Shadow was also available as a two-door coupé and convertible (sold as the Corniche from 1971 on). The convertible was retained in the model range until 1995. In total, 35,000 units of the most successful "Rolls" of all time to date were produced in 30 years.

C2 1975 D

Cubic capacity.................... 6.834 cc
Engine...V8
Power output.........................286 HP
Output per liter ....41.45 HP/liter
Vmax..............................225 km/h
0–100 km/h..............................8.0s
Weight ....1.985 kg (6.9 kg/HP)
Consumption................. 22 l/100 km

MERCEDES-BENZ 450 SEL 6.9

KEY INNOVATIONS First hydro-pneumatic self-leveling suspension in a Mercedes; central locking; headlight washer system; hydraulic lash adjusters from Schaeffler

THE CAR AND ITS HISTORY Did the Mercedes managers have any idea that by coining a new term, the “S class,” they’d be creating a synonym for large executive cars? The 450 SEL 6.9 launched in 1975 combined sporty performance (286 HP) with all the amenities of a chauffeured sedan (including an additional 10 cm of wheelbase). The large V8 was a bored heirloom from the Mercedes 600 state sedan provided with dry sump lubrication. All W116 models featured innovations such as front double wishbone suspensions, anti-dive systems, a collision-protected fuel tank, deformable switches, steering wheels with impact absorbers, a safety passenger cell and finned taillights to keep dirt away. 7,380 “six-niners” were built in four and a half years (total W116 sales were 473,035 units) and sold for the price of a handsome detached house (1975: 70,000 marks; 1981: 81,300 marks).

BMW 750 IL

KEY INNOVATIONS First German post-war twelve-cylinder; electronic damper control, car computer; electronic gas pedal

THE CAR AND ITS HISTORY Mercedes was not amused at all when the once ailing acquisition candidate from Bavaria launched the first German post-war twelve-cylinder. The 1986 BMW 750i 1986 (factory code: E32) was truly awesome. Responsible for its both timelessly modern and elegant styling was Claus Luthe, the engine was created by Adolf Fischer and his team. From the beginning, the high-class business sedan was available either with a normal wheelbase (750i) or one extended by 11.4 centimeters. The car impressed with supreme comfort. Obviously, Mercedes very soon followed suit, particularly since BMW was able to sell nearly 50,000 750i and iL models – for about 130,000 marks a piece.

C3 1987 D

Cubic capacity.................... 4,988 cc
Engine.. V12
Power output.........................300 HP
Output per liter ....60.00 HP/liter
Vmax...................250 km/h (limited)
0–100 km/h................................ 7.4s
Weight .... 1,860 kg (6.2 kg/HP)
Consumption ....13.1 l/100 km*

C4 1990 J

Cubic capacity.................... 3,969 cc
Engine...V8
Power output......................... 245 HP
Output per liter ....61.25 HP/Liter
Vmax................................250 km/h
0–100 km/h.............................. 8.5s
Weight .... 1,857 kg (7.6 kg/HP)
Consumption................ 11 l/100 km*

LEXUS LS 400

KEY INNOVATIONS Automatic air conditioning system, memory function of the front seats; radio with digital display; CD player; electric front-seat belt height adjustment

THE CAR AND ITS HISTORY At the end of the 80s, nobody knew what a Lexus was – a new separate Toyota brand created for marketing high-class and high-grade automobiles in export markets, launched as “Project F1” with eight-cylinder engines from the American Indy Car and Champ Car series. From 1990 on, the products also came to Europe – the first model was the LS 400. The design was not regarded as very innovative, but the high-class cars soon acquired a reputation of solid reliability, good quality, delightfully long life combined with luxurious details. The engine was running quietly with silky-smooth refinement, and corrosion protection was perfect. Today, Lexus is regarded as an established alternative to Mercedes, BMW and Audi for solvent customers.

D1 2002 D

Cubic capacity.......................5,513 cc
Engine............................V12 biturbo
Power output........................ 550 HP
Output per liter .... 100 HP/liter
Vmax.................. 250 km/h (limited)
0–100 km/h..............................5.4s
Weight ....2,855 kg (5.2 kg/HP)
Consumption................16 l/100 km*

MAYBACH 62

KEY INNOVATIONS The world's highest-torque (900 Nm) production engine; four-zone air conditioning; electro-transparent panoramic glass roof with solar module; electrohydraulic brake; air suspension; voice control; automatic "teleaid" emergency call system, adaptive cruise control; contactless access and locking system

THE CAR AND ITS HISTORY In 2002, Mercedes revived the former Maybach premium brand and under this name built upgraded S-class vehicles with luxury galore. The 240 model range was available as Maybach 57 (5.73 meters) or as a top-of-the line model 62 (6.17 meters). About five vehicles were built per day, some of them with up to 78 fine-wood components. For long and highly comfortable trips, the cars could be equipped with entertainment systems in any electronic form, humidors, sterling silver champagne flutes, etc. But the car was no success. After some 3,000 of them had been built, Maybach production ended in late 2012. Today, some of the top-end model ranges are called "Mercedes-Maybach."

D2 2017 D

Cubic capacity..................... 2,894 cc
Engine........ V6 biturbo plus e-engine
Power output..330/462 HP (V6/system)
Output per liter 159.31 HP/liter (system)
Vmax................................278 km/h
0–100 km/h..............................4.6s
Weight .... 2,170 kg (4.7 kg/HP)
Consumption..2.5 l/100 km (Hybrid)*

PORSCHE PANAMERA 4 E-HYBRID

KEY INNOVATIONS Full torque from the start, use of electrical energy to boost top speed; a new electromechanical clutch for shorter response times; eight-speed double clutch; newly designed display and controls concept (Porsche Advanced Cockpit) with touch-sensitive panels and custom-configurable displays

THE CAR AND ITS HISTORY The most recent electric design from Porsche is a new edition of the four-door Panamera sports sedan as a hybrid version that delivers both performance typical of Porsche (700 Nm of maximum torque from rest) and offers about 50 kilometers of all-electric travel distance at a maximum speed of 140 km/h (86.9 mph). The hybrid strategy of the all-wheel drive car stems from the 918 Spyder "super athlete." While its predecessor still had a battery with an energy content of 9.4 kWh, the new e-hybrid is equipped with a 14.1-kWh battery – without an increase in battery weight.

*Combined according to manufacturer's information based on measuring standards at the time

THE PHOTOGRAPHER

"It's all a matter of perspective" ... A palm would be large enough to park all the cars on it. They're artistically crafted 1:43 scale miniatures. Photographed in a real-world environment, they would take on completely different dimensions. A project ***Jörg Walz*** *initially started as a social media experiment on Instagram has since evolved into a unique digital automobile museum.*

THE AUTHOR

Working efficiently is daily bread for freelance motor journalist ***Roland Löwisch*** *– due to lots of driving, lots of research and lots of travel. If at all, heat losses are only incurred by a lack of time for family and friends. For those who might like to know: his own two cars have a specific output of about 54 HP/liter – at a combined age of about 70 years.*

CONCENTRATED CHARGE

IC engines have a chance for the future – efficiency being the magic word. The reason is that too much energy contained in fuel is still lost.

by Volker Paulun

A state-of-the-art lithium-ion battery has an energy density of up to 200 Wh/kg (2.2 lb) and in the case of gasoline this value is 64 times as high: 12,800. So, a gas pump serves a veritable energy drink to a car. Cheers! But: Only about a fifth of the power released by the combustion of fuel and air (see “Tank to Wheel” chart) arrives at the driven wheels. By contrast, ideally, 90 percent of the battery juice is converted into motion of the driven wheels of an electric car. To make the IC engine fit for mobility for tomorrow, the objective is to increase efficiency. “We estimate the remaining efficiency enhancement potential of current-state production engines to amount to 20 per cent for gasoline engines and 10 per cent for diesel engines,” says Schaeffler’s Chief Technology Officer Prof. Peter Gutzmer. And there is agreement among industry experts on this as well: a single measure to achieve this does not exist. It will take a wealth of individual ideas and improvements to reduce fuel consumption. In the IC engine itself as well as in the drive train.

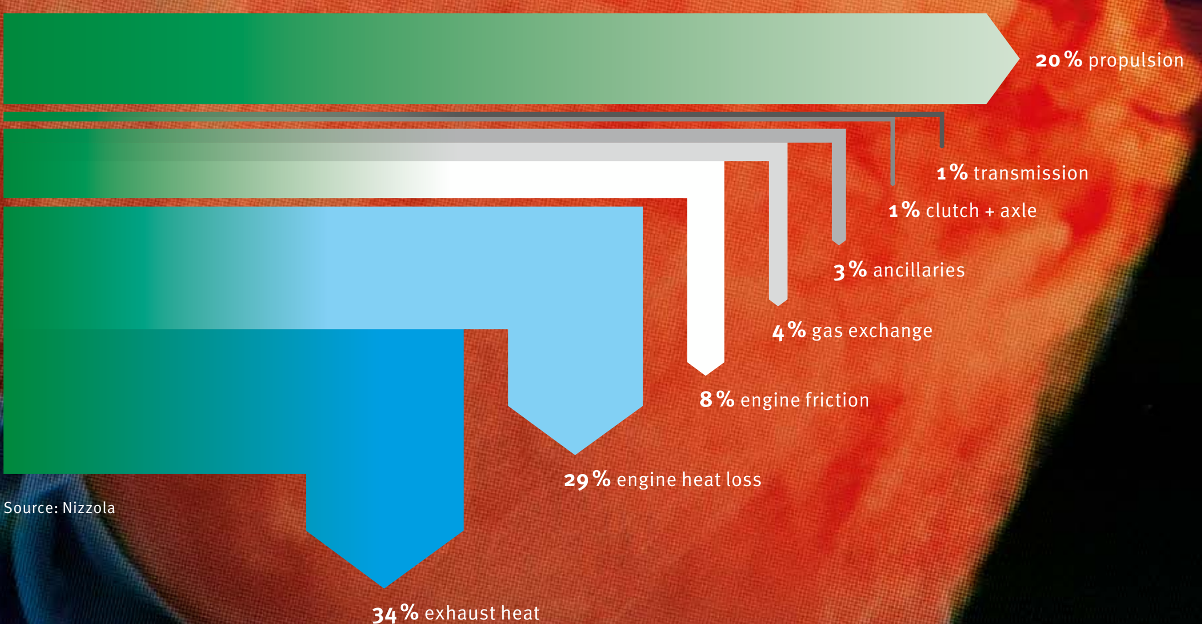
How Schaeffler enhances efficiency

This is exactly the approach pursued by Schaeffler, too. For example, the technology group launched the production of “UniAir” fully variable valve control as early as in 2009. Combined with engine downsizing, the system makes it possible to reduce fuel consumption and CO_2 emissions by up to 25 percent. These improvements are particularly evident in starting, part load and acceleration performance. Reductions in the warm-up phase include hydrocarbon (HC) emissions by 40 and nitrogen oxide (NO_x) emissions by even 60 percent. In addition, UniAir – through higher power output and torque as well as optimized engine responsiveness – enhances driving pleasure. Furthermore, UniAir increases the possibilities of the engine operating as required by the respective driving situation. As a result, modern combustion technologies such as “Miller” and “Atkinson” can be realized. Cylinder deactivation without the need for design modifications is possible as well. Consequently, even three-cylinder engines which are increasingly popular choices for downsizing solutions can be operated with rolling cylinder deactivation (“1.5-cylinder operation”).

Schaeffler’s electromagnetic INA camshaft adjuster enhances efficiency compared with conventional hydraulic systems as well. The electrical variant enables high adjustment speeds to be achieved – near-irrespective of engine speed and oil temperature. This ensures variability in cold starts (down to –30 °C/–22 °F) and when the engine shuts down. As valve timing is practically infinite, various start-stop strategies can be supported, which is another contribution to enhancing fuel economy and reducing emissions.

The thermal management module that assists IC engines and transmissions in reaching their ideal temperature window faster is another piece which Schaeffler adds to the optimization puzzle. Up to four percent improvements of fuel economy and emissions can be achieved just by using such a thermal management module. In addition, Schaeffler engineers use vibration dampers such as centrifugal pendulum absorbers to make IC engines operate at low rpm levels and within consumption-optimized operating points. And, obviously, Schaeffler is pursuing this simple approach to economy as well: anything that is not needed at the moment is shut off. All-wheel drive disconnect-clutch, cylinder deactivation and automatic start-stop systems – the automotive and industry supplier’s portfolio includes all of these. The same applies to a wide range of rolling bearings that reduce friction in the engine,

TYPICAL "TANK TO WHEEL" POWER LOSSES OF A CAR USING AN IC ENGINE



Source: Nizzola

transmission and drive train – by up to 50 percent as in the case of the TwinTandem wheel bearing.

E has to help

In spite of the optimization work that has already been done and expected further improvements: "Without electrification/hybridization we do not think it will be feasible to push mid-size cars like a VW Passat or higher below the future CO_2 limit of 95 g/km [coming into effect in the EU in 2020, editor's note]," says Prof. Peter Gutzmer. Compliance with this limit would require fuel economy of 3.6 liters of diesel or 4.1 liters of gasoline on a 100-kilometer distance with a vehicle weight of 1,372 kilos. This is another reason why Schaeffler has been driving the development of efficient yet cost-effective 48 V technology with an extensive modular hybridization kit.

In the light of 1.5 billion vehicles with IC engines still being on the road in 2025, Gutzmer views another option as a highly attractive alternative: synthetic fuels produced using renewable energies (more on this starting on P. 94): the fuel-pump energy drink of the future in a manner of speaking.


Esso
MICHELIN MICHELIN MICHELIN MICHELIN MICHELIN
ROTHMANS
DMG MORI
1
DMG MORI
2
DMG MORI

SAVE AROUND THE CLOCK

High speed and high tech: The 24-hour race at Le Mans combines both in a special way – not least because the focus has been on energy efficiency for a long time in the French iconic endurance race. Currently, there's hardly another more attractive, let alone creative, stage to demonstrate the innovative power of high-end hybrid sports cars than Le Mans. A time journey of the last 60 years billed as: racing and saving at the limit.

by Alexander von Wegner

Who will win the race? The fastest one, who else? In endurance racing, though, reliability is always an additional factor beyond pure speed and tactics, in keeping with the maxim "to finish first, you first have to finish." However, endurance racing has always had another central dimension: efficient use of the available energy. Since 2012, hybrid powertrains have been essential to the battle for overall victory at Le Mans. The present-day high-tech duels have caused the decades-long efficiency tradition of the iconic endurance race at Le Mans to pale.

Fuel thirst nearly cut in half

Today, the fastest contender at Le Mans is necessarily always the most efficient one as well, thanks to a complex set of rules. Those covering the longest distance within 24 hours have extracted the most from a limited amount of fuel. For the spectators, this sounds very simple but, in terms of detail and proof, it's a highly complex matter. The reason is that, in order to enable regularity in the competition, consumption per lap is specified – unlike it was 30 years earlier. Even back then, in Group C which existed at that time, race cars like the famous Porsche 956 – pictured left alongside its current LMP1 grandchild, the Porsche 919 Hybrid – had to comply with a limit: 600 liters (158 gallons) in 1,000-kilometer races, 2,600 liters (687 gallons) of fuel for the 24-hour distance at Le Mans. Consumption applies to the full distance. As a result, the races back then would often begin as high-speed thrillers but end – in order to keep from running out of fuel – in "crawls." And some cheating was done as well. By the way, consuming about 50 to 60 liters (13 to 16 gallons) of racing fuel, a Porsche 956 in the 1980s guzzled nearly twice as much as the current, much faster 919 Hybrid, whose thirst is limited to about 32 liters (8.4 gallons).

Half a century ago, "fast" and "efficient" are by no means congruent. Over a long period of time, the organizer, Automobile Club de l'Ouest (ACO), occasionally

»» This 24-hour race pushes both man and machine to their absolute limits

Fritz Enzinger, Vice President LMP at Schaeffler's partner Porsche

offers efficiency classifications such as the "Index of Performance" and the "Index of Thermal Efficiency." Porsche, for instance, enters its name on the winners' lists as far back as in 1955 on clinching a triumph in such a fuel economy classification with the 550 Spyder – 15 years before its first overall victory in 1970 with the 917 and a second one the following year. Both times the efficiency classification goes to the Porsche that has an output of more than 600 HP. The fact that victory is possible with such heavily different vehicles in the fuel-saving category gives an idea of the complexity of the calculation formula behind these categories.

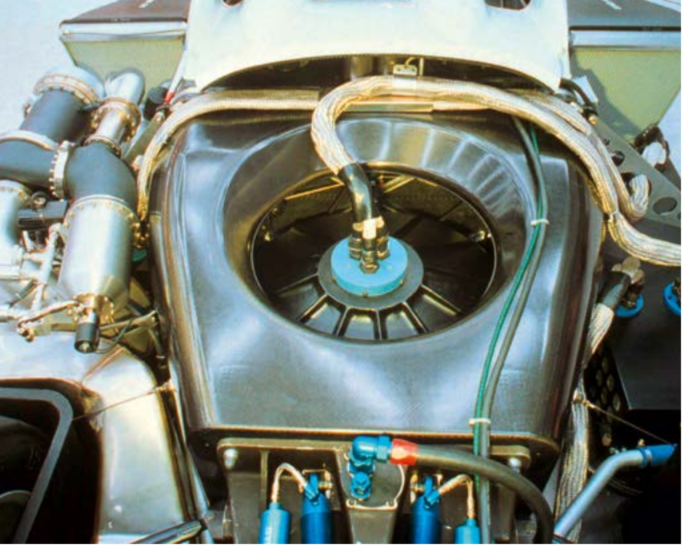
Here is an even more illustrative example: In 1966, Bruce McLaren and Chris Amon see the checkered flag as overall winners. The 470-HP 7-liter V8 of their Ford GT40 helps them achieve an average speed of 201 km/h on a 4,833-kilometer distance with the fuel consumed amounting to 41.85 liters per 100 kilometers. The dainty Alpine A210 (1,300 cc, 125 HP, 690 kg) of the French campaigner duo Cheinisse/de Lageneste finishes the event in tenth place while securing victory in the so-called consumption-performance classification. The figures in direct comparison: The Alpine weighs 42 percent less than the U.S. sports car, has 81 percent less cubic capacity, 73 percent less output and consumes 64 percent less fuel (14.8l/100km at an average speed of 172 km/h). Remarkably, though, it ultimately is only 15 percent short of the absolute distance achieved by the winner – all in all, an absolutely explicable fuel-saving triumph.

Less explicable on the other hand is the fact that in the following year, when the unequal dual is repeated, Ford not only secures overall victory but the successful Gurney/Foyt duo are honored as efficiency kings as well, even though the additional consumption of the Ford compared with the small Alpine has increased by another 0.75 liters. A "minus point" which, thanks to the additional 400 overall kilometers covered, can be "mathematically offset."

Bruce McLaren/Chris Amon in the Ford (above) and Jacques Cheinisse/Roger de Lageneste in the Alpine (below)

Turbos and turbines

Le Mans has always been open-minded toward new technologies. In 1963, the turbine-powered Rover-BRM race car appears on the scene, driven by Formula 1 campaigners Graham Hill and Richie Ginther. But its concept is anything but a pioneering one. To achieve an average speed of 173 km/h with a modest 160 horsepower, the car constructed in Britain needs 40 liters of kerosene. All the more remarkable is the fact that, three decades later, a major automobile manufacturer rediscovers the turbine. Chrysler is planning a World Sports Car (WSC), the Patriot, with an alternative powertrain, and it is a complex one. As a mechanical axle drive system is too costly and complex due to the extremely high engine speeds of 60–70,000 rpm, the axial turbine, as the main power unit, drives an electric generator. The electric power generated



The Chrysler Patriot with a turbine and generator (left) and a flywheel (mid-mounted)

in the process, via an intermediate accumulator, indirectly supplies one electric motor each on the front and rear axles – corresponding losses in the efficiency chain included. The energy source the engineers select for the turbine is cryogenically liquefied methane. The thoughts behind this choice are that this is a very clean-burning fuel, clearly lighter than gasoline, and therefore makes longer pit stop intervals possible. However, to keep the methane liquefied, it must be stored at a temperature of minus 161 °C (–257.8 °F) in a tank insulated with NASA-grade space foam. To ignite it, the refrigerated methane has to be reheated to almost 600 °C (1,112 °F). For this purpose the waste heat of the power electronics is used, among other things. Talking about electronics: Chrysler additionally recuperates electricity by using a flywheel and a small nickel-metal-hydride battery. All this sounds more like science fiction than motorsport, so it comes as no surprise that Chrysler in the end built only a few prototypes, but never the race car planned for 1995.

Other solutions prove to be clearly closer to production. In 1974, Porsche brings the first turbo engine to Le Mans. It soon starts marching down victory lane and afterwards, starting in 1978, in Formula 1 as well. Modern engine design in the age of downsizing is unthinkable without turbo. Currently, Schaeffler's partner Porsche is even using the exhaust energy generated in the 919 Hybrid at Le Mans twice. In addition to a conventional exhaust-driven turbocharger, a parallel turbine-generator unit benefits from the energy in the exhaust and transforms it into electric power. In addition, the LMP1 Porsche recuperates kinetic energy during braking. In 2015 and 2016, this concept wins the 24 Hours of Le Mans twice in succession. The dual hybrid system today represents the pinnacle of a development which Chrysler – albeit in a completely different form – began to outline for sports cars two decades ago.

Battery is ballast

Another American marque, the Panoz factory, is endeavoring to premiere hybrid drive at La Sarthe in 1998. A Panoz Q9 GTR1 Hybrid combines a 6-liter V8 from Ford as a parallel hybrid with an electric motor from today's Continental subsidiary Zytek for recuperation and traction, using a 300-volt nickel-metal-hydride accumulator as the battery. It weighs four times as much as today's lithium-ion batteries. In pre-qualifying, the front engine sports car that tips the scales at about 1,100 kilograms (2,425 lb) is more than 12 seconds per lap slower than the 890-kilo (1,962 lb) sister model, so Panoz chooses not to field it. In its only race, the Petit Le Mans

Porsche at Le Mans today recuperates energy at the front axle and from the exhaust, and stores it in a battery (orange-colored assemblies)

event at the end of 1998, “Sparky” finishes in position twelve in a field of 31 teams.

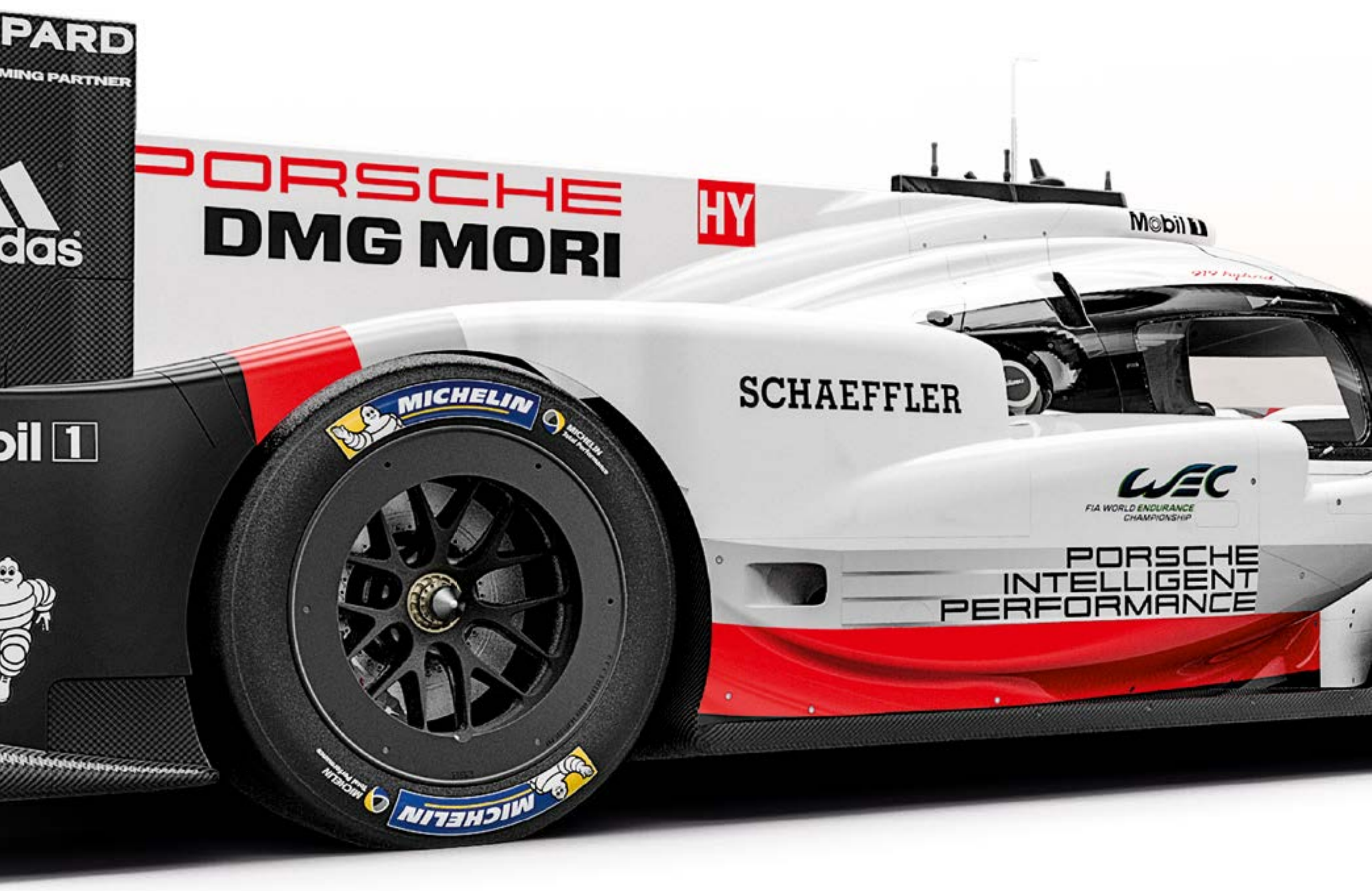
Consequently, the first hybrid sports car at Le Mans is the Oreca 01 Flybrid of Team Hope Racing in 2011. However, the LMP1 sports car featuring a rather simple, mechanically driven Flybrid flywheel energy storage system in the transmission does not see the checkered flag. The honor of taking the first hybrid sports car to victory goes to Audi. In 2012, the German brand from Ingolstadt instantly wins the 24 Hours of Le Mans with the R18 e-tron quattro after scoring the first-ever win with a diesel sports car at the Le Mans event in 2006. In 2013 and 2014, the diesel hybrid sports car is victorious at La Sarthe again. Its innovation bonus: The electric motor at the front axle temporarily upgrades the Audi race car to a vehicle with all-wheel drive.

Le Mans loves alternative concepts

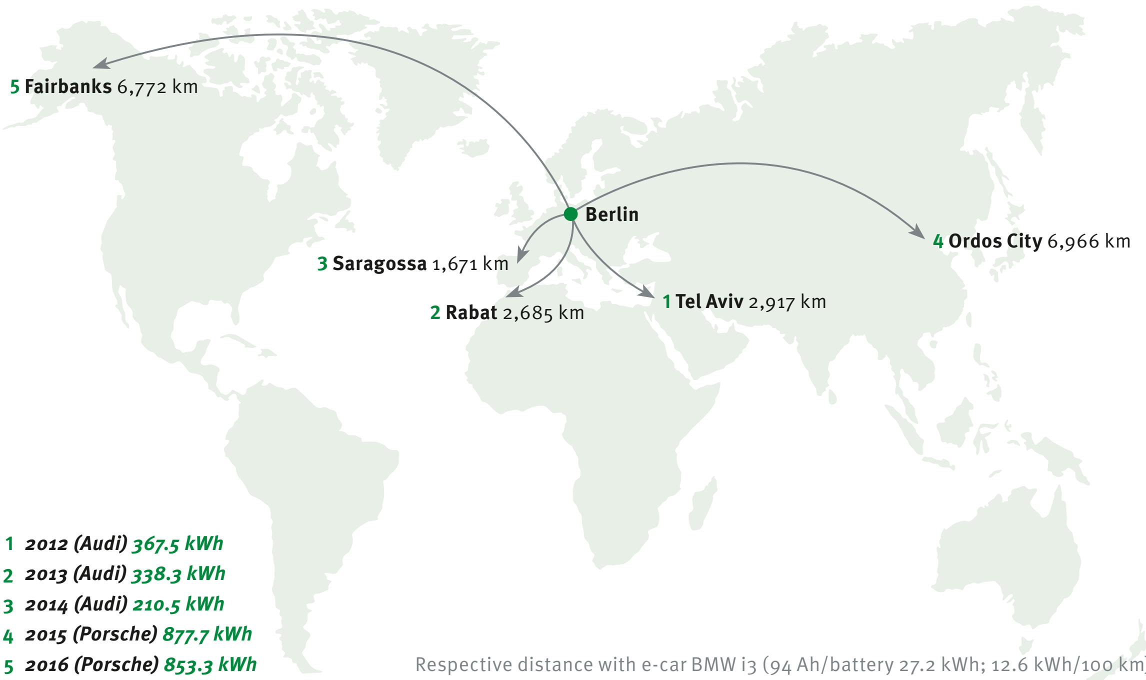
Cars at Le Mans, though, don’t necessarily have to feature complex high technology. In 2012, the ultralight Nissan Delta Wing from Highcroft proves how simple physics can be. It has an extremely tapered front and its two front wheels are just 60 centimeters (24 in) apart. That the 1.6-liter Nissan turbo engine produces merely 300 HP is no problem. With lap times of 3m 45s, the 475-kilogram (1,047 lb) vehicle proves that it’s as fast as the clearly more powerful LMP2 sports cars – while using about 40 percent less fuel and about 50 percent fewer tires. Its acceleration work equals the product of mass, acceleration and distance. If mass decreases, less work is required. Although this basic law of physics becomes clearly evident, the project ultimately remains a nice try.

The same applies two years later to the Nissan ZEOD RC which takes cues from the Delta Wing. While this hybrid arrow achieves a fully electric lap at a top speed of 300 km/h (186 mph) in warm-up, its race ends after a mere 20 minutes. Both race cars, by the way, start from “Garage 56” – a parking place in the pits the Le Mans organizer has been reserving for “CDNT” (Car Displaying New Technology) since 2012. Another car in this category is the hydrogen-powered GreenGT-H2 which, however, never reaches the state of being ready to race.

Finally, since 2014, regulations have been in effect at Le Mans that make efficiency the absolute top



MAXIMUM POSSIBLE RECUPERATION ENERGY OF THE LE MANS WINNERS



1 ***2012 (Audi) 367.5 kWh***
2 ***2013 (Audi) 338.3 kWh***
3 ***2014 (Audi) 210.5 kWh***
4 ***2015 (Porsche) 877.7 kWh***
5 ***2016 (Porsche) 853.3 kWh***

Respective distance with e-car BMW i3 (94 Ah/battery 27.2 kWh; 12.6 kWh/100 km)

LE MANS 2017

The 2017 model of the Porsche 919 Hybrid deploys a range of new innovations, particularly in the vehicle's aerodynamics, the chassis and the IC engine. Team Principal Andreas Seidl reports: "For the 2017 season, 60 to 70 per cent of the vehicle is newly developed. The basic concept of the 919 Hybrid still offers scope to optimize the finer details and further boost efficiency. The monocoque has remained unchanged since 2016, but the optimization potential of all other components was analysed and, in most cases, adjustments made accordingly." As in Formula 1, the monocoque is made from a carbon-fiber compound using a sandwich design.

Dr. Simon Opel is Director Special Projects Motorsports of the Schaeffler Group

"INTENSIVE EXCHANGE WITH PRODUCTION DEVELOPMENT"

Le Mans has been promoting diverse efficiency concepts for decades; Formula E consistently drives the advancement of electric powertrains. Are there any technological parallels in the race cars of both racing disciplines?

The components are not identical or exchangeable but due to the top-end requirements, there's a technological kinship between the electric powertrain units – the all-electric system in Formula E and the hybrid technology at Le Mans. Similarities exist in terms of hardware as well as software. Particularly in Formula E, the aim is to drive directly at the performance limits. Only a very good program can make this possible. Other areas that have to be mastered for example include vibrations which are typical for electric powertrains. We have to eliminate them by means of software – this applies to Le Mans as well as to Formula E. And, last but not least, energy management is an important topic in both series. Simulations and calculations for race strategy are based on the same methods, even though they're not absolutely identical.

What similarities are there between the two racing disciplines in terms of energy strategies? Does Formula E software produce logics that might be important for electric driving in road traffic as well?

In both racing series, energy has to be recuperated and saved, so there are phases of acceleration, coasting and energy recovery in which the conventional brake works together with the electric motor. In either case, it's an optimization task that makes a good exchange possible. It's about achieving the best compromise between maximizing the amount of recuperated energy and the fastest lap time. Principally, this applies to road traffic as well, even though lap times don't play a role here. The questions are: How can the most efficient powertrain be achieved that minimizes consumption? When does recuperation take place? How does the brake work together with the generator? So, similarities do exist.

Are battery cell technologies in Formula E comparable to those used in production?

In either case, the search is for the limit, because it's all about range, but the requirements in Formula E are very special ones nonetheless. We drive qualifying sessions and races at twelve events, so the battery, according to experience, has to last about 50 cycles per year. In everyday road traffic this number, projected over a period of many years, is incomparably higher, which means you can't go as closely to the limit. Chemical as well as physical aspects, on the other hand, are absolutely comparable.

Are there any other learning effects in areas of battery technology to be gained from racing for production?

The battery in Formula E is still a specification component, so the teams have no influence on cells, packaging, cooling or weight. The battery management system is off limits for us as well. The only thing we're allowed to influence is energy extraction in order to achieve the optimum in terms of efficiency and thermal management. This is true in this context for production applications as well.

Are there any other areas in which Schaeffler's product development profits from the Formula E commitment?

In the main areas of the powertrain – in other words the electric motor and the transmission – we work closely together with our development departments. This means that we can test special technologies, materials and manufacturing techniques using our in-house expertise. This also results in feedback: How do the systems work best? What is the resulting lifetime when the system operates at the limit? How good are our simulation models? Our colleagues from production development have a great interest in this and we're engaged in an extensive exchange.

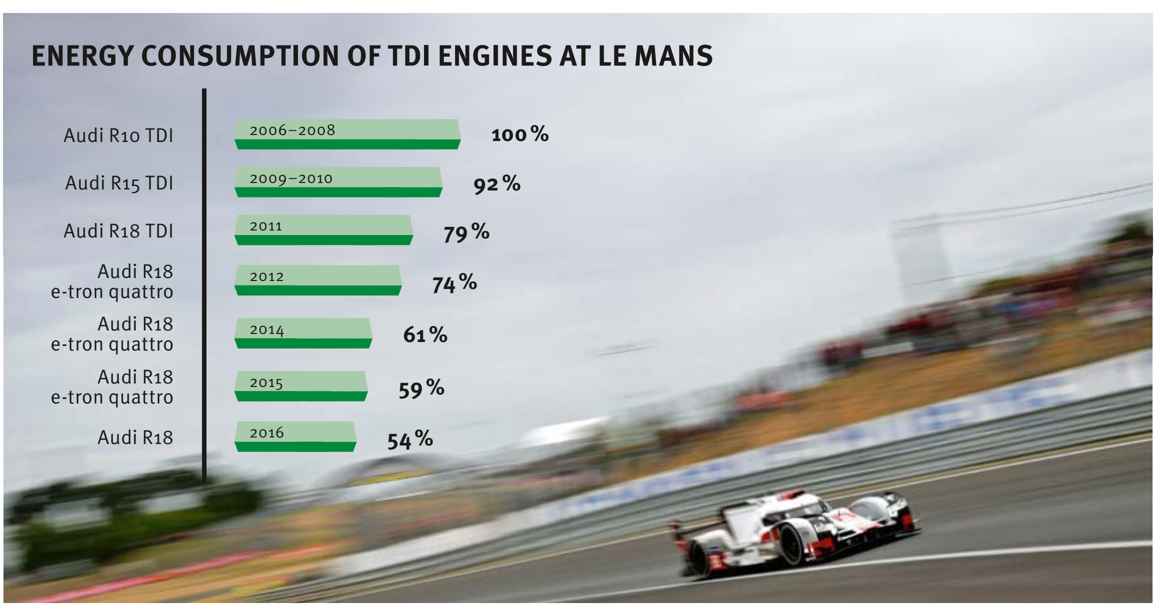
The 1998 Panoz Q9 GTR1 Hybrid was a hybrid pioneer in racing

The Nissan Delta Wing was efficient thanks to lightweight design and a small frontal area

priority and specify maximum consumption levels per lap for LMP1 race cars. Fuel consumption is monitored in real time using sensors and telemetry, and any violation is penalized. The permissible amount of energy has decreased even further, most recently in 2016, by about seven percent. Manufacturers with commitments in this class have to equip their race cars with at least one but no more than two hybrid systems. This allows them to recuperate energy that would otherwise be lost – such as kinetic energy during braking or thermal energy of the engine. So, while the available fossil energy is subject to increasingly stricter limitations, the incentives for efficiently using and recuperating it increase as well. Not only Porsche, by cutting the fuel thirst of its winning cars from the 80s to the current champion, the 919, in half proves the resulting positive effects. Audi, too, reduces the consumption of its successful TDI engines by 46 percent within a decade (see chart below).

Similar demands on road and race cars

This is not only the result of consistent developments of the powertrain modules but of the the race car as a whole. In order to extract the maximum from every drop of fuel, all systems and components have to be optimized. This means that race cars are subject to demands that are comparable to those made on road cars. Factually, CO_2 limits for passenger cars are tantamount to consumption limits, while increasingly higher expectations are pinned on comfort, safety, infotainment and space conditions.

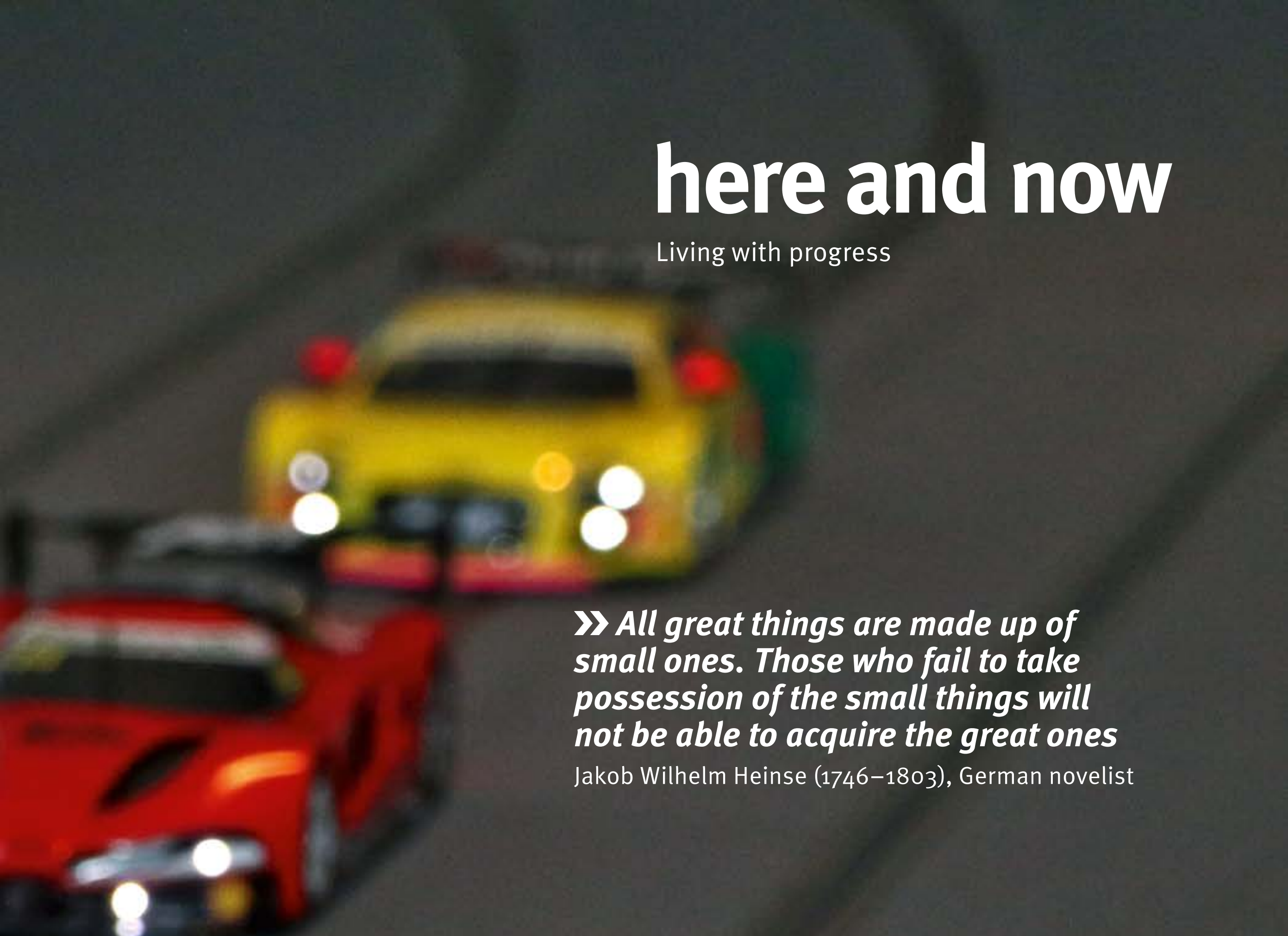


E-RACERS

Motorsport electrifies – and can be operated electrically. The success story of Formula E is a perfect example. Schaeffler has been involved in it from day one and established automakers like Audi, BMW, DS, Jaguar, Mahindra and Renault have gradually been following suit. Mercedes is at the ready. It just seems to be a matter of time until other racing formats will become electrically energized as well. In a 1:24 scale concept car competing in the RCCO slot car series, Schaeffler demonstrates what a future electric sports car might look like. The electric sports car concept is based on the "Schaeffler Glass Car" concept that is used to showcase Schaeffler products and technologies either virtually in an app or at global motor shows. The Schaeffler Vision RCCO is an electric sports car interpretation of the original glass car idea. Besides Schaeffler, ABT, Audi, KTM, Lamborghini and Volkswagen compete with concept cars of their own as well. Schaeffler, by the way, has the best-known team boss in its own ranks: five-time Le Mans winner Frank Biela.

here and now

Living with progress



»All great things are made up of small ones. Those who fail to take possession of the small things will not be able to acquire the great ones

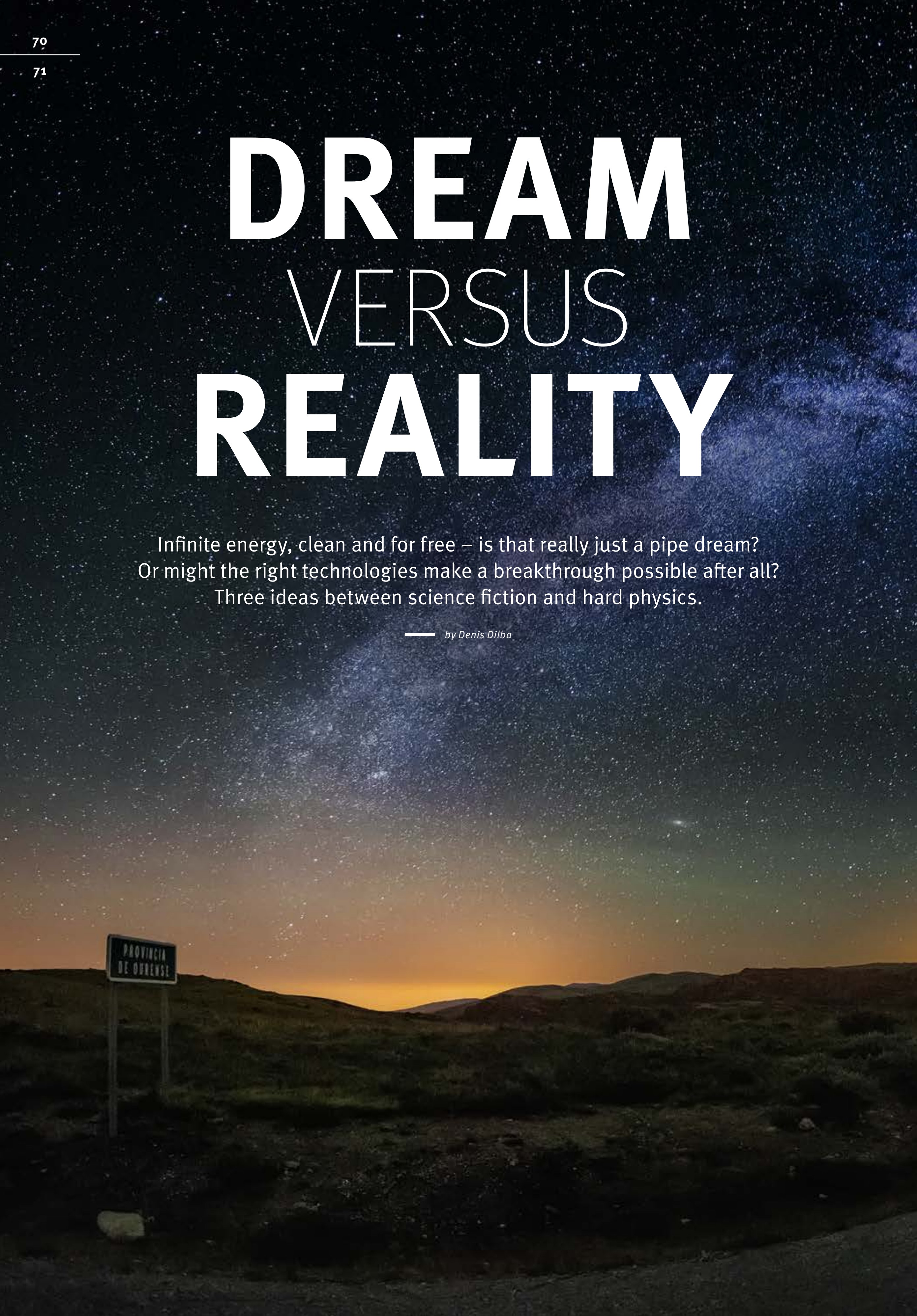
Jakob Wilhelm Heinse (1746–1803), German novelist

341 kilometers (212 miles), a distance equating to the one between Paris and Antwerp, have been covered by the Schaeffler Vision RCCO slot car of five-time Le Mans winner and former DTM Champion Frank Biela (pictured left) and his teammates in a 24-hour slot car race in Hamburg – the team finished third.

DREAM VERSUS REALITY

Infinite energy, clean and for free – is that really just a pipe dream? Or might the right technologies make a breakthrough possible after all? Three ideas between science fiction and hard physics.

by Denis Dilba



The comic book superhero Iron Man has it in his chest, Starship Enterprise uses it to fly and the Illuminati want to turn it against us as a bomb: the near-inexhaustible energy source. And what about us, in reality? We have the "choice" between CO_2 emissions, radioactive waste and landscapes littered with wind turbines. Is there really nothing we can do or develop, perhaps with a really huge amount of money? At least, ideas ranging from exotic to eerie are not in short supply. Besides antimatter power plants and black holes converted into energy generators, fusion reactors capable of fusing atomic nuclei without the benefit of the several-million-degree heat of solar fire have been purported to produce a quick energy revolution. Albeit, the problem with such clean, free and near-inexhaustible energy sources available to us all is that of so many complex questions: there's at least one big catch to them – or a closer look reveals them to be utter nonsense.

The scientific community went wild

The latter category is the one that the so-called "cold fusion" falls into as well, according to the vast majority of experts. Cold fusion is often mentioned in the same breath with Stanley Pons and Martin Fleischmann. In 1989, the two electrochemists claimed to have produced a fusion process similar to the one that takes place inside the Sun in a glass of water at room temperature. In an electrolysis process, hydrogen isotopes in a cathode of the rare metal palladium allegedly fused into helium, releasing an unusual amount of energy in the process. The scientific community went wild for weeks and hundreds of experiments were conducted to confirm the result. After all, this discovery would have solved the world's energy problems at once. The fact that we're still supplying ourselves with comparatively conventional energy anticipates the continuation of the story. Nobody was able to repeat this experiment and the term "cold fusion" became a synonym for dubious research. Fleischmann and Pons were seriously embarrassed.

"If the result could have been confirmed, the two would have become incredibly rich and no doubt have won the Nobel Prize," says Gerald Kirchner, a reactor expert and head of Carl Friedrich von Weizsäcker Center for Science and Peace Research at Hamburg University. In the light of such extremely enticing prospects, it comes as no

surprise that dubious sources keep reporting alleged breakthroughs. Most recently, the Italian Andrea Rossi presented a device named E-Cat in which nuclei of nickel and hydrogen atoms allegedly fuse. "As much as I'd love for all of us to have such a reactor – that's simply not plausible," says Kirchner. "To create such devices, we'd have to completely ignore physics the way we know it and the ways it's been confirmed in thousands upon thousands of experiments." Consequently, Kirchner is not surprised at all that the E-Cat or similar devices have never worked anywhere.

Energy from black holes? Theoretically!

Equally exotic, but scientifically plausible, is Horst Stöcker's idea. Ten years ago, the professor of

Producing 1 gram
of antimatter would take five billion years, according to the current state of the art.

One small black hole,
fed with a truckload of sand or water could cover the annual energy consumption of the whole world.

In 1926
chemists Fritz Paneth and Kurt Peters were the first to report a successful "cold fusion" – a "false alarm" as they would later admit themselves.

Typical depiction of a black hole. Real photographs of the mysterious "behemoths" do not exist

Using the LHC accelerator (above) scientists are attempting to generate small black holes. Physicists Stanley Pons and Martin Fleischmann (below) were unable to prove the theory of "cold fusion"

theoretical physics at Frankfurt University presented a calculation according to which it should be possible to cleanly and simply supply our whole planet with energy by means of tiny black holes. Yes, you read correctly: black holes, these cosmic entities which, due to their enormous mass, have such humongous gravity that they'll devour anything that comes too close to them, even light. According to Stöcker's theory, it would be possible to create mini versions of these omnivores under certain circumstances. The way this could be done would be by firing hydrogen nuclei against each other in a particle accelerator like the "Large Hadron Collider" (LHC) at CERN, the European Organization for Nuclear Research Center in Geneva. The resulting mini-holes could then be made to circulate in storage rings and be systematically fed with normal matter such as sand or water. According to Einstein's formula $E=mc^2$, mass would be transformed into radiation from which electricity could be generated. Theoretically.

It's just that the mini-holes haven't materialized yet. "Which doesn't mean they don't exist," says Stöcker. If the hydrogen nuclei were to crash against each other with even greater energy than the one that's possible in the 27-kilometer (16.7-mile) long LHC, they might still present themselves. However, this would require the "Future Circular Collider" (FCC) with a length of about 100 kilometers (622 miles) that is currently being discussed as an idea and that would be likely to cost clearly more than 20 billion Swiss francs. "However, we don't see that happening in the next 20 years," says Stöcker.

Five billion years for one gram of antimatter

And what's the story with antimatter? Isn't at least that something which could be used to generate energy? In the movie "Angels & Demons," one gram of it almost blows up the entire Vatican. "If a gram of this would actually be accumulated, its explosive force would even be much greater than it was in the movie. It would be about twice as high as that of the atomic bomb dropped on Hiroshima," says Markus Hüning, a scientist at the DESY research center in Hamburg that operates several particle accelerators as well. But Hüning assures us that there's no need to be afraid: "Even if we ran all the accelerators in the world for one year and didn't do anything except generate antimatter particles, we'd roughly get 200 picograms (0.0000000000007 oz)." Projected to time, it would take more than five billion years to produce one gram of antimatter. For that reason, if for no other, the idea of an antimatter power plant could be kissed goodbye, according to Hüning.

However, physicist Gerald Kirchner sees us heading in the right direction even without the ultimate energy source. Technologies which in his view will represent the future include the production of hydrogen from wind power and the construction of large solar power stations in desert regions. "Our greatest potential, though, lies in more efficiently using the energy we already have today."

THE AUTHOR

*During his research of exotic energy sources, author **Denis Dilba** (39) encountered a mixed picture: deep skepticism concerning results that have not been proven, contrasted by hopes that a breakthrough will one day be achieved after all. Dilba, who specializes in technology topics, particularly keeps his fingers crossed for antimatter propulsion.*

FIT TO PERFECTION

Using purpose-developed high-voltage equipment, Schaeffler makes it possible to inductively heat precision components weighing between 10 and 5,000 kilograms for perfect assembly.

by Thomas Arndt

It has to be no less than perfect. Every single part of a machine needs to be manufactured with precision down to a fraction of a millimeter so that the machine – once fully assembled – will run perfectly as well. Yet it's exactly this perfection which makes assembling individual components to create a whole machine so difficult. What may be achievable in a clock mechanism by means of manual dexterity and tweezers turns into a massive problem with a five-ton gear wheel for a huge transmission. After all, the gearwheel has to firmly and safely sit on a drive shaft afterwards. But how does the gearwheel get onto the shaft without damaging either of them, considering that there's no lash between the shaft and the hole for it in the middle of the gear wheel because the wheel has to be in a rock-solid position after assembly?

To solve this problem, Schaeffler took advantage of the law of physics according to which objects expand when exposed to heat. The special devices that are used to heat all kinds of components are called "HEATERS," followed by numbers ranging from 10 to 5,000, which simply stand for the maximum weight of the component to be heated.

The latest and most powerful Schaeffler heater, the FAG HEATER5000, was specifically developed for the brand's customer TAKRAF, a company headquartered in Leipzig, Germany, that specializes in open-pit mining systems and bulk material handling solutions. The heater uses a new technology, a so-called Delta-T control

Gearwheels like these with a weight of nearly five metric tons (11,023 lb) and a diameter of 1.7 meters (5.6 ft) can easily be handled by the FAG HEATER5000

Size comparison: the FAG HEATER5000 (left) versus the FAG HEATER10

The FAG HEATER5000 is controlled via a touchscreen

unit. It enables both reliable and uniform heating of the massive gearwheel up to 110 °C (230 °F). Magnetic sensors monitor the temperatures inside and outside of the component. As soon as the maximum permissible difference has been reached, heating power is automatically adjusted. This is important to prevent a distortion of the material and stress cracks during the heating process.

Other advantages of the FAG HEATER include the mobility of the devices, which can easily be taken by forklifts to any location in a production hall with a high-voltage power outlet where they will be ready for use. In addition, this innovative technology makes it possible for Schaeffler's customers to achieve time savings of up to 95 percent compared with conventional heaters. In assembly processes of lighter gearwheels, TAKRAF GmbH, using the FAG HEATER1200, has been able to reduce the heating period from previously six hours to 20 minutes.

THE AUTHOR

*Physics? For **Thomas Arndt** (born in 1959) this used to be a sore subject in school. And a heater was something the Hamburg journalist was merely familiar with in the form of a curling iron in his wife's beauty case. But at least he still remembered that work equals force times distance and that objects expand when exposed to heat. How marvelously this also works with huge components when the right technology is used, is something he'd have never believed as a high school student.*

TURNED BY

Offshore wind farms are burgeoning. No wonder, as constant and heavy wind movements reliably deliver clean energy. But the work at sea is a backbreaking job. Here’s a report.

by Volker Kühn

THE WIND

When the night above the village of Norddeich is as dark as it will get, the lights come on aboard the “Largo” berthed in the eastern harbor. It’s shortly before three a.m. and in an hour from now the 27 meter long catamaran with its steel double hull is scheduled to set sail. Its destination: the offshore wind farm “Borkum Riffgrund,” located 1.5 kilometers (about one mile) off the East Frisian coast. Waiting at the pier is a technical crew of eight, huddled to protect themselves against the wind. At least, the rain has stopped. The men are working for various energy companies, for turbine manufacturers or for the wind farm operator. All of them have tired eyes. An electrician is particularly pale. He’s looking forward to his offshore mission, the 39-year-year old assures us. But before getting started, he always has a queasy stomach, having suffered from sea sickness all too often.

The men make themselves as comfortable as possible in leather chairs onboard. The electrician closes his eyes. Catching a little sleep would be good now. After all, not only a rough passage but a long shift is ahead. The "Largo" will take him to the "Edda Fjord," a service operation vessel that was built in Norway and is stationed in the North Sea for maintenance of the 79 wind turbines of "Borkum Riffgrund 1." Service teams typically consisting of three men are deployed to the wind turbines where they will work for up to twelve hours before the next shift begins. The work is performed around the clock, seven days a week, during the maintenance period in summer, so that the wind turbines are fit for the gales in fall and winter.

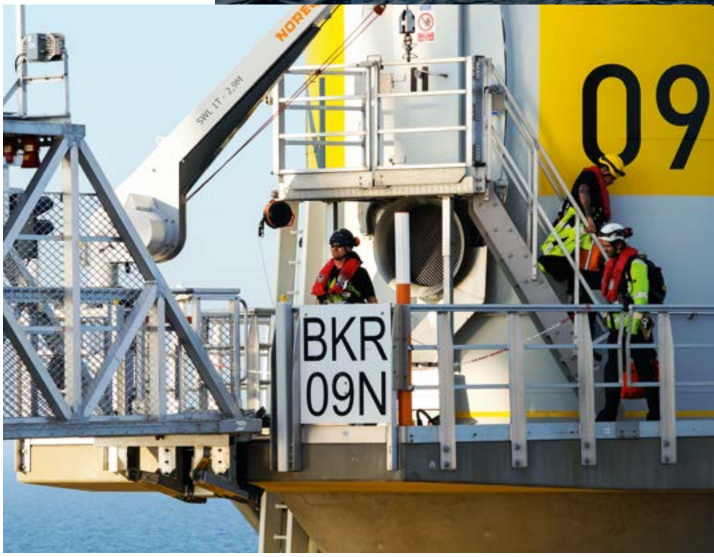
Future prospects thanks to wind power

In strong wind conditions, the farm produces enough energy to mathematically supply about 320,000 households. The electrician will be out there for two weeks, work twelve hours a day and spend the remaining time in his narrow bunk or the austere common rooms. But this is what he wanted. He loves this job. As those of many men and women working in the offshore wind sector, his eyes begin to shine when he starts talking about his work at sea. The separation from family and friends, the long shifts, the rough weather, the cramped conditions on the ships and inside the wind turbines, and even sea sickness – none of this matters anymore once you've become fascinated by this type of life. "Out there, that's like an adventure playground for grown-ups," he says. Jobs in his native East Frisia aren't easy

Steel catamarans like the "Largo" or the "Njord Thor" take technical crews from the shore to their work places at wind farms

20,000 MEGAWATTS

is the rated capacity to be provided by the most powerful onshore wind park by 2020. It is currently under construction on the edge of the Gobi Desert in China and called "Gansu." In 2012, this wind park already achieved the record capacity of 6,000 megawatts, now having increased to 7,900. About 35 turbines are being installed per day and ultimately their number is planned to increase to 3,500.



Hard job, but happy nonetheless: the men that keep the "Borkum Riffgrund" offshore wind farm running

88.4 meters

(290 ft) is the length of the world's longest **rotor blade.** It was built in Denmark for an offshore wind turbine which, with a capacity of eight megawatts, is one of the most powerful ones of all. Its rotor diameter is 180 meters (590 ft). For comparison, this is only eight meters (26 ft) less than the widest section of the elliptical Colosseum in Rome.

178 meters

(584 ft) is the height at which the world's highest **wind turbine** "hovers" above the German town of Gaildorf. The tips of its blades even rise more than 240 meters (787 ft) into the sky. The facility is so tall because the turbine tower stands on a 40 meter (131 ft) high concrete foundation filled with water. It is connected to a lower pond and serves as a pumped-storage hydroelectric station.

175

wind turbines make "London Array" the world's largest offshore wind farm. It is located in the Thames Estuary and has a capacity of up to 630 megawatts, similar to that of a small nuclear power plant. In the next few years, wind farms with even greater capacities are planned to be built in the United Kingdom, Germany and the Netherlands.

to come by. Many people leave the region after school or an apprenticeship. But the young offshore wind farm business provides them with new prospects, like it does to so many coastal regions around the North and the Baltic Seas. From Denmark, to Germany and the Netherlands and all the way to the United Kingdom – the steel wind behemoths can be found everywhere at sea. Ever since the Fukushima catastrophe if not earlier, Europe has been increasingly focusing on renewable energies and thus on offshore wind power as well, because the amount of energy to be generated at sea is much larger than on land.

The "Largo's" engines are revving up and the quay wall vanishes into the night. As soon as the catamaran has left the harbor the waves start rocking and rolling the ship. The spring-assisted chairs squeal with every movement they make trying to compensate for the "Largo's" rolling and stomping, tilting and plunging. The ship has not been at sea for long when the captain reduces engine power. From the bridge, his unintelligible voice reaches the men. He's talking into the radio, perhaps communicating with the "Edda Fjord" or the port authorities. The sea is too rough for him, this much is clear. He wants to spend the next hour waiting in the

A view from the substation of the wind turbines of the “Borkum Riffgrund” offshore wind farm – and the “endless” expanse of the North Sea

shelter of the Norderney Island before venturing out into the open sea again. Obviously, if the waves are too high, the men cannot possibly cross over from the “Largo” to the “Edda Fjord” or onto the steel substation that collects the electric power in the wind park and sends it to the mainland. The risk of them falling would be too high. Protected by the island, the ship’s rolling begins to subside and the men fall asleep. Most of them only wake up after the black behind the windows has made way for a shade of gray. The day starts breaking, becoming brighter and brighter, and the sea – who would have thought it after this night – is calming down.

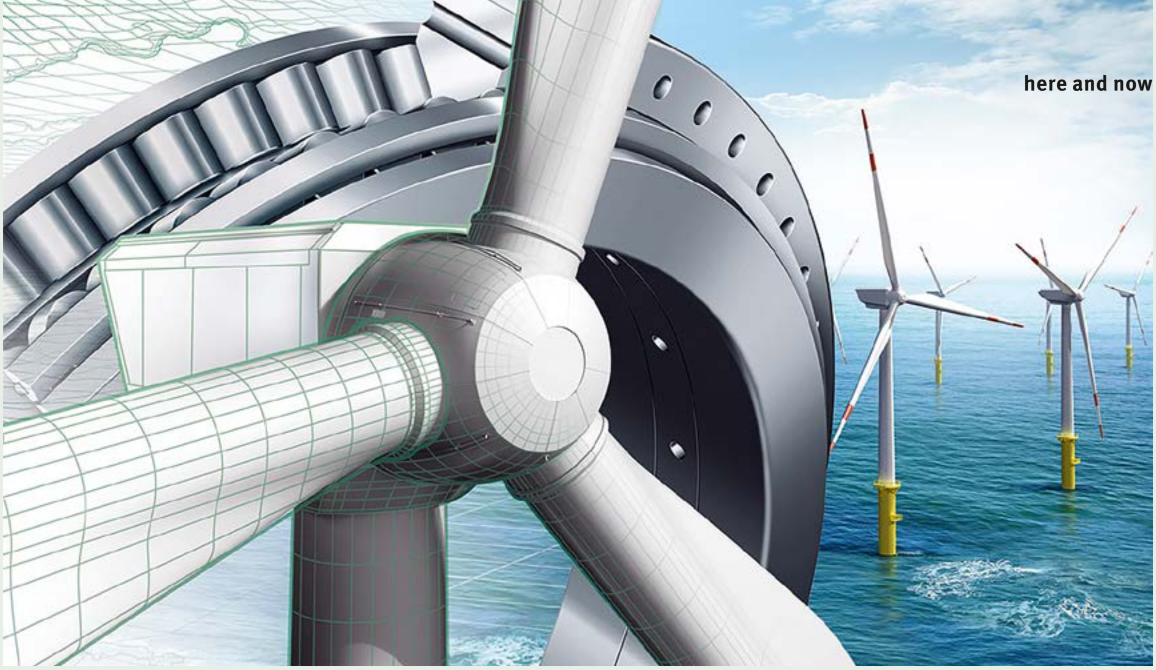
A behemoth of steel

The “Largo” has by now almost arrived at the OSS, the offshore substation. OSS is one of the many English abbreviations that exist in abundance in the language used by the mechanics and engineers at sea. When the OSS begins to tower high above the “Largo,” the captain carefully steers the ship’s bow toward the ladder leading up to the steel behemoth. With a weight of 3,500 metric tons (3,858 short tons) and a height of five stories, the OSS, including its helipad, rests on four massive steel beams anchored in the seabed. The rubber at the “Largo’s” bow meets with the ladder and the captain increases thrust in order to hold the ship in a stable position, stirring up the sea behind it. One after the other, the three technical crew members, wearing helmets, overalls and rescue vests, climb up the ladder, secured by a rope. They will be spending the day on the substation doing maintenance work. At night, another catamaran is scheduled to take them back ashore. The “Largo,” though, is heading for its next stop: the “Edda Fjord.” This so-called SOV – service operation vessel – is beginning to appear in the light of dawn on the other side of the wind farm. Its dimensions – a length of nearly 100 meters (328 ft) and a width of 22 meters (72 ft) – are impressive, but compared with other vessels from which the wind farms are serviced it tends to be on the smaller side. It can accommodate a technical crew of 60, has a large crane and a tower with a swiveling gangway from which the mechanics can directly cross over to the wind turbines. When the “Largo’s” bow docks onto the side of the “Edda Fjord,” the sea is as smooth as a duck pond.

With a deep sigh of relief, the slightly sea-sick electrician grabs his backpack. He’s still feeling a bit of nausea, but at least didn’t have to vomit. He’d like to lie down in his bunk but, instead, his working day is now starting for good, although he’s already been through the day’s first adventure.

THE AUTHOR

Anyone working at offshore wind parks has to complete safety training programs – this also applied to ***Volker Kühn*** *(41). The helicopter practice was the toughest part, says the journalist who lives in Oldenburg, Germany. A helicopter simulator is submerged in a water basin, turned by 180 degrees and the participants have to dive out of it through the windows. But it’s worth it, says Kühn: the sight of a wind farm in the ocean compensates for all the stress and strain.*



WIND POWER MADE BY SCHAEFFLER

Schaeffler ranks among the world's leading manufacturers of rolling bearings and has been producing bearings for wind farms for more than 30 years.

The technology company offers the right solution for any bearing requirement and a comprehensive concept that further enhances the reliability of rolling bearings in wind farms: the Schaeffler Wind Power Standard (WPOS). To ensure that the industry's high standards are met, Schaeffler closely works together with customers and suppliers across the entire process chain up to and including volume production. Together, the optimum solution for every bearing requirement is developed – from the rotor shaft to the transmission and generator and through to nacelle and blade adjustment. In the testing stage, the Schaeffler Astraios is used, which is one of the world's most advanced and powerful large-bearing test benches that allows bearings of up to 15 metric tons (33,069 pounds) and an outer diameter of 3.5 meters (115 ft) to be tested in realistic conditions. Reinhold Korn, Head of Electrical/ Systems Technology Test Equipment Engineering at Schaeffler, explains the Astraios in an interview.

The Astraios is one of the world's most advanced, largest and most powerful test benches for large bearings

What was the situation that prompted the development of the large-bearing test bench?

In the growing wind power market, the wind turbine manufacturers require verification of the calculations by bearing tests also for bearings with an outer diameter of more than three meters (10 ft). This bearing size is typical for rotor bearings used in 6-MW offshore wind farms.

Please describe the basics of this innovation for us.

Astraios is Schaeffler's test bench for large bearings. It is among the largest, most advanced and powerful ones of its kind in the world. This test bench allows us to achieve greater reliability and economy of wind farms.

Reinhold Korn, Head of Electrical/ Systems Technology Test Equipment Engineering at Schaeffler

What are the key technical aspects?

The large-bearing test bench weighs 350 tons, which makes it about as heavy as a jumbo jet with full fuel tanks. It is 16 meters (53 ft) long, six meters (20 ft) wide and six meters high. The weight acting on the rotor bearings is generated on the test bench by four radial cylinders, each generating 100 tons (2,204 pounds). The wind load of 150 tons (330,693 pounds) each is generated by four sinusoidally controlled axial cylinders. The variable drive system provides for varying rotational speeds of the rotors.

What does innovation mean for you personally?

Innovation, for me, means not to be satisfied with an idea. With the large-bearing test bench Schaeffler managed to set an innovative milestone for the development of testing technology.

FATHER COUNSELOR

As a young man he used to sell flashlights and lightbulbs, and today he enlightens burned-out executives. The Benedictine monk Anselm Grün ranks among Germany's most popular authors of spiritual self-help literature and leadership trainers. The most powerful source of energy, he says, is the one bubbling in ourselves.

by Claus Gorgs

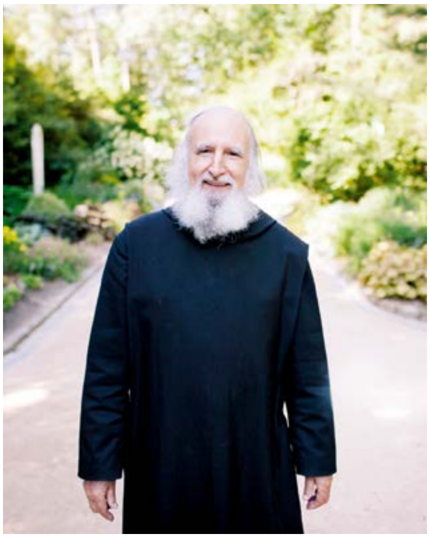
Anselm Grün has little time to spare. Having just returned from a tour of Taiwan as a keynote speaker, he'll be addressing an audience at the WHU Otto Beisheim School of Management near Koblenz, Germany, tonight, followed by events in Würzburg and Munich, Germany, and Innsbruck, Austria, the next few days, plus a discussion on a regional radio station in between. Stress? "No," says Grün, "I don't feel that I'm stretched too thin or stressed."

Somehow he's managed to squeeze 15 minutes out of his tight schedule for this interview. His voice on the phone sounds calm, almost like a pastor's. Which is not surprising. Grün is neither a politician nor a top executive – but a Benedictine monk, plus a sought-after leadership trainer, spiritual director and prolific author of self-help literature. His seminars on "Finding the Courage to Make Choices," "Mindful Speaking" or "Time for Change" are booked out months in advance. Now aged 72, Father Anselm, as he prefers to be addressed, still has a calendar as full as a CEO's. He's written more than 300 books and speaks at some 200 events on average per year. His firm belief: the greatest energy source we have in life is dormant in ourselves.

Master of deceleration

He was one of the first to offer workshops for stressed businesspeople and leadership seminars in a monastery, a novelty that was not met with enthusiastic response from all quarters of the Catholic Church. Now, in the day and age of increasing work intensification and skyrocketing burnouts and other mental health issues, he's regarded as the pioneer of a new management culture in Germany and of a more conscious approach to dealing with psychological stress – in other words a kind of mindfulness guru. "I do feel vindicated by the large number of mental trainers and psychologists who express similar notions as I do," says the theologian. "However, mindfulness by now has also become a kind of buzzword. Nobody can be mindful at all times. And resilience doesn't mean that I have to constantly be able to cope. I'm always sceptical when it comes to simple formulas for success that promise to pave the way to happiness and inner peace for everyone."

Grün is convinced that the sources of greater vital energy, joy and power are, by nature, within ourselves. God-given is how he sees it. Often, these sources are only buried under a false self-image, our upbringing in childhood or expectations of others that we adopt as our own goals. "It's important to discover these sources," says Father Anselm. "Everyone can learn this." In his book, "Quellen innerer Kraft"



The man that managers trust: Anselm Grün

("Sources of Inner Strength") Grün distinguishes between obscure and clear sources that we can tap into. Ambition, striving for power, competitive thinking, perfectionism, as well as a false sense of self-sacrifice for others, he feels are obscure forms of inner drivers that only provide short-term satisfaction and over the long run exhaust people instead of making them stronger. They're not suitable as long-term sources of energy and the basis of satisfaction and health.

The solution is within us

Those who'd like to discover and make use of the sources of energy in themselves have to dig deeper. Personal values and convictions, being in touch with our body and gauging the amount of stress it can tolerate, and people that are good for us – all these are takeoff points for unearthing the foundations of personal strength, of ridding ourselves of the "emotional environmental pollution" that rains down on us from all sides. "The original and unadulterated image of ourselves is marred by the many images others have pulled over us," writes Grün. The advice he issues includes using childhood memories as guideposts to find our own sources of wellbeing again. Memories of the feelings evoked by a favorite song from our youth unexpectedly being played on the radio or a sudden whiff of something that smells like Grandma's Christmas cookies suggest what he means.

Although in his books he's very clear about the Christian faith playing a, if not the decisive, role in all this for him, he doesn't feel that being religious is a prerequisite for tapping into one's inner sources of strength. "I'm not on a mission to make anyone a believer. Those who come to me should be open-minded for the secret of life – but you don't need to be a Christian to discover it." Many of Grün's propositions somehow seem familiar. Family therapists and yoga teachers express similar views and Grün himself takes cues from ancient philosophers, quotes occupational psychologists and – of course – the Bible. He enhances all this with examples and experiences from his seminars and his own biography, which makes his writings easy to read and understand. "The question we all ask ourselves is: how can I live a meaningful life? This is the question I attempt to provide an answer to," he says. Seen in this light, Grün's propositions are not far from those of physicians like Ralf Hosse. "Money is nothing that ultimately makes us happy," says the Head of Occupational Medicine at Schaeffler, who is placing a strong focus on burnout prevention programs (see interview at right).

One of them

That businesspeople and executives in particular seek Father Anselm's advice also has to with the fact that he understands the way they think and speaks their language. As a young man he used to sell lightbulbs and flashlights at his parents' electrical shop. In addition to theology and philosophy, he studied business administration and as the head of business operations of the Münsterschwarzach Abbey near Würzburg, he was in charge of more than 20 business entities and 300 employees for 36 years. Grün: "People from the business community are more open-minded toward me because I also speak from experience and not only as a theologian."

The 15 minutes are over, the next appointment is waiting. Father Anselm has to leave. And he wouldn't call this stress? "I work because I enjoy it," he says, as if he had all the time in the world. "As soon as I notice that I'm becoming irritable, I know that I need to spend more time on taking care of myself. If another inquiry happens to come in at that time, I simply say no."

THE AUTHOR

Claus Gorgs *(45) is working as a freelance author and producer of print media in Hamburg. As a former head of an editorial team of the "Financial Times Germany" and deputy editor-in-chief at a regional daily paper he knows what high stress and long working days are like. While he's always wanted to attend one of Father Anselm's seminars, he hasn't found the time to do so yet.*

“BURNOUT IS LIKE AN ICEBERG”

In the second quarter of 2017, Schaeffler is launching a Group-wide prevention program to counter psychological overload on the job. Project Leader Ralf Hosse explains why it makes sense to treat people who aren’t ill at all.

Ralf Hosse, Schaeffler

In collaboration with the Barmer Health Insurance Company and Friedrich-Alexander-University Erlangen-Nuremberg, Schaeffler has been offering burned out employees a wide range of therapeutic options, from video coaching through to in-patient treatment at clinics. Why is there a need for another program?
We’ve been working on a holistic health concept for quite some time. Our new prevention program is another element of it because all of our previously available offers set in when an employee already feels ill or stressed out. Our new concept aims to provide people in particularly high-stress jobs with tools that prevent burnout in the first place. A lot of people, especially those in higher-level positions, believe that they have no breaking points, but that’s not true in many cases.

Why is the incidence of mental strain among executives increasing?
The workload and speed at which information has to be processed and decisions have to be made has significantly increased everywhere in the business world. There’s a level of work intensification which, in some cases, causes people to overtax themselves. Another factor is that, unlike in the past, we discuss mental health issues more openly and at earlier stages now. The term “burnout” has contributed to this. It doesn’t have the same negative connotation as “depression,” although, from a medical point of view, it’s the same thing.

What causes burnout?
In most cases, there are several causes at the same time – you can’t just attribute burnout to the amount of overtime someone’s working. Usually, there are additional stress factors from an individual’s personal life. Affected particularly often are people with high expectations of themselves. Although they sense that they’re reaching their limits, they won’t permit themselves to show a perceived weakness. Burnout is like an iceberg: the indications are there long before it occurs. It’s just that 90 percent of them are underneath the surface.

Why does Schaeffler as an employer feel responsible for this?
Feeling responsible for our employees is part of our values. As a physician, I also feel that it’s an ethical obligation not to overtax people and to pay attention to them not overtaxing themselves. In addition, there’s obviously a business element as well. A project leader who’s unable to work for weeks or months is an enormous financial risk. We can avoid this risk through prevention.

Schaeffler is a pioneer in this field. Is that because you have a particularly large number of burnout cases?
No, not at all. In fact, the number of mental health issues at Schaeffler is below the industry average. But every single employee with burnout is one too many.

Many people at Schaeffler work in engineering jobs. How do you get them to buy into “soft” topics like mindfulness and stress reduction?
We’re not talking about mindfulness or resilience. We call it preventive maintenance. After all, we also install sensors in bearings that warn operators as soon as a problem emerges. This is a line of thinking that engineers can relate to really well. We all need to learn to be our own sensor that indicates to us when we’ve been revving our engines too high for too long. That’s exactly what this is all about.

And how do we do that?
By paying attention to our body’s signals and not overriding them, and then by starting to look for the cause of our mental strain. We’re working together with external service providers: mental trainers, coaches, physicians and sports instructors for this purpose. Especially in rural regions, the social fabric is still largely intact. That’s another reason why we have less burnout cases in Herzogenaurach than companies based in big cities.

You have a high workload yourself. What do you do to avoid burnout?
I have a very stable social environment, a network of people that support me in situations where things aren’t running so smoothly for a change. I also don’t feel the urge of having to have or having to do everything. That relieves tension. Plus, I have a wife that supports me even when working days are long. That’s the most important thing of all. I can only advise any young person pursuing the aim of working hard and carving out a career to be sure to choose the right partner.

PERPETUUM MOBILE – THE UTOPIAN DREAM OF THE INFINITE MACHINE

The idea of a machine that infinitely keeps moving without energy loss is almost as old as the invention of the wheel. For centuries, inventors including the universal genius Leonardo da Vinci (1452–1519) have been experimenting with the "perpetual motion machine." They tried to use under-pressure, overpressure, water and air, gravity, vacuums and spectacular constructions. Some of them would simply cheat. To this day, the perpetual motion machine has remained a mirage. The reason is that without fresh energy supply even the best construction will come to a stop at some point due to frictional drag or gravity. Therefore, most patent offices expressly point out that they will not accept any proposals for perpetual motion machines. In spite of this advice, countless applications are filed every year even today. The German Patent Office alone reports about a hundred of them per year. Even though the perpetual motion machine remains a utopian dream, approaches to its achievement pursued by many researchers and developers are noble aims. An important contribution Schaeffler makes to pursuits in this direction is the constant battle against friction by means of increasingly better bearing solutions. For instance, by introducing "Generation C" of FAG deep groove ball bearings, Schaeffler has significantly reduced friction by 35 percent. And this, by far, does not mark the end of the development.

PERPETUUM MOBILE MILESTONES

748

First description of a PM wheel in **India**

Around 1150

The Indian mathematician Bhaskara II describes a PM wheel with **mercury-filled spokes**

Around 1230

The French architectural artist Villard de Honnecourt shows a PM with **hammers suspended from a wheel** like pendulums

outlook

Technology for tomorrow

» Prowess, because it propels itself, is the never-discovered perpetuum mobile

unknown source

Around 1500

Leonardo da Vinci is the first to formulate that a mechanical PM is **impossible**

Baroque Period (1575 to 1770)

Interest in PM is **greater than ever before**

1775

The Paris Academy of Sciences decides to no longer accept any **patent applications** for perpetual motion machines

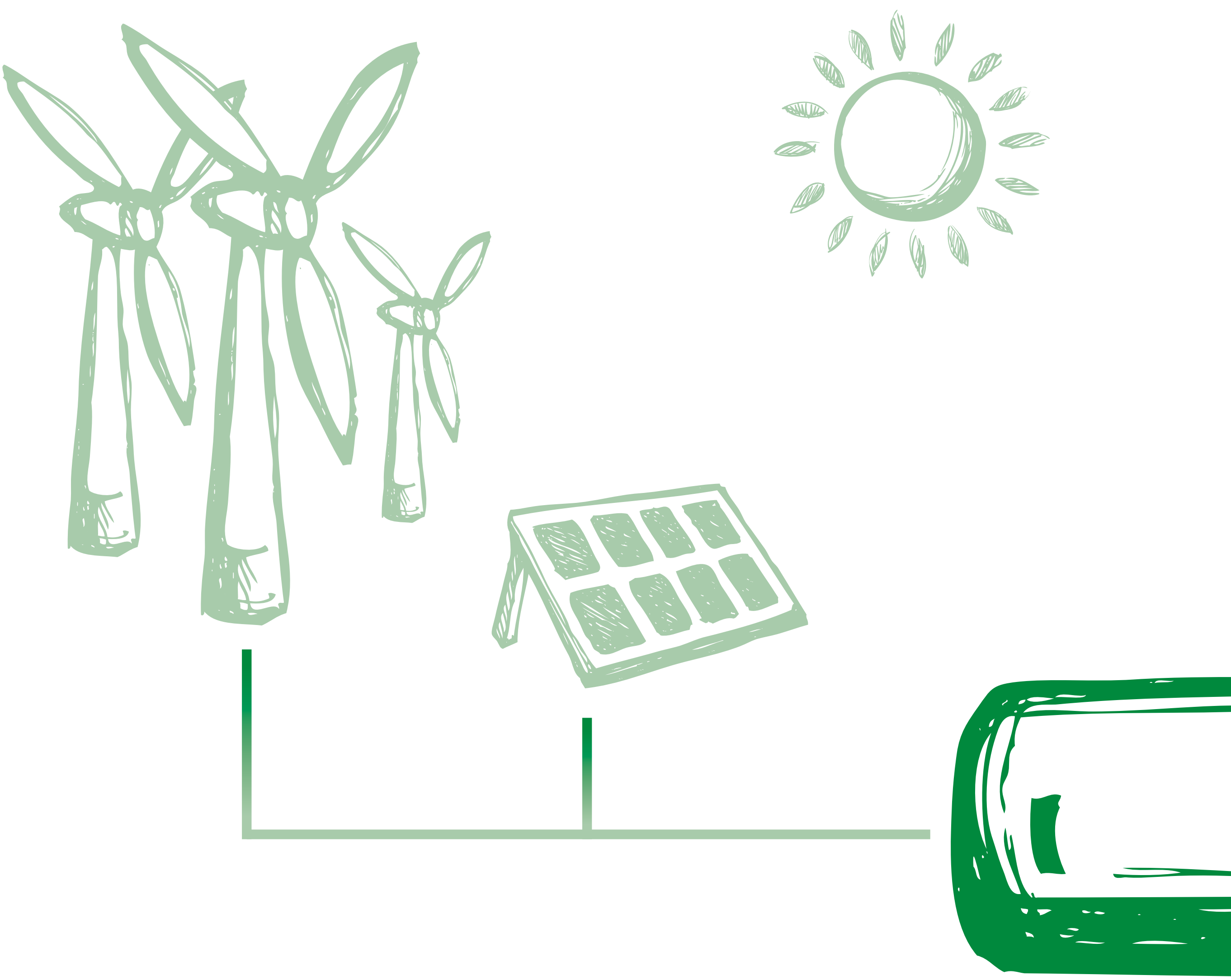
Around 1850

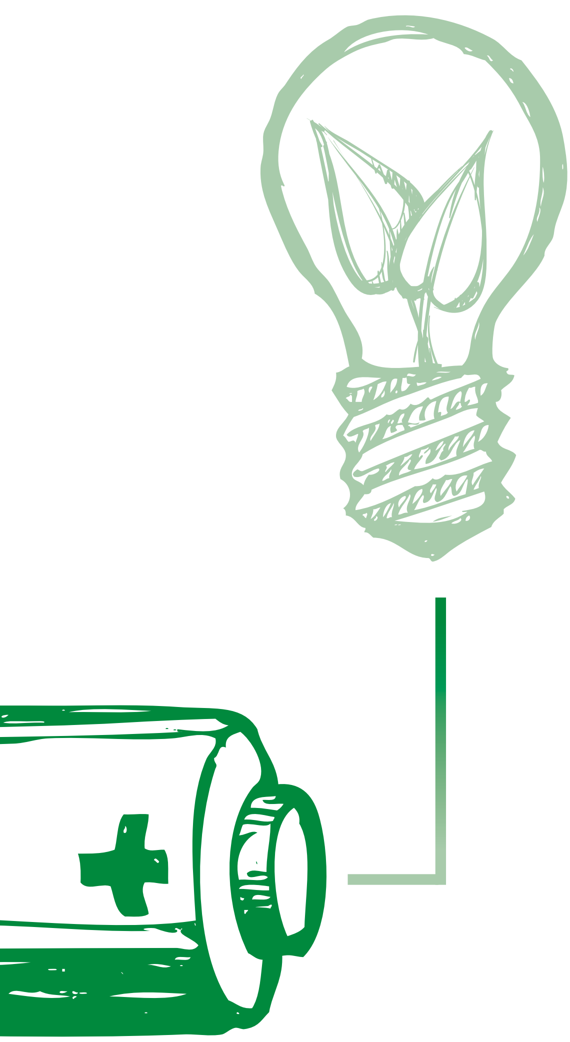
Several renowned scientists formulate the conversion of energy law, underpinning the **impossibility** of a PM

WHERE WILL WE PUT ALL THIS ENERGY

Pumped down, under water, pressurized or in pipelines: where are we going to store renewable electric power in the future? About supercaps, spherical storage and power-to-gas.

by Kay Dohnke





Generating electricity from sunlight or wind, biomass or geothermal energy – all of this has long been routine and is becoming increasingly economical. But the energy turnaround requires a second element: capacities to store solar power at night, wind power in conditions of calm, and for providing electric power to mobile devices when we're on the road.

Obviously, on the way to large scales, developments here initially had to address small ones. When batteries are mentioned, we tend to first think of coin cells and smartphone batteries. In fact, the need for increasingly powerful electricity accumulators for portable entertainment and communications technology has decisively been driving the development of effcient rechargeable batteries. But work on new battery concepts with larger storage volume, less weight and shorter charging times has long begun. Although all chemical energy storage devices still operate according to the basic principle of the galvanic cell, researchers and developers are continually testing new materials for anodes, cathodes and electrolytes. In addition to the proven lithium-ion battery, the focus is also put on lithium-sulfur or lithium-air batteries.

Search for the super battery

Being tested as well are lithium-ion based large-scale accumulators, for instance in Neuhardenberg, Germany, where a modular system capable of storing five megawatt hours of electricity is running. A larger number of such modules could be put together as needed wherever electric power has to be stored and available for use, and speed doesn't matter. By contrast, if rapid charging is essential, big hopes are pinned on so-called supercaps – high-performance capacitors that can be charged in a matter of seconds and are far superior to conventional batteries. At the moment, though, these technologies are still too complex and expensive for field use.

Even though all chemical energy storage devices operate according to the basic principle of the galvanic cell, in the medium run, any requirement will be covered by an appropriate battery system. Redox flow batteries are too complex and expensive for simple applications but offer effiency of up to 80 percent and are capable of storing even large amounts of energy. But they're not ready for field use yet either.

The search for the optimum battery storage technology is akin to the one for a jack-of-all-trades device. The battery should be light, able to store a lot of electricity and deliver many very fast charging cycles. It should be safe, environmentally friendly and cheap. Although breakthrough innovations are announced nearly by the month, there's still a long way to go before the best system will prove its viability in the field. Maybe a decisive impetus will be provided once again by John Goodenough. The co-inventor of the lithium-ion battery has announced an innovative all-solid-state battery that operates with glass electrolytes and with sodium instead of lithium. Charging in a matter of minutes, triple storage capacity, higher safety and a reduced environmental burden would be major steps in the intensive search for the super battery …

THIS IS HOW ENERGY CAN BE STORED

*Only small amounts of **electricity** can be directly stored in coils and capacitors. Larger storage quantities and longer storage periods are possible using indirect storage technologies requiring a conversion into another form of energy. There are three technologies in practical use:*

- ***Electrochemical storage** based on the galvanic cell principle in batteries and by means of electrolysis*
- ***Mechanical storage** in gas pressure, pump and mass storage systems or flywheels*
- ***Thermal storage** in water, salt, concrete, rock, ice and storage-optimized substances*

Efficiency, storage capacity, duration of the storage and release process, repetition frequency of the storage process, weight of the storage device in the case of mobile uses, and relative and absolute costs in relation to the production and market price of energy are the key factors that determine the utilization of a particular type of storage.

Out-of-the-box thinking

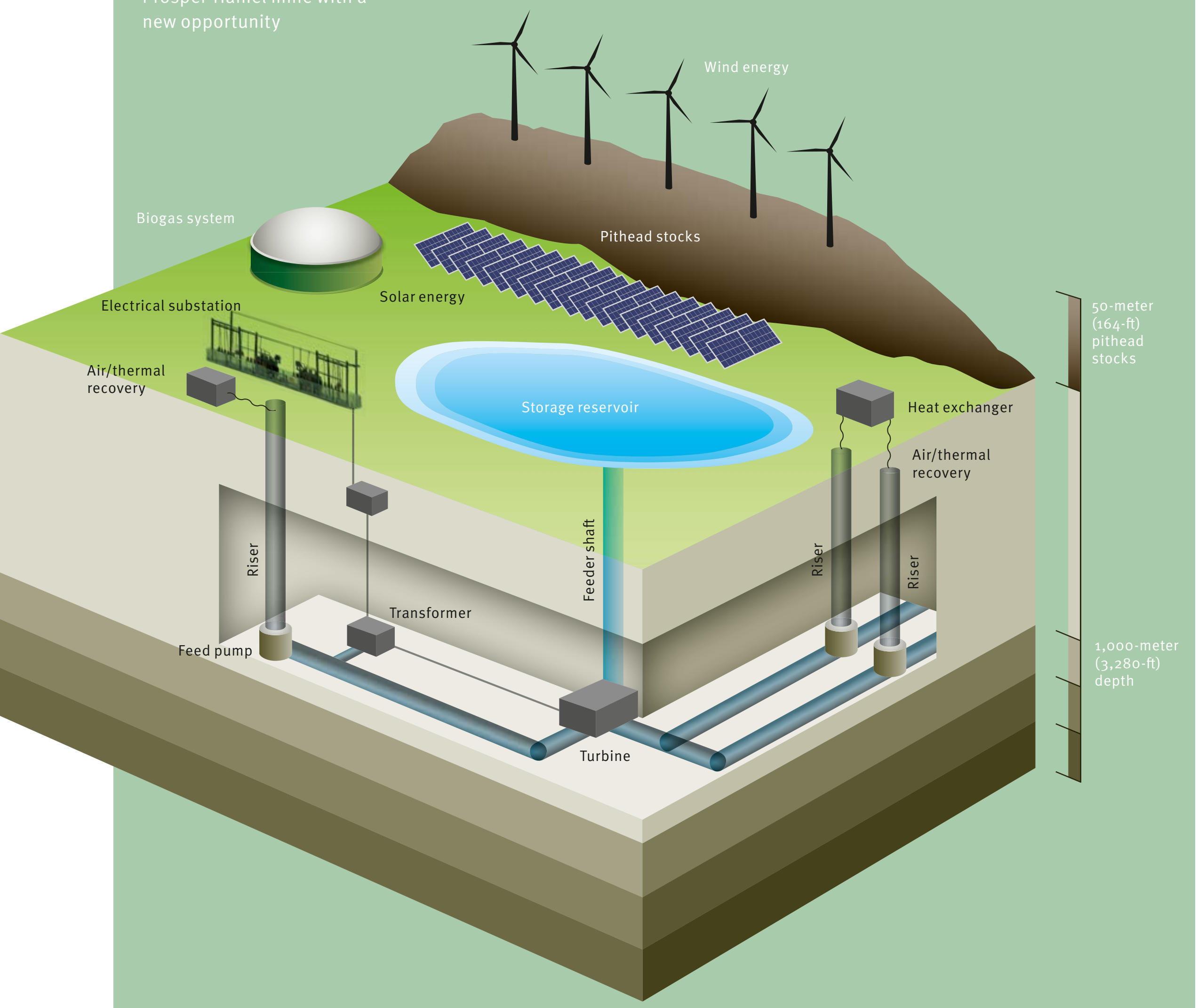
The era of renewable energies is an era of inventors. And sometimes they provide surprising answers to the question: "Where will we put all this energy?" In addition to chemical, new systems of mechanical storage are being pursued. And here visionary engineers are presenting concepts that in some cases are outright spectacular.

Pumped storage power stations for example: A pumped storage power station typically consists of two huge water reservoirs, one in the valley and one on a mountain. Whenever there's a surplus of solar or wind power, electric pumps are used to pump the water into the upper reservoir. At night or in calm wind conditions, the water can flow back into the valley reservoir through turbines and recover energy in the process. Thus, the electric power is – figuratively speaking – placed into interim storage in the upper reservoir.

As pumped storage power stations have an immense impact on the landscape, they've been subject to massive criticism. The concept of using shut-down coal mines as underground pumped storage stations might be a way out of this dilemma. For the Prosper-Haniel mine in Bottrop, Germany, a feasibility study describes a water reservoir above ground and an underground one at a depth of 600 meters (1,968 feet). When energy needs to be stored, water would be pumped from the underground reservoir up into the reservoir above ground and flow back down via turbines in the shaft to balance the grid.

A concept developed by a U.S. company, ARES, that looks totally different from the outside uses vertical differences as well, albeit with heavily laden freight trains. From their parking positions, the electric locomotives will push their load up a hill when surplus electricity needs to be stored. When the power is required, the trains will roll back downhill, recuperating the electricity like a dynamo and feeding it back into the grid. Test runs are currently taking place in Nevada.

Green electricity from old coal mines: the idea of an underground pumped storage power station provides the shut-down Prosper-Haniel mine with a new opportunity



PROSPER-HANIEL UNDERGROUND/ SURFACE PUMPED STORAGE POWER STATION FACTS & FIGURES

600 m
drop height of water

360 MW
capacity potential

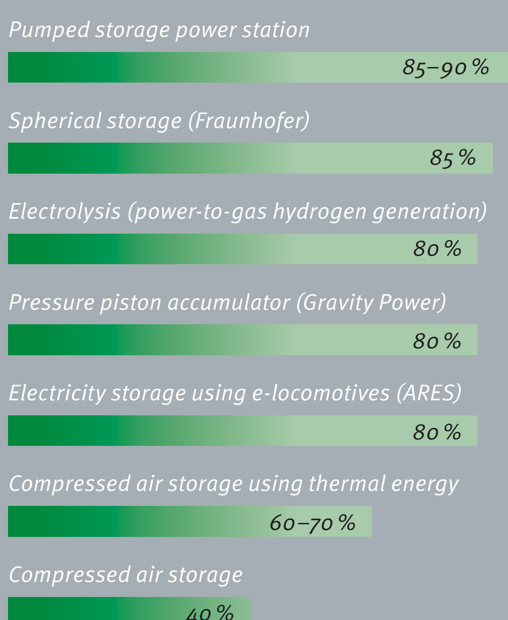
Approx. **900 GWh**
total output per year

> **The more specifically a concept is tailored to the respective situation and needs, the more efficient and economical it can be**

EFFICIENCY OF ENERGY STORAGE SYSTEMS

All storage technologies *are subject to varying amounts of energy loss. Particularly the conversion of electricity into storable forms of energy requires complex technical processes (turbine, compressor, motor, electrolyzer). Efficiency is the percentage of energy which is available again as electricity after reconversion.*

Efficiencies of various storage systems



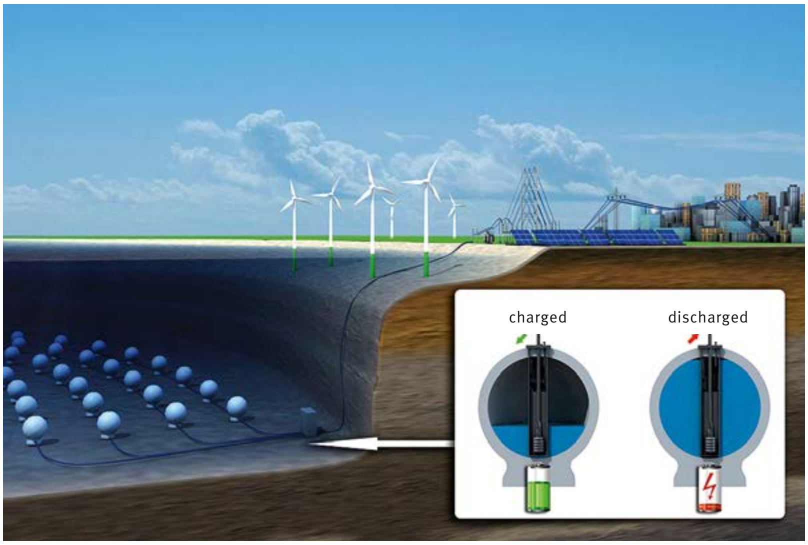
An even more complex example of out-of-the-box thinking is the "Stored Energy in the Sea" project of the Fraunhofer-Institute for Wind Energy and Energy Systems Technology in Kassel, Germany, in which the pumped storage concept has been completely shifted under water with air being additionally used as a medium. For testing purposes, a spherical storage device made of concrete was submerged in Lake Constance near the town of Überlingen and filled with water. When a surplus of electricity existed, air was pumped into the sphere using energy. When electricity was required, the lake water was caused to flow back into the sphere via a turbine generating electric power again in the process. In field use, the spheres with a diameter of 30 meters (98 ft) could store up to 20 megawatts of electricity due to the high water pressure existing at a depth of 700 meters.

In a similar concept being tested in Lake Ontario near Toronto, the Canadian company Hydrostor exclusively uses air to inflate balloons submerged in the lake water. When there's a need for electricity, the immense water pressure pushes the air out of the balloons again via turbines. The deeper the balloons are positioned, the higher the water pressure and the greater the required and recovered amounts of energy – the balloons likely being cheaper than the concrete spheres.

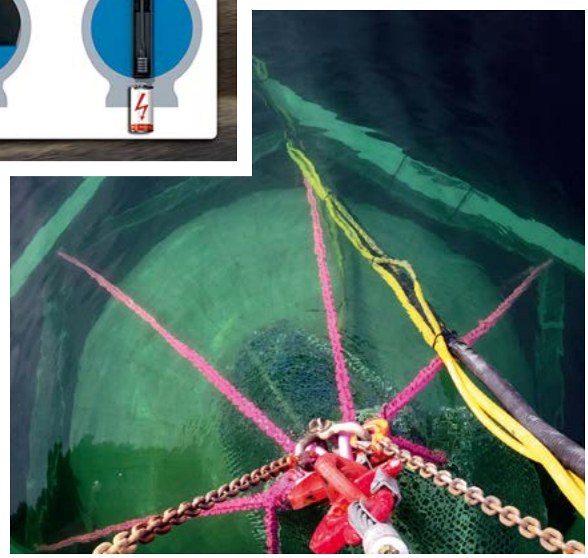
High precision, high efficiency

Concrete is also the key substance for another form of grid-scale energy storage developed by Gravity Power, a U.S. company. Its pressure piston accumulator is planned to have gigantic dimensions and be able to store a large amount of energy for a very long time. The concept calls for a huge nine-million ton concrete piston being precisely fit into a circular shaft with a diameter of up to 100 meters (328 ft) located as deep as 1,000 meters (3,280 ft) underground and hermetically sealed against the shaft walls like a piston in an engine.

When energy is to be stored, water is pumped under the piston, causing it to lift slowly. When power is needed, the concrete behemoth will systematically push the water through the turbines due to the force of gravity and generate electricity again. This system is said to be able to store up to 1,600 megawatts of electricity for controlled feeding back into the grid – once the problem of sealing the shaft walls and the outside of the piston against the immense water pressure has been solved. A test facility is currently under construction in Weilheim, Germany.



Idea and implementation: 20-ton concrete spheres are submerged in Lake Constance



Another key idea being pursued on the energy storage road is the one of fundamentally converting electricity. This is the principle on which power-to-gas systems are based which convert surplus electricity into hydrogen by means of hydrolysis. Hydrogen can be stored, pumped into natural gas pipelines, used in fuel cells for vehicles and reconverted into electricity. Several test facilities – in Stuttgart, Prenzlau and Werlte, Germany, among others – are already operating in field-like conditions.

Many current concepts prove that even within the scope of conventional technology and the laws of physics there are hardly any limits imposed on the imagination of the developers: cases in point being the storage of energy in the form of heat in salt or concrete, the pumping of compressed air or hot steam into large vessels to drive turbines when power is needed and even storage in ice.

However, no matter how great the enthusiasm for experiments may be and how fascinating the solutions achieved, the realization clearly emerges that these pursuits are not about coming up with an all-encompassing system solution for all requirements because, the more specifically a concept is tailored to the respective situation and needs, the more efficient and economical it can be.

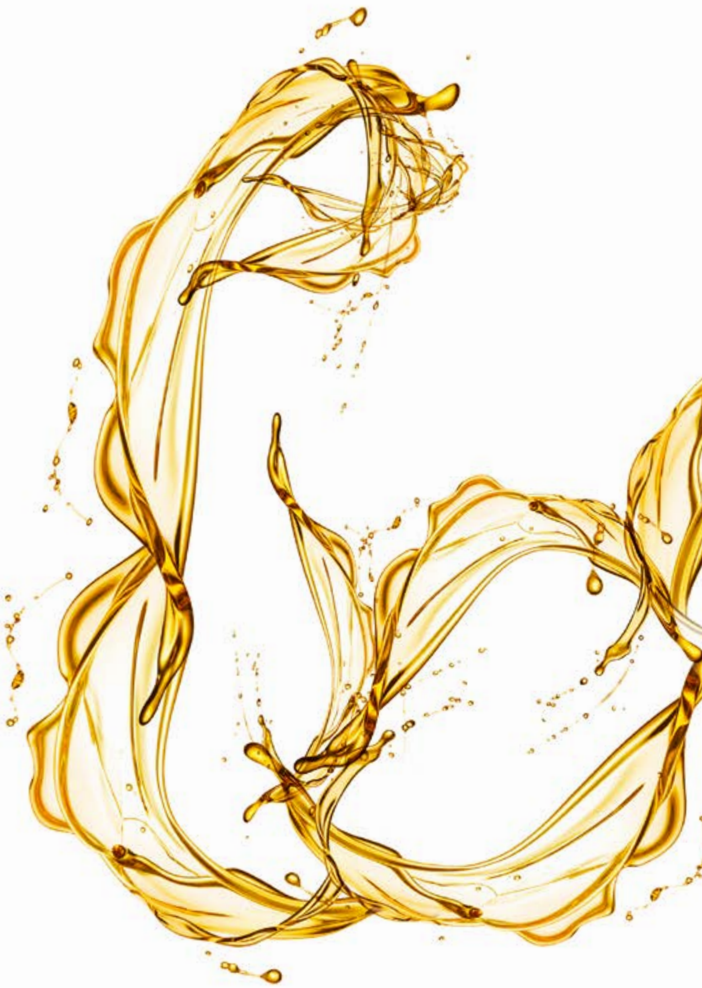
THE AUTHOR

So much power from the air – and the number of wind turbines keeps growing! ***Hamburg freelance journalist Kay Dohnke*** *– specializing in sustainability topics – has been impressed about the inventive spirit that has made the energy turnaround possible in the first place. And there's no doubt in his mind that the storage problem will be intelligently solved as well.*

ENERGY DRINKS

For more than 100 years, combustion processes using gasoline, diesel or kerosene have been the backbone of our mobility. Now the future is supposed to belong to electric and fuel cell vehicles. Yet for the foreseeable future we won't be able to dispense with liquid fuels. What makes them so special?

by Denis Dilba



Whenever the future of mobility is under discussion, it quickly involves the "usual suspects": electric vehicles – be it automobiles, bicycles, motorcycles or trucks. Even ships and aircraft should be operated fully electrically in the future if at all possible. In a few years – it seems – there'll hardly be any type of vehicle that won't have a drive battery in one form or another on board. After all, we have to do something against the emissions from internal combustion engines that are harmful to the climate and to our health. Plus, we'll hardly have any other options sooner or later because petroleum resources will soon be depleted. This means that the days of liquid fuels like gasoline or diesel are counted, doesn't it? That's not completely wrong but not completely right either, says Wolfgang Warnecke, Chief Scientist Mobility of the Durch-British oil corporation Shell: "I think that the future viability of liquid fuels in particular is underrated." This, he feels, is due to the fact that implications and correlations are often heavily simplified in the discussion of the future of mobility. "A closer look, though, shows that they're a lot more complex – and then the answer is no longer as simple as originally thought," says Warnecke, who has a PhD in engineering.

Generally, an in-depth investigation is necessary to determine what combination from the wide variety of the powertrain concepts and energy carriers available today is best suited for what type of mobility. "A single solution optimally suited for all forms of mobility will, unfortunately, not exist in the foreseeable future," says Warnecke, because everything has its advantages and disadvantages, depending on the application: IC engines, fuel cells, batteries, liquid and gaseous fuels. Batteries, for instance, have the major advantage of not causing harmful emissions locally. But Warnecke adds: "The greater the distance you want to drive with them the larger, heavier and, above all, more expensive the batteries become. And when they're empty it takes at least 20 minutes to 'fill up' on electricity even when using quick-charging systems." Added to this is the fact that the production of the electricity that is used to charge the batteries causes carbon dioxide emissions as well, depending on the available electric power mix. Of course developers around the world are working on improving all aspects of battery cell technology but Warnecke doesn't expect any huge leaps in the coming years.

» ***Liquid fuels are underrated***

Wolfgang Warnecke
Shell Chief Scientist

Points-win for the fuel cell

That's why at the moment fully electric powertrains only make real sense on small city cars where they help improve the frequently poor quality of air today while offering customers an acceptable compromise between range before reaching the next charging station, available space, weight and price, the Shell expert explains. But even for slightly longer distances, there are indications that fuel cell powertrains may have the edge over batteries. On one tank of hydrogen, fuel cell vehicles can cover a longer distance than battery-electric vehicles on their battery charge. Not to be underestimated either is the time advantage when refueling the vehicle, says Warnecke: "Hydrogen is put in a tank just as quickly as gasoline or diesel." Although hydrogen filling stations are still lacking, this disadvantage applies to quick-charging stations for batteries as well. By contrast, the infrastructure for liquid fuels already exists. But that's not the only reason why today there's hardly

In 1886
the use of (light) gasoline was documented for the first time in the Benz Patent-Motorwagen Nummer 1.

12,800 Wh/kg
of energy are contained in gasoline, i.e. 40 times more than even future lithium-ion batteries will contain: 12,800 vs. 200 to 300 Wh/kg (2.2 lb). Albeit, to extract energy from gasoline, air is indispensable: at a ratio of 1kg gasoline to 14.7 kg (32.4 lb) air for clean combustion in a conventional gasoline engine, which equates to about 11,370 liters (3004 gal) of air.

Source: Fraunhofer IWS

10 %
more energy than kerosene is produced by algae biofuel – and thus could be used in aviation.

an alternative to them whenever it comes to even longer distances, higher payload and tight schedules.

One of the main reasons – and also the one why the position of liquid fuels has been uncontested for more than 100 years – is their high energy density compared with all other types of fuel. "When I compare one kilogram (2.2 lb) of gasoline, diesel or kerosene with one kilogram of battery, the liquid fuels contain up to 40 times more energy than even future electricity storage systems will," says Warnecke. In all fairness, though, he adds that the efficiency of IC engines is clearly below that of electric motors. In other words, clearly less of the energy contained in fuels reaches the driven wheel than in a powertrain combining a battery and an electric motor. But even when factoring this in, about 15 times more energy can be extracted from the same volume of liquid fuel than from a battery. And that, the scientist explains, has crucial advantages: "The volume per energy unit is smaller, so less space for storage is needed, which also means less onboard weight, which additionally lowers overall consumption once more." Plus, he adds, that more energy would get into the vehicle per unit of time, so refueling is faster.

That's also why in the foreseeable future there'll be no serious alternatives to kerosene in aviation. "Batteries and fuel cells as principal propulsion systems are currently out of the question for passenger planes simply due to the required sizes," says the Shell expert. All the space would be taken up by the propulsion and energy storage systems and the passengers would have to stay on the ground.

Where to put carbon dioxide?

"However, if we have to or want to continue using liquid fuels, we'll have to think about solutions for dealing with CO_2 and pollutant emissions," says Warnecke, because at least CO_2 is produced in any combustion process. Currently being investigated and discussed are so-called carbon capture and storage (CCS) technologies of storing the greenhouse gas in underground rock layers or salt cavities. However, they'd have to ensure safe storage of CO_2 for centuries. There are doubts about this really being possible. Therefore, research done by Shell scientists includes a method of converting CO_2 into climate-neutral rock, among other things. The most elegant solution, though, would be to just use CO_2 again as a raw material for the production of liquid fuels. Indirectly, for instance, this is possible using biofuels from plants. They absorb CO_2 from the atmosphere, are harvested and subsequently processed into fuels.

This method, though, is controversial as well, because producing fuel instead of food from sugar beets, corn or rapeseed is questionable. And even growing plants that are not suitable for food production at least requires a lot of space. On the other hand, the utilization of plant residues wouldn't be harmful but so far scientists haven't been able to achieve any real breakthrough here. Stefan Jennewein, a biochemist at the Fraunhofer-Institute for Molecular Biology and Applied Ecology (IME) in Aachen, Germany, has therefore abandoned biofuels and developed an alternative, using genetically modified bacteria to produce short-chain alcohols and acetone from CO_2. From these substances, kerosene or marine diesel oil can be produced in a comparatively simple process. The potential, the scientist says, is huge. With the CO_2 emissions of just one major steel mill an airline providing international service could be supplied with kerosene, according to his estimates. At the moment, he's working on a pilot plant to convince investors of this method. Investors are absolutely necessary to market the technology because, says Jennewein, we're talking about millions of tons of fuel per year.

By means of such methods the carbon dioxide emitted by automobiles, aircraft, ships and factories could be captured and reconverted into fuel in the future as well. "Ideally, such processes would consume exactly as much CO_2 as we emit in the combustion process of such synthetic liquid fuels," says Shell scientist Warnecke. "This could then be called CO_2-neutral." However, not all the problems would be solved this way. Local emissions of pollutants such as nitrogen oxides or sulfur oxides are also produced in the combustion process of synthetic liquid fuels.

While research is dedicated to this aspect as well, "new liquid fuels don't give us a license to simply continue to use them for every form of mobility," says Warnecke. "Wherever we're able to use sensible alternatives we need to do so."

THE AUTHOR

Even if Shell's chief mobility scientist Wolfgang Warnecke and technology journalist ***Denis Dilba*** *(39) had spent several hours more on this discussion, the results concerning the future of mobility would just have been snapshots. One thing is clear, though: liquid fuels will be staying with us in this challenging context longer than we may have thought.*

THE IC ENGINE IS ALIVE AND WELL

Schaeffler has evolved into a leading partner of the automotive industry over the past decades. Prof. Peter Gutzmer explains why the IC engine with its liquid fuels will continue to play a major role in this engineering company.

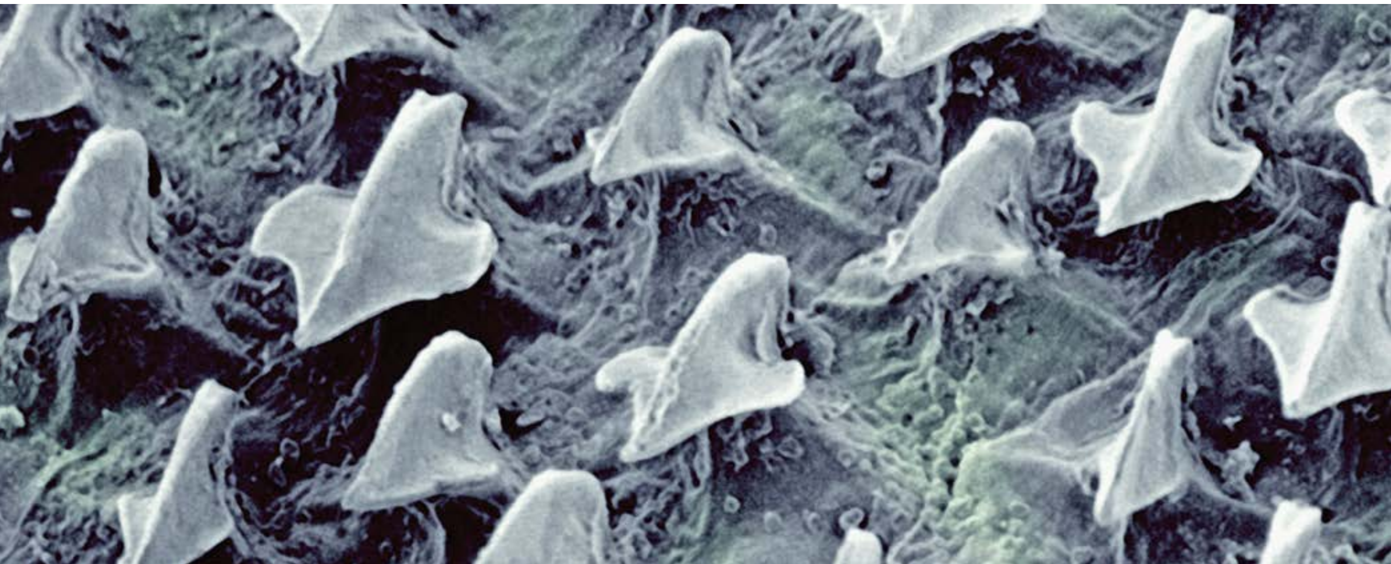
"Neither in the passenger car nor in the commercial vehicle sector will we be able to get around using the internal combustion engine. That's also why we welcome the development that increasingly puts the focus on synfuels. When looking at the energy chain of synthetic hydrocarbon compounds – produced from solar power for instance – CO_2 may become a raw material. Although this debate already took place years ago, it never really progressed. But now it's being resumed. These new fuels will then require efficient combustion and the diesel engine with its efficiency may be an example in this context. However, changed overall conditions as well as the development of costs will cause the share of diesel engines to decrease."

Schaeffler's Chief Technology Officer
Prof. Peter Gutzmer

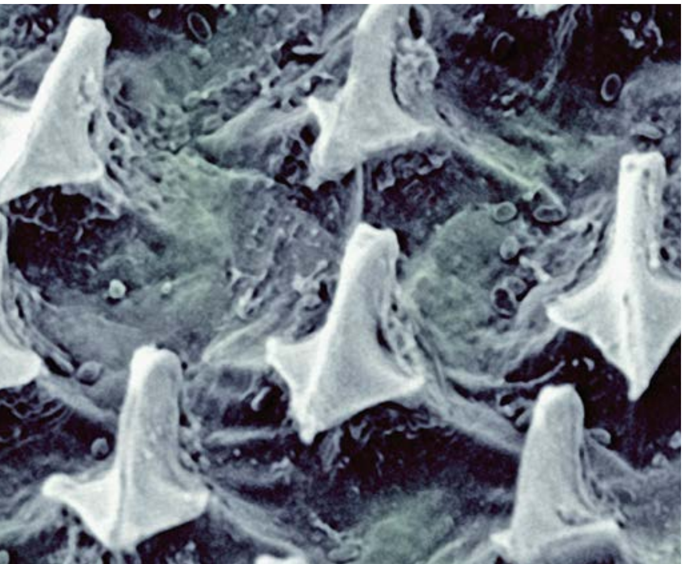
SLICK AS A SHARK

All smoothness is not created equal. Seemingly perfect plains resemble jagged mountain ranges under a microscope. Yet the right surface coating harbors plenty of energy-saving potential. Schaeffler is working on innovative coating systems at full stretch.

by Jan Oliver Löfken



Dr. Yashar Musayev, Senior Vice President and Head of the Surface Technology Competence Center at Schaeffler, examines ultra-thin nano-structured surfaces



Smooth as a mirror – swiping across polished car paint or a sparkling crystal glass with a finger produces a quick verdict. But a look through a microscope will reveal the whole truth, exposing a jagged landscape of hills because our fingertips can't sense irregularities smaller than three thousandths of a millimeter (0.03 in). More than a thousand times smoother are mirrors in space telescopes or exposure optics used in computer chip production. After polishing, often done for days on end, only few atoms protrude from a surface coated with noble metals.

The smoother the better: This strategy spontaneously suggests itself for surfaces of wind turbine blades and ship hulls or for the components in engines and transmissions as well. At first glance, the incentives for achieving maximum smoothness would include less friction, almost no wear and higher energy efficiency. This is a fallacy, though. Coating and polishing of all contact surfaces – with just a few protruding atoms remaining – would practically be cost-prohibitive. And in many cases, a certain roughness is even desirable for optimizing the flow of air and water or movements between steel components.

Experts at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen, Germany, have been doing research on the development of a coating with a surface structure taking its cues from shark scales. Such a surface could prevent deposits on a ship hull and, due to the resulting water flow, reduce ship resistance. For this purpose, a film of water

Tailored modular coating kit for Schaeffler

» Our versatile coatings form a key technology for all industrialized countries

Dr. Yashar Musayev,
Senior Vice President and Head of the Surface Technology Competence Center at Schaeffler

forms in the microscopically small grooves of the shark scales so that there's practically no friction effect, which enables high speed with minimal exertion of force. For a ship coated with articifial shark skin, the energy consumption decreases at higher speed. The IFAM experts in Bremen have already demonstrated in the laboratory that friction could be reduced by more than five percent this way.

Components with Schaeffler coatings in worldwide use for years

Even the rotor blades of wind turbines can benefit from microstructured surfaces. In addition to enabling nearly vortex-free airflow, the adhesion of water drops could be prevented. This is particularly important in winter to prevent ice crystals from interfering with the smooth running of the rotors. Undesirable vortices that reduce efficiencies should be avoided this way.

In engines, transmissions and wheel bearings, friction is undesirable as well because it causes abrasion, wear and lower efficiency. That's why in Germany alone over a million metric tons (1.1 million short tons) of lubricants and oils per year are filled into engines or used in plain, ball or rolling bearings. Special surface coatings make it possible to use less and less lubrication, while increasing machine life and efficiency. "Therefore, our versatile coatings form a key technology for all industrialized countries," says Dr. Yashar Musayev, Senior Vice President and Head of the Surface Technology Competence Center at Schaeffler.

Components with sophisticated Schaeffler coatings have been in use around the world for many years. Carbon-based diamond-like carbon (DLC) coatings cover valve components and reduce wear and friction. The life of rolling bearings, which are particularly stressed, is extended by carbon-based, diamond-like coating systems as well.

Numerous wheel, plain and rolling bearings in modern trains can be protected against pitting corrosion with zinc-phosphate or zinc-iron and zinc-nickel alloy coatings. In generators and electric motors, ultra-thin insulating aluminum oxide layers prevent undesirable leakage current and short circuits. The range of available materials and coatings is enormous. "We have developed a kind of modular kit from which every user, from engine designers to wind turbine developers, can select a tailor-made coating," says Musayev.

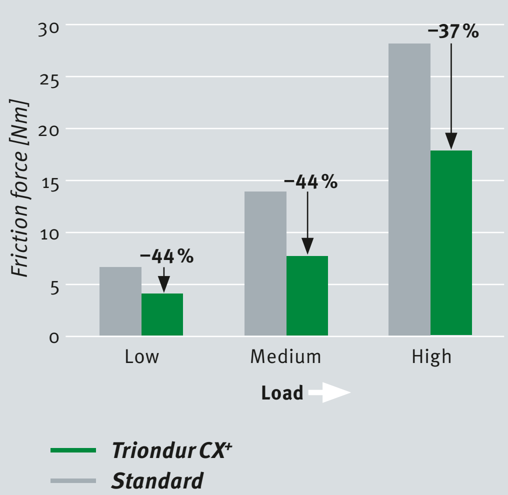
Coating of the future to feature sensory capabilities

But the search for the material and coating system best suiting a respective requirement – particularly hard, low-friction or corrosion-proof – doesn't mark the end of the work done by Musayev's team. In parallel, they optimize techniques for finishing steel components with the thin coatings measuring a maximum of five thousandths of a millimeter (0.03 in), which is all developers of engines, bearings and transmissions allow for today. In addition to spraying, painting or electroplating, special vacuum techniques have been gaining importance. In these processes – referred to as CVD or PVD (chemical or physical vapor deposition) – the desired substances deposit from the gas phase on the components in thin, uniform layers. For surface coatings containing carbon, a plasma of ionized particles is very efficient as well.

But Dr. Musayev and his colleagues are working on the future of coatings too. And such future coatings may even exhibit something similar to intelligence. "Sensory applications are currently one of the latest development trends," says the expert for surfaces. Possible applications of the new, often nano-structured coatings cover a wide range: from smart washers which, as pressure sensors, indicate the clamping force of a threaded joint, to a coating which detects elongation or temperature and indicates the smooth running of a machine or even warns of an impending overload. These parameters can usually be measured via minor changes in the electrical conductivity of the respective coating – realibly, fast and in automated mode. "But these sensor surfaces are not ready yet for mass production," says Musayev.

Dry running with the vision of engines operating without oil and bearings without lubrication is another worldwide trend. From today's perspective, this sounds utopian. "But we're working on this as well," emphasizes the lord of coatings. Thus, the costly proportion of lubricant could be reduced by functional surface coatings while the no-lube machines could continue to be operated at high levels of energy efficiency. "Theoretically, this is definitely possible," Dr. Musayev is sure.

ROLLING BEARING
Low-lube rotational speed: 40 rpm -1



Source: Schaeffler

Triondur coatings minimize friction for maximum wear protection and have specifically been developed for rolling bearing applications.

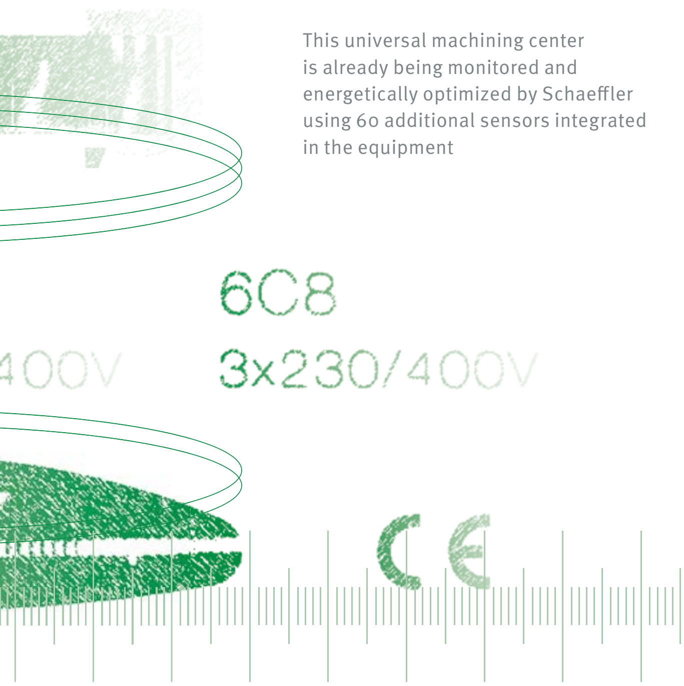
THE AUTHOR

Science journalist and physicist ***Jan Oliver Löfken*** *appreciates the chrome polished to a high gloss on his classic car that still masters the distances it travels without any sophisticated functional surfaces.*

INDUSTRY 4.0
USING ENERGY EFFICIENTLY

Digitalization gives energy-intensive industries rise for hope because it can help save quite a bit of electric power, heating and cooling, with cost benefits for customers and the companies themselves – vis-à-vis competitors. Schaeffler is building this vision for the future in several projects – and has already achieved tangible results today.

by Frank Urbansky



This universal machining center is already being monitored and energetically optimized by Schaeffler using 60 additional sensors integrated in the equipment

— In IoT-based Industry 4.0 smart factories, a machine runs when the price of electric power is low. The machine itself knows when that's the case. It automatically turns itself on, measures its energy requirements during the individual process steps, simulates them for future steps and subsequently orders its corresponding electricity requirement automatically.

A vision of the future? Perhaps, but efforts to make it reality are already underway today – at Schaeffler as well. But first, let's take a look at the opportunities for Industry 4.0 in terms of energy, which – logically – are found in purchasing and consumption.

Optimized buying

For starters, let's take a look at buying energy. Digitalization already causes business models to emerge that in the future will allow companies to precisely schedule their energy purchases aligned with their production operations. This, by the way, applies to all types of energy, be it electricity, gas, heating or cooling. Energy-intensive businesses are already using various purchasing options today, for instance by having employees trained at the Leipzig Energy Exchange (EEX), who subsequently ensure that their company will optimize its energy buying practices. While energy today is still being purchased via major trading platforms and exchanges, in the future, customers will be able to buy energy directly from the producer, which may be a local energy co-op or a regional wind farm operator. In Germany, the Renewable Energies Act (EEG) amended in 2017 has largely eliminated previously existing legal hurdles.

Reducing consumption

So, let's shift our focus to energy consumption now. Schaeffler is already active for its customers in this context today (see box on Page 105). Three very realistic fields in which energy can be saved in smart factories by means of digitalization are conceivable.

Consolidating mutually complementary forms of energy represents the first field, illustrated by two examples. If both cooling and heating are required in a company's production processes the requirement for cooling can be covered by absorption refrigerators that use in-process heat. Or if an office building requires cooling in summer and heating in winter the bivalent operation of heat pumps would make sense because they can cover both needs. In terms of technology, this is already happening today, but not in a way that is integrated in a superordinate digitalized energy strategy of an Industry 4.0 company.

In the second field, all energy consumers in a company are optimally entered into a system and monitored – in keeping with the maxim: "You can't manage what you don't measure!" The data volumes generated in this context are immense. For humans, it's difficult to read this data quickly and to derive sensible recommendations for action from the analysis. Therefore, the first digitalization step is data acquisition and visualization, which provides a quick overview and facilitates decision-making. In the future, this will be possible in an automated process. Experts expect energy savings of at least 10 to 20 percent to be achievable through these measures alone.

"End-to-end transparency in energy and resource consumption, ideally in real time, is the name of the game," says Roberto Henkel, Director Digitalization Operations at Schaeffler. The consumption of electricity, cooling lubricant and compressed air by a machine down to the level of the single component and individual processing steps is completely transparent. Henkel calls this an "energy performance certificate at component and process level."

This glass exhibit of Machine Tool 4.0 shows the locations at which sensors have been installed

The third field is focused on a company-wide energy-optimized coordination of plant and equipment. For example, this may mean machines operating at times when electricity is cheap and, additionally, automatically powering down at other times. It could also mean utilizing on-demand on-and-off cycles. “In our Machine Tool 4.0 project, we’re showing how transparency of energy demand and energy consumption at individual machine level can be successfully achieved through technology. Still, sensoring of an individual machine merely provides the basis,” says Henkel: “In the future, we’ll be equipping entire factory halls with smart energy measurement technology, which will not just encompass machines but facility engineering as well in a factory for tomorrow.”

> **» *End-to-end transparency of energy and resource consumption***
>
> Roberto Henkel, Director Digitalization Operations, Schaeffler

Working on the “factory for tomorrow”

With that, Schaeffler is realizing all-encompassing approaches to energy efficiency of entire factories, the vision being an energy-generating factory that produces more energy than it consumes. With 75 manufacturing locations, the company has huge worldwide potential for energy optimization of its own value chains.

When it comes to equipping machines, Schaeffler can leverage its advantages as a component and systems supplier. The objective of digitalization in production operations is the sustainable improvement of key performance indicators in terms of quality, cost and delivery performance. “Transparent benchmarks focused on the energy consumption of individual machines, interlinked production lines or even entire locations enables us to identify optimization potential and initiate improvement projects,” Henkel explains. For example, knowing how much energy a process step requires would make it possible to plan the energy requirement for the production program of the next two to four weeks, purchase this energy on the open electricity market or reduce peak loads.

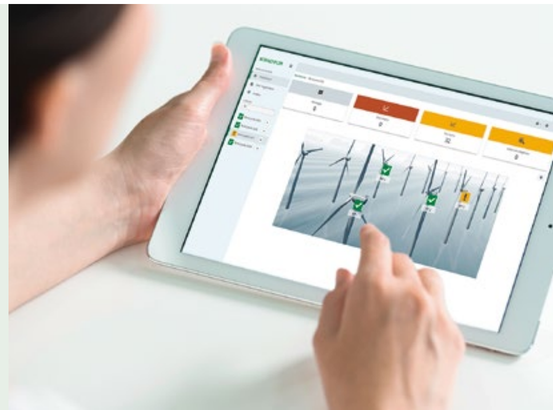
Schaeffler is going to test this. Before the end of this year, an entire production hall at one of the company’s locations will be retrofitted with energy measurement technology. Here up to 200 machines plus the infrastructure of the hall will be equipped with smart energy measurement technology and connected to Schaeffler’s digital platform. Schaeffler know-how and IBM technology will be analyzing the data on site for

SCHAEFFLER IS COMMITTED TO DIGITAL EFFICIENCY

In addition to Machine Tool 4.0, Schaeffler has rolled out a number of other projects that have been testing and achieving ways to save energy and thus money in Industry 4.0 smart factories.

Monitored wind turbines
In the “Predictive Maintenance” project, for instance, the transmissions of wind turbines are monitored and their condition predicted (see also “tomorrow” 3/2016). This is done based on energy production and mechanical system data. The “Schaeffler Service Cloud” analysis program analyzes the data. The system is used in the propulsion systems of cruise ships as well.

Powertrain for Formula E
Schaeffler has developed a powertrain for FIA Formula E. The ABT Schaeffler MGU 01+ is a complete electric motor with performance electronics. They ensure optimized energy consumption because nothing would be more embarassing than a Formula E car that prematurely runs out of juice.



further use in the comprehensive energetic optimization of the production hall. As early as in 2019, this technology is planned to be rolled out in an initial “factory for tomorrow” to optimize an entire Schaeffler location.

A scenario might look like this: Entire machines and lines “sleep” in non-productive stages until the next production order prompts them to “warm up” again. This, says Henkel, is not unrealistic but comparable to a printer in standby mode within a network being reactivated by external information.

However, a machine that automatically powers up when electricity rates are low or an autonomous array of machines that optimize themselves based on energy prices and order sequencing are not the primary goals at the moment. Henkel: “Visions like these take time. But that time will come.”

THE AUTHOR

Frank Urbansky *studied journalism and for many years worked in communication agencies where he primarily supported customers from the energy sector. Drawing on this knowledge, he’s been working as a freelance journalist and specialized author since 2014. He’s the founder of the daily EnWiPo blog. His focal topics are Energy Economy 4.0, the thermal market, energy-efficient construction, renewable energies, alternative drive systems and the oil and gas markets. He’s a member of the energy bloggers network.*

MAST**HEAD**

Published by
Schaeffler AG
Industriestraße 1–3
D-91074 Herzogenaurach
www.schaeffler.com

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Blattwerk Hannover GmbH

Graphic Design
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English Translation
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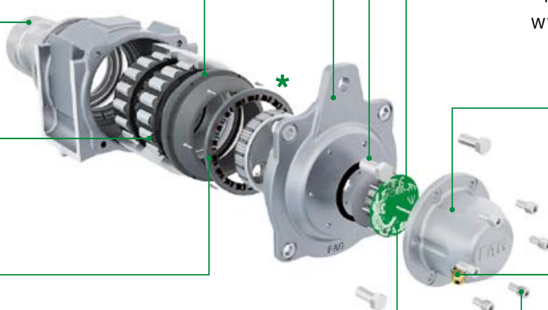

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In the form of a generator integrated in a housing cover for a wheelset bearing, Schaeffler showcased the concept of a self-sufficient power supply system for – unpowered – rail-bound freight cars at InnoTrans 2016. The generator produces about 200 watts to supply a freight car with power, enabling additional functions such as GPS, sensor-based condition monitoring, lighting, brake assistance or the operation of folding doors.

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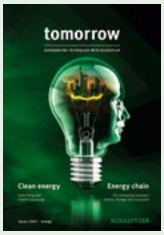

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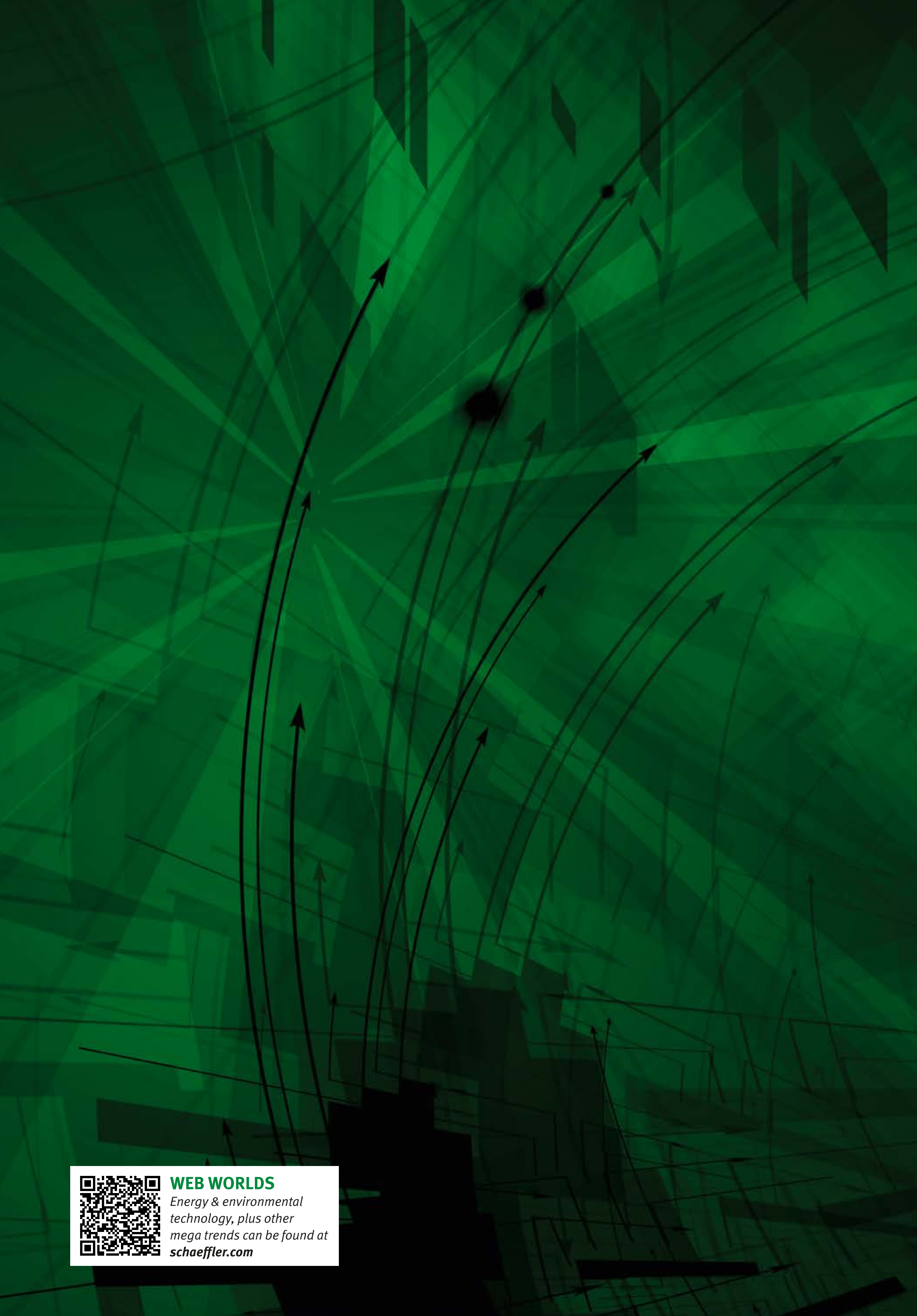

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