tomorrow

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Harnessing efficiency

Sustainable achievement of goals hinges on sparing use of resources

SCHAEFFLER

Issue 2/2021 · Efficiency

Ef|fi|ciency; - /ıˈfɪʃnˌsi/

Efficiency is the (often measurable) ability to avoid wasting materials, energy, efforts, money, and time in doing something or in producing a desired result. In a more general sense, it is the ability to do things well, successfully, and without waste. [...] In more mathematical or scientific terms, signifies the level of performance that uses the least amount of inputs to achieve the highest amount of output. It often specifically comprises the capability of a specific application of effort to produce a specific outcome with a minimum amount or quantity of waste, expense, or unnecessary effort. Efficiency refers to very different inputs and outputs in different fields and industries. [...]

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tomorrow has won recognition



Special Mention "Communications Design Editorial"



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Silver Special Award "International Communication"



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Gold Winner "General Website, Categories-Magazine"



Award of Excellence for Cover (2/2017) and cover story "Electric Leader"



Silver "Writing: Magazines Overall"



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Grand Winner "Magazine"

Dear readers,

Welcome to the new issue of our technology magazine "tomorrow" focused on "efficiency." Enhancing efficiency – in other words achieving a goal with minimal use of resources - has been a driving force in our company for more than 70 years. The cage-guided needle roller bearing invented by our company's founder, Dr.-Ing. E.h. Georg Schaeffler, is such an efficiency enhancer in more ways than one: The development of the needle cage enabled much higher rotational speeds to be achieved with lower friction and wear. As a result, engineers were able to replace other bearing designs by cage-guided needle roller bearings and to clearly improve the performance of their applications. Starting on page 68, you can read about how we're accelerating transformation processes by continuously innovating bearing technology, today and going forward, and the role that extremely thin and multifunctional surfaces play in this context.

Efficiency is a key indicator when measuring energy input and useful output. The efficiency of incandescent light bulbs amounts to "modestly bright" five percent – and that's why they're disappearing from our lamps for good reason. Especially in light of climate change, such energy hogs are no longer appropriate today. Our recently unveiled power electronics for 800-volt powertrains achieve near-perfect efficiency of more than 99 percent in defined load ranges, thereby helping to raise the overall efficiency of electric vehicles, which is good to begin with, to even higher levels. Starting on page 18, we present to you a host of other Schaeffler innovations in the field of electric mobility pursuing the same aim.

However, looking at and optimizing individual products or activities is not enough to seriously combat climate change. We need to include the relevant event chains in our considerations as well. How can we produce steel, one of the world's main materials, in "green" ways, how can we not only achieve carbon neutrality while living in our buildings but also while constructing them, and how can we produce energy, or travel in comfort without adding to the environmental burden? On the following pages, you're going to find a wealth of concepts and ideas as well as solutions ready to



be deployed – including some from our company – that can help master the pressing challenges of our time. Irrespective of the type of innovation, efficiency is the key to a sustainable future.

Efficiency has always accelerated the present-day pace and pushed open the gates to the future. Around the World in Eighty Days – a science fiction novel written by Jules Verne 150 years ago – is tantamount to a snail's pace in today's world of tourism. Above all, though, efficiency as an effective way to cut costs allows many people to participate in technological progress. The cell phone is a case in point. Originally a luxury for high-income earners, it's a powerful mass-produced means of communication for people from all walks of life today.

Going forward, "tomorrow" is going to inform you even more efficiently, right in line with our current focus topic. Complementing the printed, multiple award-winning magazine, schaeffler-tomorrow.com will be keeping its ear to the ground of technological progress even closer for you: as an efficient analog and digital combination. Enjoy your read and exploration of "tomorrow's" new worlds.

Mans Rempla

Klaus Rosenfeld Chief Executive Officer

In Motion

Future mobility

In control of heat and cold

Less energy consumption, longer range – how Schaeffler enhances the efficiency of e-cars with smart thermal management

Air Green

The aviation industry is revving up for takeoff toward a lower-emissions future with innovative propulsion systems and fuels



Take your pick to suit your volts

Whether hybrid or fully electric, whether 48 or 800 volts, Schaeffler's modular powertrain portfolio has the right solution for any e-car

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The mega web

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In Motion

Future mobility has many facets but, above all, it must be sustainable, efficient and user-friendly.



While the Hyperloop has not made its way into the real world of transportation yet, an even more extreme idea is approaching at high speed: the Aeroslider maglev concept that Manyone, a team of designers and strategists in Denmark, has come up with. The train with a length of 250 meters (820 feet) is supposed to travel at a speed of 800 km/h (500 mph) – without an onboard propulsion system. Propelled through a connected system of electromagnetic portals perched on 20-meter (65 feet)-tall pylons in the countryside, the maglev Aeroslider would use no rails, tubes or other physical stabilizers but have a unique feature: **reservoirs in the capsule filled with helium** to reduce the weight of this "rocket." It remains to be seen whether the train will ever zip from Moscow to Shanghai in 12 hours as imagined. But, as Albert Einstein said: "If at first the idea is not absurd, then there is no hope for it."

Inclusion meets motorsport

For the inclusion project "United in Dreams," Schaeffler Paravan converted electric karts for disabled drivers with Space Drive drive-by-wire technology. The agile e-kart is controlled by various input devices, depending on the driver's type of disability. The electric vehicle designed for karting slalom competitions can be operated either by means of a 2- or 4-way joystick, an accelerator-brake slider or a force-feedback steering unit. In a kart like this, people with physical disabilities can compete with non-disabled opponents without using a steering wheel and pedals. The project, in which the German Motorsport Federation (DMSB), the x4in (Experience for Innovation) association and the "Aktion Mensch" charity are engaged as well, was presented to a large audience at the Formula E finale in Berlin.



"If anyone would rather live in the past, they don't know history very well"

Elon Musk, Entrepreneur and mobility visionary

18 days

That's how long it took the **first direct train** to travel the 10,000-kilometer (6,200-mile) distance between the Chinese province Anhui bordering Shanghai to the German North Sea JadeWeserPort. As a result, the transcontinental train route proved **twice as fast as the sea route.** However, the train had room for 100 containers, whereas large ships can haul more than 20,000.

So long Formula E, hello E-DTM

Founding member Schaeffler has said good-bye to Formula E. Two title wins and 47 trophies – including a victory scored by Lucas di Grassi on the final weekend in Berlin – prove Schaeffler's extremely successful involvement as the team's technology partner. **The Audi Sport ABT Schaeffler team has been the most successful outfit in the innovative series to date.** Schaeffler continues to be committed to electric motor racing, though: **The automotive and industrial supplier is now developing the powertrain system for the future fully electric DTM.** The know-how from motorsport will continue to be transferred directly into the development of innovative production solutions in the field of electric mobility.



Let there be heat where heat should be

Cold feet, a hot electric motor, and the battery somewhere in between: Temperature control on board of an electric car is a complex and sensitive subject. This is how efficient multitasking of optimal thermal management works.



By Volker Paulun

Somehow, we've gotten used to it: Setting the temperature control of our car's automatic air conditioning to 20 degrees centigrade (68 degrees Fahrenheit) and letting the system take care of the rest. Whether it's freezing cold outside or sweltering heat, the cabin remains comfortable. In many cars, the driver and passengers can even select different temperature levels - to suit their personal preferences. But not only the occupants have their individual thermal comfort zone. Technology operates most efficiently in a special temperature window as well. Excessive variations may even cause damage. Since optimal temperature windows may greatly vary, depending on the component assembly, thermal energy has to be skillfully distributed or stored. This is a job for thermal management. Schaeffler has been producing the first thermal management module for powertrains using gasoline engines since 2011: in Audi's 1.8-l TFSI engine. Just by means of this Schaeffler technology the CO_2 emissions of the vehicles using it were reduced by up to four percent. Since then, the system has been subjected to consistent further development, especially for meeting the clearly more complex requirements of electrified powertrains.

Current hybrid electric vehicles have up to three cooling circuits operating at different temperature levels: for the IC engine, the electric motor including power electronics, and the battery. Even so, these circuits are interlinked via heat exchangers. The individual components are no longer bound to performing fixed roles as heat sinks and heat sources but can definitely swap these roles. In addition, their higher complexity required switching from central to decentralized thermal management for electrified powertrains.



Schaeffler's thermal management system

Efficient heating, especially in combination with a heat pump, is decisive for the cabin and the battery of an electric car when cold-starting the vehicle. High cooling power is crucial at hot outdoor temperatures and during fast charging. The new integrated thermal management system from Schaeffler as the central control unit interconnects the coolant and refrigerant circuits. In addition, it uses the waste heat from the electric drive efficiently for optimized energy balance. The thermal management system integrates two electric water pumps, the central electronics unit for the pumps and valves as well as the sensors and chiller as the refrigerant circuit interface. The compact design

reduces the space requirement by up to 60 percent compared to conventional, non-integrated systems. At the same time, Schaeffler's new thermal management system with its hydraulically optimized design provides the basis for high overall efficiency.

250 mm (9.8 in) 190 mm (7.5 in) 270 mm (10.6 in)

Thermal management even more important for fully electric vehicles

Because the ample supply of the IC engine's waste heat as an abundant source of heat does not exist in all-electric vehicles optimized energy management is even more crucial. The objective of the development engineers is to achieve a maximum intersection of high powertrain efficiency as one set and ensured comfort functions and optimal component protection as the other – by means of sophisticated thermal management.

The interaction between the cooling and the refrigerant circuit in fully electric vehicles is particularly important due to its significantly higher impact on overall vehicle efficiency than in an ICE or hybrid electric powertrain. On cold winter days and nights, to mention an especially challenging issue, the heater in an electric car consumes a similar amount of energy to produce comfortable temperatures in the cabin as the car uses for propulsion. The more efficiently the heater can use the heat dissipated by other units the higher the car's range. A reversible heat pump in the refrigerant circuit delivers any additionally needed degrees centigrade or Fahrenheit. It is able to increase the electrical energy diverted from the traction battery by as much as a factor of five and use it not only for heating but also for cooling, as needed.

Ailing batteries due to fever or hypothermia

In contrast to a conventionally powered automobile, in which the IC engine is the central element in the powertrain, the battery – including thermal management – is the focus of attention in an electric vehicle. The energy storage device with its liquid electrolytes is highly temperature-sensitive

"Schaeffler's high manufacturing and technology expertise across all components of electric drive systems is the key to products that combine technological leadership and economic efficiency"

Dr. Jochen Schröder, President, Business Division E-Mobility at Schaeffler

and therefore typically has a dedicated cooling circuit. All of us are familiar with this phenomenon from our smartphones: battery power decreases in cold temperatures due to an increase of internal resistance. The same happens in an electric vehicle, whose energy storage device is essentially nothing but an XXL-sized smartphone battery. However, the decrease in usable capacity is just one of several issues. High charging currents at low, sub-zero temperatures can damage the battery due to the risk of the lithium ions forming metallic lithium instead of depositing in the anode as desired while the battery is being charged. This dreaded process is called plating and can lead to short circuits or even fires. Therefore, predictive thermal management moves the energy storage device into a "healthy" temperature window prior to the charging process.

The ideal temperature window of a lithium-ion battery ranges between 20 and 40 degrees centigrade (68 to 104 degrees Fahrenheit). If the battery gets hotter it will not just lose energy but age as well. Because a normal cooling circuit will soon reach its limits at high ambient temperatures a refrigerant circuit with a heat pump operating according to the same principle as the air conditioning system for the cabin can be activated additionally. The high weight of a traction battery amounting to several hundred kilograms makes it more difficult to achieve an optimum thermal window. Here, extensive interlinking of the thermal management system and the vehicle control unit helps detect potential stress early and respond accordingly. For instance, if the driver uses GPS navigation to head for a fast-charging station the system can put the battery into the ideal temperature range for charging at maximum power input. The more

data is made available to the predictive management module the more effectively it can respond. Therefore, adequate computing power is becoming an increasingly important pillar of efficient thermal management.

Electric motors need cooling too

Even though the power dissipation of an electric motor is clearly less than that of an internal combustion engine it does get hot as well – due to friction and current flow. Overheating of the motor may result in damage, for instance to the winding. Therefore, nearly all electric traction motors are now liquid-cooled. The same applies to the power electronics controlling the complex current flow of an electric vehicle. The cooling circuit controlled by the thermal management system dissipates this thermal energy and conducts it toward a place in the vehicle where it's needed.

Schaeffler's thermal management system controls the complex interaction between the cooling and the refrigerant circuit via a highly integrated cooling module consisting of pumps, valves and the coolant reservoir with a dedicated control unit, complemented by decentralized, smart valves that are coordinated centrally. Based on the prevailing temperatures and operating condition of the vehicle, the central electronics unit controls the actuators and pumps - and thus, continuously, the flow of thermal energy. This explains why Jochen Schröder, President of E-Mobility at Schaeffler, says: "Thermal management is the unsung star of the show when it comes to making vehicles even more efficient and user-friendly."

The future of flying

Flying after the pandemic? Yes, but only in more energyefficient and sustainable ways than before. That's the name of the game for policymakers and the aviation industry, and a number of interesting concepts exist to support these goals.

By Andreas Spaeth

Flying, but greener – that's what the future of aviation has to look like. There's no other option considering the current footprint of air travel on the global climate. Airline CEOs and policymakers agree on this point. The aviation industry has committed to cutting its net CO_2 emissions in half compared to 2005 by 2050. Scientists say that 2050 is too late and are pressing for change by 2030. Air travel accounts for 3.5 percent of human-induced global warming, according to an international study led by Manchester Metropolitan University with participation of the German Aerospace Center (DLR) and others that was published in September 2020 and provides the most comprehensive insight into the climatic impact of aviation to date.

CO₂ emissions, which have been the key metric for the environmental impact of aviation, account for only one third of it, whereas other effects account for two thirds of the climatic impact of aircraft. Nitrogen oxide (NOX) emissions at altitudes below 12,000 meters (39,000 feet) promote the undesirable formation of ozone. Undesirable because ozone does not block UV rays in these layers of the atmosphere but, like CO₂, has the effect of a greenhouse gas. On the other hand, depending on weather conditions, soot particle emissions as cloud condensation nuclei contribute to cloud The fuselage shape of the Flying V is energyefficient (–20% compared to an Airbus A350) and provides ample room for space-filling hydrogen tanks

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formation (in the form of the generally known contrails, among other things). These clouds reflect thermal radiation from the Earth and therefore contribute to global warming as well.

In this article, we present some interesting ideas of how aircraft and their propulsion systems might become more environmentally friendly going forward and which sustainable energy sources could be tapped for this purpose.

Traveling more efficiently in a flying wing

To gain efficiency in flying, new aircraft designs have to be studied. Flying V (pictured below) is a V-shaped concept consisting basically only of a wing, put forward by the Technical University of Delft in the Netherlands, supported by KLM and Airbus. "If this configuration indeed becomes the next long-haul aircraft, it would be the most revolutionary change we have seen in aviation since the introduction of jet engines," says project leader Roelof Vos. In 2014, a first model of the flying wing took to the air for tests. Since then, the Technical University of Delft has further refined the aircraft concept and in July 2020, a 1:5 scale model of the Flying V flew with a wing span of over three meters (10 ft) and a weight of 22 kilos (49 lbs). The design itself is fairly conventional on purpose and the original is supposed to be slightly smaller than today's Airbus A350, currently one of the most efficient airliners. Flying V can use existing airport facilities and haul the same number of passengers and cargo volume as the A350 – while burning 20 percent less fuel. "And this just comes from the fuselage shape, maybe we will be able to gain even more efficiency by improving propulsion technology," Vos hopes. Potentially, the aircraft could be powered by hydrogen in the form of fuel cells or e-fuel. Hydrogen needs huge tanks that conventional jets could hardly accommodate. "This would be much easier in the outer wings of the Flying V than in the thin wings of current aircraft," says the professor from Delft.

Efficiency through open fan-blade architecture

A new generation of aircraft has to be at least 20 percent more efficient than the preceding one, and that's only possible with radical changes to propulsion such as open rotor engines that were first unveiled as far back as in the mid-1980s. Two openly exposed, counter-rotating fans with swordlike blades looked spectacular, but caused many problems – from noise to vibrations. Almost three and a half decades later, the successor model could turn into a big leap forward by being available as propulsion for an anticipated replacement of the Airbus A320neo family around 2030. Called RISE (Revolutionary Innovation for Sustainable Engines), manufacturer CFM in mid-2021 unveiled a new open rotor concept using just one unducted fan with carbon blades. This open architecture eliminates the whole structure around the fan and therefore a lot of weight and drag, so enabling ultimate propulsive efficiency. The diameter of the unducted engine shrunk to nearly four meters

Fit for today, tomorrow, and day after tomorrow: openrotor engines run on all kinds of fuel

(13 ft), similar to the dimensions of current turbofan engines including their casing, for example on the A320neo or the Boeing 737 MAX. The key advantage is that RISE can run on all kinds of fuel, be it up to 100 percent SAF (sustainable aviation fuel) or even hydrogen. The RISE engine is supposed to reduce fuel burn by 20 percent and that, says the manufacturer, is only one component of the overall efficiency of the concept. With further improvements to the aircraft itself, the total effect could be increased to 30 percent more efficiency versus the status quo by 2035.

"Green" fuels as a bridge to the future

To make flying more environmentally friendly, alternative sources of energy are needed, and currently sustainable aviation fuels (SAFs) are the focus of attention. As the growing of biomass can lead to competition with the cultivation of food crops, the production of biomass as a basis for sustainable fuel is limited to exploiting food or wood waste and even used cooking oil. This naturally limits the amount of bio-kerosene that can be produced. In the pre-corona year of 2018, about 15 million liters (4 million gallons) of aviation bio-kerosene were produced globally - not even 0.1 per cent of the total aviation fuel required. For larger volumes, pilot projects are already using so-called methanol-to-synfuel synthesis. However, to produce one kilowatt hour (kWh) of synthetic, electricity-based fuel today by means of the power-to-liquid method, two KWh of electricity are needed. 52 large wind turbines, each with a rated capacity of 4.6 megawatts, would be necessary to cover the daily synthetic kerosene demand of an Airbus A350, according to calculations by the Hamburg University of Applied Sciences (HAW). But the flight of an aircraft solely using such fuel would be carbon-neutral because it would emit only CO₂ previously extracted from the atmosphere. Synthetic kerosene is currently used only in small quantities blended with fossil-based kerosene as so-called drop-in fuel. To increase its share, many countries are now imposing minimum quotas for the amount of SAF that has to be used for flying. Germany is planning to require 0.5 per cent starting in 2026 and two per cent in 2030, while Neste Oil, one of the biggest manufacturers, considers a share of five percent by 2025 and ten percent by 2030 to be realistic in Europe.



"Since the beginning of aviation engineers have been striving to continuously improve the efficiency and safety of aircraft. Only as a result of these efforts have aircraft become the safest means of mass transportation. And only few people know that a fully occupied Airbus A319neo requires just two liters of kerosene per passenger per 100 kilometers (62 miles). The next goal pursued by the aviation industry is zero emissions. This goal can only be achieved with a technology mix for the various applications. I can imagine a world in which short hauls in regional aircraft will be battery-electric. For distances of up to 2,000 kilometers (1,250 miles), hydrogen is the suitable energy source, either as carbon-neutral fuel burned directly or by powering electric propulsion systems via a fuel cell. For long-haul flights, I do not see any alternative to synthetic fuels produced from renewable energies in the next few decades. These developments result in outstanding opportunities for Schaeffler Aerospace going forward. Aviation has its own exacting standards and we see ourselves in a position to transfer our very good in-house development and production knowhow in the area of electric drive systems to this sector"

Armin Necker, Managing Director Schaeffler Aerospace

The P-Volt electric aircraft is planned to start all-electric shorthaul service in Norway in 2026

Plug-in engine power

Electric propulsion could be ready for use in hybrid regional aircraft of up to 50 seats on short routes in the next few years. The Swedish startup Heart Aerospace received a huge boost in July 2021 by US giant United Airlines ordering up to 200 units of the biggest fully electric aircraft under development so far, the ES-19. Finnair also cooperates with Heart and has secured up to 20 of the 19-seaters. It's supposed to fly as far as 400 kilometers (250 miles) before the batteries have to be recharged, which will take a 1-MW charger on the ground about 40 minutes. After about 1,000 cycles, the batteries have to be replaced. The very first electrical aircraft for passenger flights could be in service in Scandinavia by the middle of the decade. In Norway, regional airline Widerøe, engine maker Rolls-Royce, and Italian aircraft manufacturer Tecnam have teamed up. The trio is aiming to put the nine-seat P-Volt into service in about five years as the first passenger aircraft solely powered electrically. However, the principal problem of electric propulsion still lies in the energy density of today's batteries. 200 to 250 Wh/kg are the maximum that can be achieved, while kerosene offers an energy density of 12,000 Wh/kg. The available efficiency of lithium batteries, though, is increasing by five to eight percent every year and NASA expects them to

> The ES 19 from Heart Aerospace flies 19 passengers over a distance of up to 400 kilometers (250 miles) as a fully electric aircraft. Finnair and United have secured purchasing options for the electric city hopper

achieve an energy density of 350 Wh/kg by 2030, enabling a 30-seater electric aircraft for shorthaul flying. The car manufacturing industry is now working on solid-state batteries of up to 400 Wh/ kg and there are even plans for vehicle batteries with 1,000 Wh/kg. In aircraft, though, fully electric propulsion will only be viable for smaller propeller aircraft even in the mid-term future. For bigger regional jets with about one hundred seats, hybrid concepts, i.e., a combination of electric motors and conventional jet engines, are the most suitable approach. This would enable a much longer aircraft range, while an added electric power source, mainly during takeoff and landing, would lead to significant reductions of fuel burn, emissions and noise.





By 2035 Airbus is planning to bring the first "zero-emissions" airliner to market. Independent scientists have dismissed this announcement. Dieter Scholz, a professor at HAW, for example, says that zero emissions will never be possible. The aircraft manufacturer from Toulouse has presented three different concepts, among them a conventional-looking jet and a blended-wing body, of which one is supposed to become reality, most likely the turboprop variant. The idea to use hydrogen instead of kerosene as an energy source for aircraft engines is difficult to realize. So far, there is a lack of hydrogen aircraft concepts that could cope with everyday flight operations and be economical at the same time. Establishing the infrastructure on the ground required for storing hydrogen and refueling aircraft is a complex proposition as well. Hydrogen is not easy to han-

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dle: It offers three times the energy density of kerosene, which is a major advantage over batteries, and only weighs a third, but requires up to four times more volume. And space on board of aircraft is notoriously scarce. Additionally complicating things is the fact that hydrogen is a so-called cryogenic fuel: a gas that only liquefies at minus 253 °C (-423 °F) and can be used for propulsion only after having been compressed under high pressure. Hydrogen can be used on aircraft in different ways: for direct burn in modified gas turbines, converted to electrical energy in fuel cells, or as synthetic kerosene produced in combination with CO₂. The startup Universal Hydrogen has developed a simple capsule system for delivering hydrogen to turboprop aircraft. On the ground in between flights, hydrogen capsules measuring two meters (6 ft) in length would be replaced in the aft of the aircraft to produce in-flight energy in a fuel cell powering two electric motors. The first airlines have already ordered the technology and are planning to use it for nearly emission-free operation in existing aircraft such as the ATR-72 and Dash-8 starting in 2025.

Replacing instead of refueling: hydrogen capsules supply energy for fuel cell propulsion systems

Two major airlines have already secured options for Concorde's successor Overture that achieves a speed of 2,100 km/h (1,300 mph)

Supersonic, but sustainable this time around?

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Since the end of Concorde in 2003, there have been no more supersonic passenger flights. Due to their extremely high energy consumption, the inevitable sonic boom, and emissions at high altitudes, such flights would no longer be appropriate today. Even so, a new supersonic era might begin soon: Boom Supersonic from Denver is planning to reintroduce supersonic flights by the end of the decade with its Overture aircraft as a smaller successor to Concorde, in more sustainable ways and causing a less noisy boom. United Airlines, the world's fourth-largest airline, in June 2021 announced its intention to purchase 15 Overture aircraft and Japan Airlines holds options as well. Starting in 2029, it's supposed to fly passengers at 1.7 times the speed of sound (2,100 km/h (1,300 mph)), which is significantly slower than Concorde that achieved Mach 2.02 (2,494 km/h (1,548 mph)). Although accommodating only 50 to 60 passengers – fewer than Concorde used to with its one hundred seats – the new airliner would emit three to five times more CO_2 per passenger than a subsonic aircraft flying the same route. Plus, according to estimates by independent scientists of the International Council on Clean Transportation (ICCT), it would burn five to seven times more fuel per passenger. Boom is planning to enable Overture to fly with 100 percent SAF as the first airliner ever. However, the supply of greener fuel is still far too scarce. The 15 United Overture aircraft alone might require twice the amount of SAF that will be available in all of the EU at the end of the decade, estimates the ICCT.



The author

Andreas Spaeth is one of the most well-known German and international aviation journalists. With a passion for aviation ever since his early life, he felt that flying on Concorde for professional purposes on eight occasions between 1993 and 2003 was a great privilege. At the moment, he's observing the

apparent revival of supersonic flying and seriously asking himself if – in a more sustainable form this time around – he's going to again have the chance to fly faster than the speed of sound in the next ten years.

Scalable and customized

The variety of the vehicle market is matched by the diversity of the required propulsion solutions. Schaeffler's extensive electric modular system portfolio comprehensively meets these needs. The supplier offers automotive OEMs the entire output range, from 20 to more than 300 kW for battery voltages between 48 up to 800 volts.



By Volker Paulun

After more than two decades of research and development work and the formation of a dedicated business division three years ago, at the beginning of 2018, Schaeffler's consistent commitment to electric mobility is reflecting significant success. Numerous delivery contracts awarded by automotive OEMs across all electrification levels prove that Schaeffler has successfully established itself in electric mobility. "We have achieved a lot and continue to be on a very good path," says Dr. Jochen Schröder, President of the E-Mobility business division. "With our modular product portfolio, we are now in a position to offer a production solution tailored to any customer wish." Another advantage of Schaeffler as the preferred go-to partner for its customers is that the Group is able to fully cover the entire industrialization of its components and systems inhouse. Everything comes from a one-stop shop. Here are some examples from Schaeffler's extensive modular e-mobility portfolio for environmentally compatible vehicles.





"We will be involved in shaping electric and sustainable mobility decisively going forward. For this purpose, we are developing highly innovative solutions – with high vertical integration, modularity and scalability"

Dr. Jochen Schröder, President, E-Mobility business division

Dedicated hybrid transmission

Dedicated hybrid transmissions (DHT) are highly integrated solutions that have been developed exclusively for use in hybrid electric vehicles. The electric motor is intelligently integrated into a simplified transmission – this saves space and weight, plus it's cost-efficient in high-volume production. Power output typically ranges between 80 kW and 140 kW. The electric motors of the DHT operate in combination with the IC engine as an additional propulsive force or they produce electric power as a generator, depending on the operating mode of the transmission or powertrain. In 2020, Schaeffler was awarded a record contract for dedicated hybrid transmissions and from 2025 on will deliver an entire drive unit with two electric motors (system output: 120 kW) and transmission-integrated power electronics.



Hybrid modules

The hybridization of conventional IC engines is a **major key to efficient, more sustainable and needs-based mobility,** at least during a transition period. For 2030, Schaeffler expects a worldwide market share of 40 percent for all newly registered passenger cars with hybrid powertrains. For this vehicle category, Schaeffler offers a modular solution with powerful electric auxiliary drive units, so-called hybrid modules. As electric motors in these applications, highly efficient permanent magnet synchronous and asynchronous motors are used. The modular hybrid system is **flexible and can be adapted precisely to various transmissions and motors,** for instance as a hybrid module with an integrated torque converter or as a hybrid module with a triple clutch.



E-axle transmissions

Since 2017 e-axle transmissions from Schaeffler have been mass-produced successfully, ensuring **optimal gear ratios and power transmission from the electric motor to the wheels** for a wide range of applications: In the Audi e-tron, e-axle transmissions from Schaeffler are used in different designs (see illustrations) on both axles for an all-wheel drive system. **In the Porsche Taycan, a highly efficient coaxial e-axle transmission from Schaeffler provides the right gear ratios at the front axle** – an award-winning innovation: In 2020, Schaeffler was recognized with the prestigious PACE Award that's regarded as the benchmark for successful automotive projects worldwide.



Power electronics

The power electronics unit is the brain of an electric or electrified powertrain. Its main purpose is to control the current flow between the battery and the motor (see also illustration on next page) using a so-called inverter. It does so in two directions: During propulsion the motor has to be supplied with the right voltage and while braking, the flow direction reverses, the motor recuperates energy and charges the battery with it.

FUNCTIONS



Model-based software platform, complying to AUTOSAR standards; for flexible integration of OEM software components



Extensive safety and monitoring measures with online thermal management and flexible derating



Integrated control of hydraulic actuator systems (electric oil pump, valves and sensors)



Modulation methods with random switching frequency strategies to optimize efficiency and NVH



The inverter converts the DC voltage (battery) into AC voltage or vice versa. In addition, the power electronics unit acts as the "reverse gear" of an electric vehicle. For driving in reverse, it reverses the polarity and thus the rotational direction of the electric motor. As a novelty, Schaeffler is now presenting a proprietary 800-volt power electronics unit for application in e-axles of high-powered vehicles. The scalable solution can handle permanent power outputs of up to 330 kW and shortterm peaks of up to 500 kW – in spite of small housing dimensions. The utilization of special semiconductors ("wide-bandgap silicon carbide technology") enables efficiencies of more than **99 percent** in defined load ranges. This increases the overall range of electric vehicles considerably. Moreover, due to the 800-volt voltage class, clearly higher charging speeds are achieved than in the previous widely used 400-volt voltage class.



#MOBILITY

"Whether for single components or complete systems, we, as Schaeffler, want to be the preferred technology partner of our customers"



Matthias Zink, CEO Automotive Technologies

Global manufacturing expertise

Schaeffler offers its customers decades of know-how from a one-stop shop and operates a globally interlinked manufacturing network. When establishing production facilities, Schaeffler benefits from the high-level expertise of in-house tooling and special-purpose machinery engineering. Close integration of research and development with prototyping and manufacturing ensures the required agility and efficiency of all processes. In 2018, Schaeffler decisively strengthened its capabilities in electric motor engineering by acquiring Elmotec Statomat, the leading manufacturer of mass-produced electric motors. Elmotec Statomat has unique expertise in winding technology and been a technology leader in the field of production machines for electric motors for more than 60 years. Especially rod wave winding technology is regarded as a leading technology in terms of power density, efficiency and efficient mass production going forward.



Integration of research, development and prototyping



In-house tooling and special-purpose machinery engineering



Unique expertise in winding technology



Globally interlinked manufacturing network

Keep it simple

Convenience – that's what the strategy is centered on with which Schaeffler's Automotive Aftermarket business division is striving to shape the future of independent parts retail in spite of growing complexities. The aim is to make life easier for garages and their customers.

By Jan Horst

The independent spare parts market is in a state of fundamental change. Digitalization and electric mobility are gaining ground. Repairs and service jobs increasingly require specialized know-how or even specialty tools. The pressure on independent garages to operate profitably and efficiently keeps growing. Schaeffler Automotive Aftermarket strives to support garages in this context. The objective is to make life easier for them and their customers. This strategy is centered on convenience targeting the following areas:

- **Customer Convenience** describes Schaeffler Automotive Aftermarket's claim of putting garages, and therefore their customers, at the heart of the division's activities by delivering real added value with its products and service offering. Joining forces with the data platform Caruso to promote free access to vehicle data is a case in point. Plus, together with other companies, Schaeffer Automotive Aftermarket has launched Repdat, an online appointment scheduling system, that can be integrated easily into the systems used by garages.
- Repair Convenience means always putting together the best possible offering for a repair job and thinking beyond a particular spare part, because in many cases replacing just the part that's obviously worn is no longer sufficient. Instead, the entire system has to be looked at, because parts that in the past would not have been the focus of an impending repair may be worn as well. That's why Schaeffler's repair

53%

of garages prefer **direct contact** with their suppliers, 19% prefer online channels and 10% using hotlines, according to the 2021 REPXPERT forward-focused survey of independent garages.



"Schaeffler is a globally leading development partner for original equipment and our Automotive Aftermarket division is a longstanding and reliable provider of impetus to independent spare parts retail and independent garages. If we didn't, who else should manage to provide the right answers to key questions pertaining to vehicle services of tomorrow?"

Jens Schüler, President GKAM, Global Sales & Marketing Schaeffler Automotive Aftermarket

sets and kits contain the spare part, plus all the required accessory parts, specialty tools, and information for professional removal and installation as required by the system concerned. This is a major benefit for garages, because they can satisfy their customers' needs with just one visit to their facilities, the so-called "Fixed First Visit." After all, garage customers expect their problems to be fixed by making just one appointment – with a lasting effect and without subsequent visits.

• **Commercial Convenience** stands for Schaeffler Automotive Aftermarket's claim of enhancing the commercial success of garages. The repair sets and kits play a crucial role in this context too: They generate more sales because they contain more parts – which is in the vehicle owners' best interest of receiving a system repair that precludes premature wear or even consequential damage.

At the same time, Schaeffler helps prevent the electric mobility business from bypassing independent garages, because the company, while developing its e-axles and hybrid modules for vehicle manufacturers around the world, keeps a close eye on independent parts retail. Whenever electric vehicles become relevant to the independent spare parts market, the Automotive Aftermarket division is ready to serve it with a portfolio of repair solutions and services aligned to support garages. Solutions that make it easy for the companies to benefit from the increasing prevalence of electric vehicles and to tap into this new segment themselves – for a secure and profitable future.

In **2020**

Schaeffler began working together with Auteon, a startup company operating a same-named comparison portal where garages can identify spare parts, compare their availability and the prices offered by their commercial partners, and place orders.

Independent garages under pressure

Do you think that increasing complexity of repairs will reduce your ability to fulfill your customers' requests?



Digital

Artificial intelligence, virtual realities, data economy, the Internet of Things – digital technologies are boosters of technological progress.

Swift and smart

Assembly robots used by automakers Ford, Toyota and Nissan that have **optimized their workflow by means of AI learning processes** work 15 percent faster. Although that may not sound like much, it's a huge efficiency gain in the world of mass production that battles for every cent of margin. The robots are watched at work by a computer while an artificial intelligence from startup Symbio Robotics permanently analyzes and optimizes their movements. Research scientists are already working on other ways in which AI can enhance the skills of robots such as independently detecting disruptive objects moving on belts and grabbing them. Situational adaptation skills not only enhance the performance of robots but make them more universally usable as well.

97.2%

of all European smartphone users communicate via the 4G network – holding the top spot in the global ranking. In Asia-Pacific 94.2 do and in the Americas (North and South) 88.7%. Africa, at 44.3%, is at the bottom of the list and, at 40%, 3G is even the front runner in rural areas.

Source: International Telecommunication Union 2020

"It's no longer the big beating the small, but the fast beating the slow"

Eric Pearson, CIO, International Hotel Group

What's happening on the internet in 60 seconds

Googling something on the fly, watching a movie, posting vacation pictures or sending an email – **the internet has become a highly efficient and indispensable data exchange and therefore a really busy place ...**



Digital reforestation

Droughts, heat and pests: The world's forests are in jeopardy. "Forest management has to respond now and weigh complex aspects in the process," says climate researcher Dr. Joachim Fallmann from the South-German Climate Office at the Karlsruhe Institute of Technology (KIT). Where to plant what tree species and when to cut it: The cloud-based EDE 4.0 system developed by experts from various departments at KIT is designed to assist forest managers in making optimal choices using an interdisciplinary database. However, for the system to deliver relevant results, it first has to recognize correlations and patterns. For this purpose, large data volumes from diverse areas such as data about mid-term climate development, specific silvicultural data,



and information about the market environment are blended. Not least, though, the assistance system considers local forestry expert knowledge. The objective is to create an app in which knowledge can be accessed conveniently and converted into sustainable choices.

Quantum leap in the web

The interconnectivity of quantum computers is supposed to create not only secure lines but, above all, accelerate the process of raising the processing power of the new computer generation to a level where it serves useful purposes in industrial settings.

By Denis Dilba

Twice, the international research community has by now demonstrated that quantum computers are able to solve specific computing tasks much faster than conventional supercomputers: In 2019, internet giant Google put forward its quantum processor Sycamore that's based on 53 cryogenic supraconductive qubits (see info box). In record time, the microchip that was cooled down to near-absolute zero of minus 273.135 °C on the centigrade scale (minus 459.67 °F) to ensure reliable operation determined the probability with which the coupled qubits produce specific exotic sequences of numbers in the readout.

A little more than a year after Sycamore, another computing record was set: At the end of 2020, the quantum processor prototype developed by a team of researchers led by Jian-Wei Pan at the University of Science and Technology of China solved a computing task for which a classic computer would need 2.5 billion years – thereby showing so-called quantum supremacy as well.

Independent observers feel that the research work about which quantum researcher Pan reported in "Science" magazine is convincing: Jian-Wei Pan, a former PhD student of Austrian quantum pioneer Anton Zeilinger, has long been regarded as a leading expert in experiments with light particles with which he also demonstrated quantum supremacy. Like IBM publicly challenged Google's results in 2019, Google expressed doubts about whether classic computers would really do so poorly in solving the Chinese team's computing task. The task was to predict the passage of photons in a highly complex labyrinth of beam

The power of the Q

Commonly used computers today work with bits that only assume two states, represented by the values 1 and 0. Processors translate the value commands into a current flow: with 1 current flows, with 0 it doesn't. Digital commands using light operate in a similar way, for instance when reading a CD, where 1 and 0 represent light on or off. By contrast, quantum computers work with quantum bits or qubits for short. They can process not only 0 and 1 but both simultaneously and, theoretically, an infinite number of states in between. That makes these computers so fast and secure.



A **qubit** can simultaneously be in the state of 0 **and** 1 and in an **infinite number** of states in between

splitters, mirrors and prisms. Pan's optical apparatus used 76 qubits – more than Google's 53 – and that may have been one of the reasons for Google's slight chagrin.

Physical limits for quantum computers

However, in spite of all the progress that's been made, both Google's Sycamore and Pan's quantum processor are still completely unsuitable for practical applications like calculating chemical structures in the fields of medicine and material science, route optimization for autonomous driving, or portfolio analyses. "To be able to compute truly useful tasks with a quantum processor I need somewhere in the neighborhood of a thousand or better yet several thousand qubits," says Simon Baier, a quantum physicist at the University of Innsbruck. "When you look at the cryostats of Google's or IBM's quantum computers and see how many countless cables are already running into them it becomes clear that at some point there's no more room for even more cables." In other words, Baier expects the implementation of a quantum computer to entail physical limits clearly before the level of a thousand qubits can be attained. This problem might be solved, though, by interlinking individual quantum processors in a quantum computing cluster.

Baier, who was doing research at the Dutch quantum research center QuTech in recent years, is working on a technology that is to enable this in the future: the so-called quantum internet. Together with former QuTech colleagues, the scientist described the fundamentals of such a network in a pioneering work published in "Science" magazine this April. In the laboratory, the team managed to connect three separate quantum processors in the world's first multi-node quantum network. In previous attempts, only two quantum devices were successfully interlinked. Diamonds with so-called nitrogen vacancies serve as a minimal version of the quantum memory required for such a network; the communication between them is handled by photons exchanged via fiber optic cables.

Quantum internet achievable in seven years

Even this first rudimentary quantum network is still far from practical implementation – which was not the objective of the work anyway. But it does demonstrate that such networks will be feasible in the future. The architecture the team selected is extensible, says Baier: "Basically speaking, we can add any number of nodes to the network, practically by means of copy-and-paste." So, the problem of the quantum internet's scalability has been solved. Even so, several years will more than likely pass before a usable technology is available. A lot of development work still has to be done to enable the transportation of information across long distances. "For the photons from the quantum memory to have the suitable wavelength, a conversion step between the memory and fiber optics is required," says Baier.

Another question yet to be answered is which protocol language a quantum internet should be based on. Baier expects this hurdle to still be overcome by the EU's ongoing flagship project that's funded with one billion euros, in other words within the next seven years. That's when quantum networks for secure communications for banks and government authorities will be possible, as well as the design of telescopes and atomic clocks with even higher precision than those existing today, and quantum computer networks with higher computing power. For the latter, though, the quantum internet is not an absolute requirement. Andreas Wallraff from ETH Zurich, for instance, is working on interlinking individual quantum processor cores to form a kind of cluster or local area network (LAN) by means of a permanent "quantum connection." At the beginning of 2020, the researcher's team established the so far longest microwave-based quantum connection in the world with a length of five meters (16 feet) at the Quantum Device Lab of ETH Zurich.

The old-school web is becoming QUICker

The Transmission Control Protocol, better known under its abbreviation TCP, is the engine of the internet: Together with the Hypertext Transfer Protocol (HTTP) TCP organizes internet page views. Since pages have become clearly more complex since the internet's early days, TCP that was developed back in the nineteen-seventies has a hard time loading pages. The new QUIC internet standard that was rolled out this May is supposed to change that. Unlike TCP, the new transmission protocol allows parallel data streams and additionally enables lost data packets to be delivered later. For the end user, this means that complex websites load clearly faster. At the same time, the developers have integrated an encryption in the QUIC standard that was originally designed by Google. Unsecured connections are excluded in QUIC by design. So, network operators, network researchers, and even law enforcement and intelligence agencies will soon have fewer things to watch.



There's a lot yet to be discovered: Quantum scientist Dr. Maika Takita at IBM's quantum lab

Faster computing in the quantum LAN

The ETH physicists were able to demonstrate not only that their quantum connection can be cooled adequately - it has to have the same cryogenic temperature as the quantum processing cores but also that quantum information can actually be transmitted with it reliably. "This does mark a milestone achievement for us," says Wallraff, "because with it we can show that quantum LANs are basically possible." Since, like Baier, he expects that the number of gubits of an individual guantum computer cannot be increased to any desired number, Wallraff estimates that quantum computers will depend on such quantum connections in the next 10 to 20 years. His team has already begun to work on longer ones: for the current 30-meter (98 feet) version, a dedicated room was prepared at ETH.

IBM wants to resolve the space issue for the qubits and the technology they require in the current cryostats in a different way: a super-fridge named "Goldeneye" is supposed to keep the quantum processors that will become increasingly complex in the future at the right temperature. The three meter-tall (10 ft) and two-meter-wide (6 ft) behemoth has been designed "with a million-qubit

system in mind – and has already begun feasibility tests," writes Jay Gambetta, IBM Fellow and Vice President IBM Quantum, in IBM's research blog. "Ultimately," the IBM man continues, "we envision a future where quantum interconnects link dilution refrigerators each holding a million qubits like the intranet links supercomputing processors, creating a massively parallel quantum computer capable of changing the world." The goal of a fault-tolerant quantum computer, Gambetta feels, is achievable within the coming decade.



The author

During his quantum network research science writer **Denis Dilba** learned that the implementation of this technology is even

more complex than he imagined – as well as that, amazingly, quantum researchers always find ways to work around the problems this entails.

Digital beats 20/20 vision

Why travel across the world when you can visualize the project by wearing a high-tech headset while working from home? Welcome to augmented reality (AR). Examples from the Schaeffler world show how this digital-visual technology makes processes more efficient and can even enhance quality.

By Volker Paulun

"Without using augmented reality, we couldn't have managed this project during the pandemic," Schaeffler quality expert Dr. Achim Donnermeyer is sure. He and his colleagues had to get two large-bearing test benches up and running for Schaeffler right in the middle of turbulent coronavirus times: one of them in China and the other one in Romania. The high-tech systems boasting the dimensions of a volleyball field had been custom-developed and built to meet Schaeffler's exacting specifications in one-off production by a specialized company in Israel.

Four countries (including Germany, where Donnermeyer and his colleagues are based), several thousand kilometers apart from each other, at a time when the coronavirus had brought travel to a standstill: "By using so-called HoloLens headsets, the AR system of our IT partner Microsoft, among other things, we managed to create on-site scenarios, so to speak. In this way, we were able not only to check the production of the machine in Israel in real time as needed, but also employed this technology during the entire acceptance process," explains Donnermeyer.

A workaround becomes an object lesson

Originally just meant to be a workaround, the solution proved to be truly beneficial during the course of the production process. "In problem-solving situations, we were able to respond not only faster but more precisely as well. Consequently, the list of adjustments that routinely emerge was shorter during the acceptance process than with similar projects in the past," says the Schaeffler expert. He provides an example to explain this kind of HoloLens use: "Let's assume a specific component is causing problems. It could be one in thousands of installed screws. Now, instead of laboriously describing which screw is meant

76.7 million

professional VR headsets are expected to be sold worldwide by 2024, ten times as many as in 2020. The market for virtual reality will grow by 30% per year by 2024 and, in the best case, by as much as 57% for augmented and mixed reality.

Forecast: Deloitte; source: marketing-boerse.de

exactly, we just mark the problem area on our monitor at home directly in the live image the colleague working on the machine at the site that's thousands of kilometers away has transmitted to us by HoloLens. Our marking is then displayed to him in real time as well so that he knows exactly where to take action. Such ad hoc solutions proved to be extremely efficient and helpful because we were able to make adjustments throughout the entire production process." The HoloLens again displayed these strengths when the test benches were set up in China and Romania. In spite of the Covid travel restrictions both systems were put into operation as scheduled. "Due to the HoloLens, I - alone - saved two weeks of on-site work and, obviously, that's a cost factor too," says Donnermeyer.

Deployed around the globe

Schaeffler has been using augmented reality in many different areas for many years. Now, practically every location is equipped with HoloLens systems. The Automotive Aftermarket unit, for instance, is planning to increasingly employ such virtual animations and interactive elements of HoloLens technology for explaining to garage customers around the world in easily understandable ways how to use repair kits and specialty tools.

In the form of the Schaeffler Virtual Fitter, the Industrial division offers its customers fast, efficient and – again – globally accessible installation support using augmented reality. If needed, Schaeffler will send an AR headset to the customer for this purpose. The customer's employee will wear this set while inspecting a machine, joined remotely by a Schaeffler technician via a secure data connection. The live transmission of photographs and videos provides Schaeffler's experts with a comprehensive picture of the machine's condition, enabling them to assist in the on-site work with their expertise. Due to the projection of images into their field of view, the people performing the work have both their hands free to do the job.

This remote mounting service is usually available faster than a local Schaeffler expert would be, who would have to travel to the site in person. Plus, this time advantage saves hard cash because travel and personnel expenses are reduced and, in many cases, the costs associated with machine downtime are lower too. "Compared to on-site service, our customers save up to 50 percent of costs by using the remote service. In addition, the expert instructions transfer know-how to the customer," says Reinhold Daft, Head of Mounting Services at Schaeffler.

Schaeffler Virtual Fitter: Due to the information recorded and transmitted via HoloLens, the Schaeffler expert is able to support on-site work by audio-visual instructions from his desk back home – in real time



Fully connected

While the rollout of the 5G network is in full swing scientists, corporations and countries are already working on its successor. The next generation of wireless communications, 6G, is supposed to deliver even higher data rates and shorter latencies, marking a new, more efficient dimension in the human-machine interaction.



By Björn Carstens

Day by day, billions of phone calls are made around the globe – but this particular one, on July 1, 1991 in the middle of the Finnish summer when Kaarina Suonio, the deputy mayor of Tampere, somewhere on a narrow neck between Lake Näsijärvi and Lake Pyhäjärvi, took the call by her prime minister, Harri Holkeri, went down in telecommunications history. It was the first-ever conversation using a commercial, fully digitized wireless telecommunications network that started a mobile communications revolution. All of us at one time or another have probably heard the network's uninspiring official name: Global System for Mobile Communications, or GSM for short. However, the GSM developers at that time were focused on telephone calls and less on wireless data transmission. Data rates of 9.6 Kbit/s make today's kids burst into laughter. Having to wait nearly twelve weeks for a favorite movie to be downloaded sounds like the digital stone age – and that's what it was from today's perspective.

But with each new mobile communications standard the transmission rate picked up speed. While WAP technology at the end of the nineteen-nineties was still deprived of making a major breakthrough – WAP facetiously stood for "Wait And Pay" back then – cellphone users, thanks to UMTS (3G), in 2004 started surfing the network with 384 Kbit/s – a speed with which some are still stuck today. With 4G, the first wireless broadband internet, data can theoretically be sent back and forth at up to 1,000 Mbit/s. With 5G, the latest standard, it can be done even ten times faster.

99.999999999% reliability

As a result, a host of all-new possibilities has been opening up for industrial production, for healthcare, in autonomous mobility, and in farming since 2019. In 2020, more than 20 billion machines or other devices worldwide were already connected to the network via the Internet of Things (IoT) – many of them by wireless communications. And now, while 5G is just being rolled out, the political, business and scientific communities are working on rolling out the next generation: 6G. In the coming decade, it's supposed to be available across the board.

Peak transmission rates of 1,000 gigabits and real-time communication are the goal. 50 to 100 times faster than 5G. Constant connectivity at terabit speed. With visionary reliability of 99.999999999 percent. That's the plan. Enabled by the utilization of higher frequencies from 100 to 300 gigahertz. For comparison: 5G uses frequencies from 22 to 60 gigahertz. So, is 5G obsolete before it has even been rolled out everywhere? "No," says Professor Wolfgang Kellerer from TU Munich, the project leader of the 6G Future Lab Bavaria. "5G plays a vital role for Industry 4.0 and the Internet of Things, facilitating a new dimension of intelligent communication between machines." However, he adds, "experience shows that it takes around ten years to develop a new wireless generation. To be ready for a big rollout in the early 2030s, those of us doing basic research want to work with the other key actors right





Automation and manufacturing

6G enables wireless applications where safety is imperative. This applies to **cobots** or **remotecontrolled cranes** as well as to various types of **production machinery.** Machines and logistics chains benefit from the fast data transmission.

Special solutions

High-resolution holograms displayed via smartphones, extended reality (XR), in which real and virtual worlds combine, and digital twins that monitor real-world vehicles or machinery without time-related or spatial delays will develop further with 6G.

Autonomous driving

6G enables precise determination of the position of self-driving cars and commercial vehicles and **distance measurements between the host vehicle and other vehicles,** persons or obstacles in real time, plus a 360-degree view thanks to a variety of sensors gathering an enormous wealth of data that have to be shared simultaneously.

Medicine

Thanks to 6G robots perform **surgical procedures** that are remote-controlled with millimeter-level accuracy by physicians. Using **high-resolution monitors** or **mixed-reality headsets** and with the help of 3D holograms, they can see exactly what's happening inside the patient's body. 6G is also supposed to enable **wearable mini sensors** that continuously monitor the vital signs of healthy persons and patients.



from the start to lay the groundwork for success." Because, says Kellerer, "6G will be human-focused." Human-focused, what does that mean?

Reliability more important than speed

According to Kellerer, it's about "a wide range of technologies integrated into our everyday lives that we interact with almost without thinking about it." Humans and machines on "an equal footing" so to speak, so high reliability of the network is paramount, says Kellerer, explaining its importance, for example, in the context of using assistance robots in household settings or high-resolution 3D maps in autonomous vehicles. Because, thanks to 6G, the data signals arrive at the target device at lightning speed, the feasibility of time-sensitive artificial intelligence applications in particular can be expected to improve.

The crucial aspect here is the network architecture, which researchers at the Karlsruhe Institute of Technology (KIT) are exploring as well. "To serve as many users as possible simultaneously while transmitting large data volumes as fast as possible, the wireless networks of the future have to consist of numerous small cells," explains Professor Christian Koos. This has the advantage that the data do not have to travel across long distances. "This enables the transmission of high data rates with minimal use of energy and low ambient electromagnetic emissions," says Koos. Hundreds of gigabits per second on one channel can be transmitted between the individual cells.

The network itself becomes a sensor

6G will be the first wireless communications generation where a whole host of sensors will be interconnected, for instance in robots, machines, household appliances and autonomous vehicles, or in cobots that can interact with human workers by means of sophisticated sensor technology. They've become firmly established in the world's factory halls. Going forward, shorter response times will enable even more flexible collaboration between humans and machines.

The network itself can become a sensor as well, because specific information can be gained based on the radio signals, for instance whether an object is located between the transmitter and the receiver – with even greater sensitivity than the way in which Google Maps already works today. This sensor information is then supposed to be analyzed with the help of artificial intelligence in order to continuously optimize the 6G network, in other words to make the required output available in the right place at the right time.

Schaeffler is establishing test beds

Schaeffler, as well, is preparing for the myriad opportunities for which the rollout of 5G (and the


"6G will be humanfocused"

Prof. Wolfgang Kellerer, Project leader of the 6G Future Lab Bavaria

prospects of 6G) creates the foundations. The company has already set up initial use cases in a test environment at its plant in Changwon, South Korea – an operation of self-driving robots, augmented reality and production facilities in an inhouse 5G network. "5G technology – especially Release 18 to be launched in 2023 – is showing us major benefits compared to the current Wi-Fi 6 standard. It enables us to control and localize driverless transportation systems in real time by using one device. This eliminates the need for sensors and the related integration effort, in other words it reduces costs and time," explains Christina Fischer from the Schaeffler Technology & Innovation Center in Herzogenaurach. But she cautions that the 5G Release 18 features that have been publicized would actually have to materialize. Fischer: "Only if they do will 5G be able to fully display its fortes, that is if latencies of 1 millisecond are possible in wireless data transmission. In that case, we'll be able to use wireless

transmission even for safety-critical and production-critical sensor data."

All in all, the rollout of 5G as well as of 6G is a herculean task on which not only Prof. Kellerer and his team are working, as numerous 6G research and development activities are being pursued around the world. China and Tesla's founder Elon Musk have sent the first 6G satellites into orbit for testing purposes. The German federal government is making 700 million euros available for 6G research until 2025. Scientists at TU Dresden are engaged in research work of the world's fastest microchips that will be needed for 6G. South Korea has invested in a huge project aimed at launching 6G in 2028. Let's see who will ultimately win the race in a hyper-connected world.

Future vision for Schaeffler plants in 2030

- Devices communicate on the Internet of Things with cloud-based artificial intelligence systems. Every machine becomes "smart" even without a dedicated high-performance computer.
- Industrial robots respond to their environment fast and reliably, plus fully autonomously (Advanced Robotics).
- With digital twins real-world manufacturing processes can be analyzed in real time by means of digital replicas.
- End-to-end communication with very low latencies across diverse networks is guaranteed.
- High energy efficiency of an adaptable, needs-based network enables sustainable manufacturing.



Think Green

Climate change is one of the great present-day – and future – challenges. New technologies help us make more efficient use of our resources.

Flying a kite

HEHARD MILL

This high-speed boat is said to achieve a speed of 150 km/h (93 mph) or 80 knots. **That would be a new world record.** The current record is 121 km/h (65 Kn) and supposed to be broken in 2022. By a race boat without engine power and emissions. Only a huge kite with a 20-meter (65-foot) span provides propulsion. The sailboat hanging on the other end of the ropes is seven meters (23 feet) in length, six meters (20 feet) in width and blends design elements of a catamaran, an airplane and a race car. The hull is an all-carbon construction pushing itself out of the water by means of foils and so escapes the water's resistance forces. The French Syroco team is reaching for the record with a similar kite sailboat as well. Let's see who's going to do a better job of controlling their kite ...

MILLL RICHARD **2**1280

DBels

CO₂ put to good use

Large-scale storage systems are a key technology in the context of switching to renewable energy sources. They're supposed to stash away energy when the sun and wind are working overtime and give it back in the form of electricity when the wind and sun are taking a break. The Italian company Energy Dome has now developed a technology that uses CO₂ as a storage medium. The gas is stored in a huge, flexible bubble. Turbines driven by surplus electricity compress the CO₂ into increasingly smaller volumes and liquefy it in the process. The heat generated during the compression stage is stored and used to evaporate the CO₂ again in the discharge stage. On its way back into the bubble, the gas - now expanding again – flows past the turbines once more that now generate electricity. The systems are scalable up to a storage capacity of 100 to 200 MWh. Their efficiency is said to be 75 percent. Energy Dome estimates the storage costs at 50 to 60 U.S. dollars, which would be clearly below the 132 to 245 U.S. dollars for comparable systems using lithium-ion batteries.



"Future is not a stroke of fate but the consequence of the decisions we are making today"

Franz Alt, German journalist

4

layers from a 3D printer form a **supercapacitor of biodegradable materials** that can be composted after use. Researchers at the Swiss EMPA Institute have developed it. Examples of applications are one-way sensors in transportation logistics or similar uses on the Internet of Things.

Aspirin for plant protection

Can aspirin help make plants more resistant against droughts, heat and pathogens? Tests in which cultivated plants such as tomatoes were treated with aspirin's basic substance acetylsalicylic acid have **already produced initial positive results.** Now, Australian researchers have applied a coating of a very low concentration of salicylic acid to the seeds of three different grass species. The outcome of the field test revealed that the seeds treated in this way showed **significantly higher survival and growth rates** than untreated ones. Aspirin for plant protection? That would make this medication come full circle because its basic substance is the syntheti form of salicylic acid that naturally occurs in willow trees and other plants.

Green is the color of hope

The objective of the "Great Green Wall" is more than ambitious: The planting of billions of trees and shrubs across Africa is designed to create a green world wonder – plus new prospects for the lives of millions of people. Now innovative ideas and technologies are intended to support the implementation of the project.

By Christel Trimborn

"50 percent of the population in the Sahel region are under 25. We need to give them hope," says Inna Modja, a young musician and activist from Mali. In a documentary about the project produced by Oscar-nominated movie director and producer Fernando Meirelles ("City of God," "The Constant Gardener") Modja travels thousands of miles along the planned restoration belt across Africa. It's intended to become the largest living structure on Earth, three times the size of Australia's Great Barrier Reef. On her journey, Modja meets people who are already working on growing the "Green Wall," for instance in Senegal: in the country from where she embarks on her journey more than 18 million trees have been planted since 2008, mostly indigenous species that cope well with arid conditions.

At the next stops Modja again meets people who with great dedication and obvious enthusiasm want to actively help make their region more livable. A region that has suffered severe damage due to a drought of biblical proportions in the nineteen-seventies and eighties and now is additionally threatened massively due to climate change. It's people like the young girls from the north of Nigeria who were abducted by the Islamist terrorist militia Boko Haram a few years ago and are now helping to grow the green wall from their orphanage.

Mammoth CO₂ storage

Due to the roughly 8,000-kilometer (5,000-mile) belt of trees and shrubs – extending from Dakar in the west to Djibouti in the east – 100 million hectares (250 million acres) of currently infertile land are supposed to be reforested. But that's not all. By establishing the Great Green Wall (GGW) the eleven participating countries, Senegal, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, Ethiopia, Eritrea, Djibouti, and other supporting nations also intend to create thousands of jobs and fight poverty. In addition, the finished green belt is supposed to store 350 million metric tons (386 million short tons) of CO_2 , which is nearly half of Germany's annual emissions.

Restoration projects such as the GGW that make rural areas fertile again are truly silver bullets in terms of sustainability and emerging around the globe. They cover no fewer than 15 of the UN's total 4%

is Africa's contribution to **global CO**₂ **emissions,** but the continent is hit particularly hard by climate change.

million hectares (30 million acres) of farmland are lost to desertification worldwide every year. That's more than Germany's entire farmland.

300 years That's how long it may take before

one centimeter (0.3 in) of **fertile** soil has been **formed again.**

of 17 sustainability goals, above all goal number one: the fight against poverty. Greater wealth helps avoid conflicts and creates reasons for young people to stay which, in turn, helps break the migration cycle. This context also shows clearly that the Great Green Wall is not a regional environmental project but one that concerns the entire world population. The mammoth green belt is supposed to create a total of 10 million jobs for the local rural population someday.

A stop-and-go project

Since it was launched nearly 15 years ago, the project has been called visionary, hopeful, ambitious and inspiring. A look at the facts and figures published in 2020 by the United Nations Convention to Combat Desertification (UNCCD) shows in which areas the greatest successes have occurred, as well as the stumbling blocks the project has encountered. The good news first: In Ethiopia alone, around 5.5 billion seedlings have been bred and



100 million hectares (247 million acres) of land are supposed to be turned into fertile soil and 10 million jobs created along the Great Green Wall

planted, one million hectares (2.5 million acres) of land cultivated, 220,000 jobs created, and more than 60,000 people trained as specialists in the areas of food, energy and biodiversity. In Eritrea, whose entire national territory – a third of the size of Germany – belongs to the GGW area, 130 million seedlings have been planted and 65,000 fields restored for farming. Niger on the other hand – besides having been successful in other areas – has been particularly active in curbing Sahara sprawl, having stabilized more than 80,000 hectares (200,000 acres) of dunes.

However, in view of the goals formulated in 2007, it's obvious that some of them are still a long way off. Only 15 percent of the GGW's overall goal has been achieved, according to the United Nations. The various reasons range from political instability to lack of money.

Financial support from around the world

For the latter problem, help is currently in sight. At the beginning of 2021, on the occasion of the One Planet Summit for Biodiversity, the GGW was promised an infusion of cash in the amount of 16 billion U.S. dollars (around 13.5 billion euros). This sum, at least, covers around 30 percent of the 31 to 37 billion U.S. dollars that the UN estimates are still needed to actually achieve the ambitious goals by 2030. Previously, four billion U.S. dollars (around 3.35 billion euros) had been promised during the UN's Paris Climate Conference in 2015. Aside from that, the project is financed, for instance, by support from the African Union (AU), the United Nations, the World Bank, the EU and, not least, individual countries, first and foremost France that is one of the initiative's official partners.

In terms of innovative ideas and their implementation, there's still ample room for improvement in the project, according to experts. Elvis Paul Tangem, the coordinator of the Great Green Wall initiative in the AU commission, agrees: "The future of the Great Green Wall will rely on the project's ability to innovate. It needs to move into new areas," he says. This includes not only encouraging communities to switch to renewable energies but also raising additional financial means from the private sector and by national investors.

To achieve this, two action-oriented innovation platforms, 1t.org and UpLink, joined the initiative: Their "Trillion Trees Challenge" launched in March 2021 aims to drive the activities for building the Green Wall. The idea is for 12 previously selected startups to be given an opportunity to present their ideas for resolving various GGW issues (see righthand page). The goal is to "source innovative solutions that help accelerate landscape restoration, help sustain livelihoods, foster food security, combat desertification and create economic opportunities in the region." An intensive exchange among the twelve participants is planned for learning and sharing: innovative help for self-help. This is also in line with a mantra that kept crossing Inna Modja's mind during her journey along the future Great Green Wall: "We will dare to invent the future."



The Author

The research for her article about the Great Green Wall has left a lasting impression on freelance journalist **Christel Trimborn,** especially with respect to the

optimism and active engagement of the large number of people persistently supporting the green lifeline across the African continent.

12 innovative growth accelerators

The Great Green Wall is thriving – but not equally well in all places. The "Trillion Trees Initiative" aims to drive the development with the following projects.

- Forested Foods wants to use forests in Ethiopia in sustainable yet lucrative ways. The agroforestry business is working across the entire supply chain, from cultivation to packaging.
- GasLowCost is enabling the population to generate energy from biogas instead of charcoal. The biogas is produced from slaughterhouse waste, household waste and compost.
- Green Aid One Billion Trees for Africa is restoring and growing native trees across the Sahel by using traditional technologies for integrated agroforestry practices, developing a non-timber forest products value chain, and creating rural land restoration-based jobs.
- Green AgroFarms from Tele Bere promote community-managed agroforestry and agroecology initiatives that serve as a catalyst for landscape restoration, income generation, and food and nutrition security for rural women and youth.
- Groupe de Réflexion et Développement Durable works closely with Mali's local population to take up sustainable forest management practices and to develop new value chains based on restoration and agroforestry.
- Labousitari in Niger is focused on protecting and restoring local tree species in the fight against desertification and to creating animal fodder value chains.

- Landscape Restoration for Ecosystem Recovery is dedicated to the sustainable management and restoration of wetlands and pasturelands coupled with sustainable agroforestry in Niger. In addition, the initiative empowers and supports Africa's most vulnerable indigenous peoples.
- ProNat, a women-led social enterprise in Niger, provides local and regional markets with a healthy and balanced diet based on hive products and natural oils.
- Sahara Sahel Foods processes and markets foods from indigenous wild perennial crops. This creates jobs for rural small-holder farmers, destigmatizes these foods, and brings them back into peoples' food habits.
- SeriousShea champions a novel value chain for shea butter. The innovative processing centers are supposed to be run on renewable energy, and logistics optimized within a sustainable forestry management model.
- SoilWatch applies remote sensing technology and machine learning to provide reliable and low-cost soil carbon measurements and to develop verified carbon offset projects for regenerable agricultural and pastoralism projects.
- **Typha Alimentation Animale** produces sustainable animal fodder from invasively spreading Typha, among other things.



Simply magnetic

Microplastics – the tiny problem of mammoth proportions in our oceans. Scientists around the world are engaged in research to come up with solutions and have achieved initial successes using a variety of efficient approaches: magnets, gels or plastics made of plant proteins tackle the problem at the source.

By Björn Carstens

Arguably, everyone has heard about microplastics by now: They're the microscopically small plastic particles to the surfaces of which toxic substances can be bound and ultimately enter the human body in that way. But plastic particles can be even smaller than that. Even less visible. Imagine a microplastic particle as a football and place it next to a pinhead. Nanoplastic particles are about 1,000 times smaller than their "big brothers," microplastics. That's hard to imagine and conventional purging methods (filtration, oxidation) don't stand a chance against them. But a game changer is just around the corner, says a German team of research scientists.

Magnets collect lumps of plastics

Scientists at Friedrich-Alexander University Erlangen-Nürnberg (FAU), a cooperation partner of the Schaeffler Group in nearby Herzogenaurach, have shown how plastic particles of various materials (polyethylene, polystyrene, polyvinylchloride, Teflon, etc.) and dimensions – including nano-sized ones – can be removed from water. The principle: Like a type of glue, non-toxic, specially coated iron oxide nanoparticles called SPIONs (superparamagnetic iron oxide nanoparticles) clump together with the plastics to form larger agglomerates that can subsequently be magnetically collected very easily due to the iron oxide content. The team headed by Professor Marcus Halik refers to this bonded material as "smart rust." A more efficient method is not currently known, according to Halik.

The scientists' plan is to use the SPIONS even before the plastics can pollute the oceans: in a container through which river water is conducted. It's equipped with a metering and mixing unit, a magnetic separator, and analytics. Optimally, the system would operate directly at a water treatment plant as the final purification stage before releasing the water "into the wild."

Alternative methods promise similar success

The principle developed by Fionn Ferreira, a student and winner of the 2019 Google Science Fair, works in similar ways. Ferreira extracted microplastics from water using a "magnetic liquid" invented



4,000 kg (8,800 lbs.)

That's the amount of plastic waste the solar-powered waste collection ship "Circular Explorer" of the One Earth – One Ocean environmental protection organization collects out of the ocean per day. The catamaran is initially intended to gather fishing nets drifting in the Baltic Sea. In 2022, the ship is planned to be deployed to Manila Bay (the Philippines) to take up the battle against plastic waste in one of the world's most heavily polluted waters.

12 billion

metric tons (13.2 billion short tons) of plastic waste will accumulate in the environment by 2050, according to scientists' predictions.

15 percent

of the waste drifting in the oceans is floating on the surface.

"Our innovation is the only one that can remove nano-sized plastic particles from water"

Professor Marcus Halik

by NASA. This so-called ferro fluid combines with microplastics in water. The method achieved an 87-percent success rate in 1,000 tests.

The German green-tech start-up Wasser 3.0 pursues a different strategy, where the contaminated water is mixed with non-toxic hybrid silica gels. Stirring causes the tiny particles to clump together, forming a popcorn-like entity that floats to the surface, where it can be skimmed off for further use. Initial research projects are said to have shown very good suitability as an insulation and construction material.

Biodegradable plastics

Substituting the plastics that survive in nature "for eternity" is another alternative idea. US scientists have developed a plastic material that becomes biodegradable and recyclable within the space of a few months. A team at Yale decomposed wood powder, a common waste product at lumber mills, using a solvent to create a slurry of organic polymers and cellulose that was then suitable for casting as a bioplastic. Research scientists at Cambridge, on the other hand, created a plastic material from plant proteins by adding nanoparticles. In this way, the structure of the substance can be controlled for creating flexible films – a material that looks like spider silk on the molecular level.

Albeit: "There's no major sense of suffering and pressure yet to massively combat the microplastics problem," Professor Halik is sorry to say, "because no limits have been established for microplastics in water." In view of the steadily growing volumes and the inestimable risks to humans if plastic particles enter the bloodstream this can be expected to change in the near future.

Clean energy galore

Wind power and hydropower, photovoltaics, geothermal energy – our planet offers huge potential for renewable energies. Here are five examples of plans for large-scale tapping of Earth's natural batteries.

Hydrogen from the grasslands



In the middle of the Western and Central Kazakhstan steppes (plenty of wind, hot summers, sunny winters), the German-Swedish company Svevind intends to establish one of the largest production plants for green hydrogen. The total capacity of the **wind and solar farms planned for this project is 45 gigawatts (GW), roughly equating to 45 coal-fired power stations.** The electrolyzers for hydrogen production are supposed to have a total capacity of 30 GW – enough for producing around **three million metric tons (3.3 million short tons) of hydrogen per year** that could either be exported to the European and Asian markets through pipelines or used locally to produce ammonia, steel or aluminum. In June, Svevind signed a letter of intent for the project with an investment promotion agency in Kazakhstan. If everything goes as planned, the entire facility will be up and running within eight to ten years.



the worldwide energy consumption could be covered by wind and solar power, according to the UK think tank Carbon Tracker. If we managed to use nature's power efficiently, says Carbon Tracker, it would be possible to **displace fossil fuels from the electricity sector by the mid-2030s and from energy supply as a whole by 2050.**



Green fuels from Australia

With a capacity of 50 GW, the Western Green Energy Hub (WGEH) in Western Australia is supposed to be even a bit larger than the huge Kazakhstan project. The objective here is to produce green hydrogen as well, particularly for processing into carbon-neutral fuels. The WGEH consortium, which includes Morning Traditional Lands Aboriginal Corp. representing the indigenous land owners, expects to produce **3.5 million metric tons (3.9 million short tons) of hydrogen per** **year.** The WGEH extending across a desert area of 15,000 square kilometers / 5,800 square miles (four times the size of Majorca) includes a **port so that the hydrogen could be exported by ship.** The Western Australian government still has to approve the project – the state recently refused to consent to a similar one. However, since the WGEH is partially located on the coast and said to take environmental aspects into greater consideration, the project owners expect approval.

Wind power export by cable

The wind blows most consistently on the ocean. Denmark now intends to carry offshore energy production to extremes by planning the construction of an artificial island to which 200 wind turbines with a total capacity of ten GW would be connected. Potentially, around 300 gigawatts of offshore capacity are supposed to be established in the North Sea, which equates to the power consumption of 860 million people. As a result, the European Union with a current population of 447 million would have enough energy to largely cover even industrial requirements. The electricity is supposed to be distributed by so-called high-voltage direct current (HVDC) cables. The currently longest sea cable in the world, the 516-kilometer (320-mile) "Nordlink," connects Germany with Norway. In October, an even longer line of 720 kilometers (450 miles) between Norway and the United Kingdom is supposed to be activated. It has a capacity of 1.4 GW. The Netherlands (via "NordNed") and Denmark (via the Skagerrak line) have connected themselves to Norway as well. The hydropower country is supposed to not only supply electric energy but become Europe's green-power battery as well. Whenever the North Sea wind farms produce surplus electricity, it's supposed to flow via the bidirectional HVDCs to Norwegian pumped storage power plants that can fill their water reservoirs with a current storage volume of 84 TWh. Potentially, this volume could be increased significantly because many of the roughly 1,250 Norwegian hydropower stations are currently still without a pumping function. They could be converted with a relatively minor investment because they have both an upper and a lower reservoir that's needed for pumped storage.



Norway is a pioneer in converting hydropower into electricity. The Vemork plant shown here was the world's largest power station when it was put into operation in 1911. Today, the building is a museum, its successor is buried in the ground underneath it



The Inga Dam is currently Africa's biggest hydropower station and would be the biggest in the world after the planned extension



Current from currents

With 4296.8 TWh, which corresponds to a share of 16.02 percent of the worldwide electricity production, hydropower in 2020 was **the third most important form of power generation**, trailing the conversion of coal and natural gas into electricity, and ranking ahead of nuclear power, according to the Statistical Review of World Energy 2021 published by the energy corporation BP. Forecasts for the coming decades assume that the currently installed capacity of hydropower stations of around 1,300 GW worldwide will increase to 1,700. At the moment, the hydroelectric record is held by the Three Gorges Dam in China that's also the biggest power plant in the world in general. With its 32 turbines, it produces 22.5 gigawatts and supplies some 100 million people with electricity. **The projected capacity of up to 44 GW of the Inga III dam on the Congo River,** where the production of green hydrogen is planned, would be nearly twice as much. However, just like the Three Gorges Dam, Inga III is a controversial project. It would require the resettlement of thousands of people and destroy the habitats of numerous animal and plant species. The decision of whether and how the project that's been discussed ever since the nineteen-nineties will be implemented is still pending.



The 10 biggest hydropower countries Source: Statistical Review of World Energy 2021

Methanol from geothermal energy

Regions in which geothermal energy boils the groundwater have particularly easy access to renewable energy. The world's biggest geothermal power station complex "The Geysers" is located about 110 kilometers (68 miles) north of San Francisco. 18 small turbine units with a capacity of 1.5 GW are spread across an area of 120 square kilometers (46 square miles). The energy they generate supplies the Californian counties of Sonoma, Mendocino and Lake with electricity by cable. The **world's biggest single geothermal power station is located in Iceland.** Its capacity is 303 MW. The volcanic island covers 90 percent of its warm water and heating water and 26 percent of its electric power consumption by the thermal water that

Iceland has so much thermal energy that even some streets in the country's capital, Reykjavík, spas like the "Blue Lagoon" and a bay for swimming can be heated with it



reaches temperatures of up to 500 °C (930 °F) making it number one in the world. In interaction with hydropower, Iceland produces a surplus of electricity. Because it has not been possible so far to export it due to the island's exposed location, energy-intensive industries such as silicon-metal and aluminum production have established operations there. Now the Icelandic energy corporation HS Orka is planning to use the geothermal energy of its island to produce hydrogen that together with CO₂ is supposed to be processed into green methanol. The plan is to establish a small 30-MW pilot plant to be followed in a second step by "much higher" capacity. Methanol aka methyl alcohol is easy to transport and suitable for versatile uses, for instance as an alternative to diesel fuel in ships. Iceland's know-how in the area of geothermal energy is an export hit as well because in all regions with tectonic shift such as California and Iceland the Earth's heat can be tapped profitably. Experts are focused particularly on countries such as Kenya (which already has eight geothermal power stations), Indonesia, the Philippines and Japan as well as European regions like the Rhone Valley in France. Its decentralized presence is another advantage of geothermal energy over conventional energy producers such as nuclear and coal-fired power plants. Therefore, geothermal energy makes sense particularly in developing nations without a country-wide grid, said Stefan Dietrich from the German Geothermal Association (BVG) in an interview with "Deutsche Welle."



The author

The large number and magnitude of the projects being planned to tap renewable energy sources that **Denis Dilba** came across during his research

for this article makes him hopeful that it will still be possible to put the brakes on global warming. However, the science writer also knows that "planned" is far from meaning "implemented."

All lights switched to green??

Electricity? Has to come from renewable sources. Manufacturing and materials? Must be as sustainable as the vehicle itself. Driving an electric car is eco-friendly only when the energy and supply chains are. Many gears have to mesh for all the lights to switch to green.

By Björn Carstens and Volker Paulun

Does only the type of drive determine whether or not a car is carbon-neutral? In other words, a vehicle with an IC engine is a polluter and an electric car merits distinction as a product of high environmental value? Right? Wrong? Or, as is often the case, is the truth somewhere in between? In fact, electric cars do not emit any pollutants on the road, but they do consume energy. And this means that in the current electricity mix in most countries, emissions are generated elsewhere, for instance at coal- or gas-fired power stations. The energy chain plays a key role in the environmental assessment of electric vehicles - not only on the road, but as early as in production, because that's where

the environmental footprint of e-cars is worse than that of cars with IC engines. What's more, the electric motor and the battery require special raw materials and their extraction causes environmental damage. On the inside of these fold-out pages, we'll take a look at energy and supply chains.



One goal, many factors

For CO_2 emissions to truly decrease significantly, a lot more has to happen than switching from IC engines to electric powertrains. Here are some facts and figures along the energy, supply and manufacturing chains.

> 3 rotor revolutions of a large-scale 10-MW wind turbine suffice to charge the battery of a mid-size electric car. The rotors of these behemoths have a diameter of 200 meters (650 feet) and more. For wind turbines, Schaeffler offers heavy-duty, frictionoptimized bearings with diameters of up to 3.2 meters (10.5 feet), condition monitoring systems and lubrication solutions. In that way, Schaeffler helps enhance the reliability, efficiency and economy of wind turbines.

Conventional power stations

be caused during charging processes if e-cars were preferably charged whenever a surplus of green electricity is being produced. However, this requires smart grids like those that Norway and Sweden have, for example. Source: Dominik Husarek, Siemens

less emissions could

66 g CO₂/km



Electricity mix

This is how electric power is produced in the world

Renewa

energies

Volvo has compared the **carbon footprints** of the gasoline-powered Volvo XC40 and its all-electric sibling across their entire lifecycles, incl. 200,000 km (125,000 miles) of distance traveled, and come up with some interesting figures.

What does a car consist of?

A mid-size plug-in-hybrid for example

- 50% steel/ferrous materials
- 13% light metals
- 19% polymer materials
- 6% other metals
- 5% service fluids 7% other materials

Source: Mercedes-Benz

8,500 passenger cars can be loaded onto the world's largest car carrier

vessels of Höegh Autoliners in Norway. The ships are equipped with fuel-saving technology that reduces the equivalent unit of CO₂ emissions per car by 50 percent compared to standard car carrier vessels. In 2021, Höegh deployed a vessel powered by biofuel that even cuts CO₂ emissions by 90 percent. The remaining 10% was offset by the shipping company. For 2040, Höegh is targeting "zero emissions."

Shipping

aw materials

17.000 l of fuel are consumed by an average car with a gasoline engine during its entire useful life. This equates to 12,500 kg (27,560 lbs) of mass to be moved. In an electric vehicle, this is contrasted by 160 kg (353 lbs) of metallic raw materials for the battery. Source: transportenvironment.org

1,605 kg

Car plant

Bans on sales of diesel and gasoline cars Plans by individual countries/regions

Norway Denmark, Ireland, Iceland, Israel, Japan, Netherlands, Sweden Scotland

Canada, GB, US States of California,

Egypt, France, Singapore, Spain, Sri Lanka 2025 2030

Source: theicct.org

more CO₂ is caused in the production process of an E-Volvo compared with the equivalent gasoline version. **The main reason is the battery.**

2035

47,000 even point, provided that only green electricity is used for charging.

2040

K be enough for reaching the CO_2 break

Transportation emissions

Grams of CO_2 equivalent per metric ton-km



Source: Fraunhofer ISI and CE Delft, 2020

Reservations against e-cars

Survey of persons 16 years and older in Germany



<mark>64%</mark>

of the energy used to propel an e-car is actually transferred to the road – **three times more than in the case of cars with IC engines,** which have an energy efficiency of 20%. Ranging in between are hydrogen cars (27%). Source: Schaeffler

Suppliers

Each of the lithium-ion battery cells consists of two electrodes, a separator and liquid electrolytes. The electrodes consist of graphite, lithium, nickel, manganese and cobalt. **Electrochemical batteries with comparable properties are not currently producible without these raw materials.** These quantities of the raw materials are installed in a 58 kwh-battery (385 kg/849 lbs) of a VW ID.3. Especially graphite, cobalt and lithium are deemed to be problematic.

59,9 kg (132 lbs)	Graphite
36,8 kg (81.1 lbs)	Nickel
24,3 kg (53.6 lbs)	Copper
15,9 kg (35 lbs)	Cobalt
15,7 kg (34.6 lbs) 7,4 kg (16.3 lbs)	Manganese Lithium

Schaeffler climate goal: CO_2 neutrality from 2030 on

Suppliers like Schaeffler make a significant contribution on the road toward climateneutral mobility. Not only with energyefficient products but with their CO₂-neutral production as well, which Schaeffler is aiming for by 2030, worldwide. To achieve this goal, the company has set its sights on its entire value chain, incl. raw materials, packaging and logistics, is increasingly focused on a circular economy and prepares life cycle assessments (LCAs). With LCAs, the environmental impact of individual products can be made transparent across their entire lifecycle and improvement actions derived. Achieving this goal continues to be a challenge. As of 2020, Schaeffler mastered 26 percent of the way toward climate-neutral production, among other things, by exclusively purchasing green electricity in Germany, Austria, the Slovak Republic, Mexico, Spain and the United Kingdom, with plans to do so at all locations from 2024 on.

84,000 km (52,200 miles) is the required CO_2 breakeven distance if the car is charged using the EU electricity mix.

146,000 km (90,000 miles) with the global electricity mix

Car travel needs to catch up

Unlike sectors such as manufacturing and construction, no CO₂ has been saved in automobile usage since 1990. The opposite is true: CO₂ emissions have gone up. Now the EU is taking countermeasures. **Stricter emission standards for passenger cars and light trucks** are supposed to accelerate the transition to zero-emissions mobility. From 2030 on, the average annual emissions of new vehicles have to be **55% lower and from 2035 on by 100% lower than in 2021.** In the final analysis, 60% of all new cars will have to be emission-free from 2030 on and 100% of them from 2035 on, according to the EU.

approx. **18%**

That's how much the electricity requirement in Europe would increase if **all 325 million existing passenger cars were electrified** and charged regularly. Source: in-house projection



cle utiliza

of the parts or materials of a car are **recycled** EU-wide. Source: Eurostat 2020

TON

Shredding instead of smelting

At the end of January 2021, the VW Group launched a pilot plant in Salzgitter for recycling high-voltage batteries from electric cars. Instead of the energy-intensive (more than 1,000 °C / 1,800 °F) and problematic smelting technology (the incineration of the electrolytes produces fluorine gases) VW uses a combination of shredding and subsequent chemical extraction of the recyclables. In a first stage, up to 1,500 metric tons (1,650 short tons) per year are supposed to be recycled. "Subsequently, the system will be scalable to larger quantities with further optimized processes," according to the Group. Recycling is focused particularly on elements such as lithium, nickel, cobalt, manganese and aluminum, but also on plastics. VW is targeting a recycling rate of 90%.

Recycling

10–12 years

is the potential **second life** of a discarded traction battery that will still have a storage capacity of 70–80%, for use in a forklift truck or as a storage device for a domestic solar system, for example. Source: ADAC

58 metric tons

(63 short tons) of CO₂ emissions are caused by the gasoline Volvo based on the lifecycle incl. production used in the comparison. The e-version causes 27 metric tons (30 short tons) in the best and 54 metric tons (60 short tons) in the worst case.



How Bob becomes an eco-builder

If our efforts to protect the climate are meant to be serious, we need to challenge conventional ideas and established methods. That goes for architectural projects as well, because buildings should reduce energy consumption and emissions not only in their operation and maintenance stage but as early as in their construction.

By Andreas Kühl

The construction and real estate sectors have a history of being focused on reducing energy consumption and emissions in the operation and maintenance stage of buildings – which continues to be important considering their top spot in the worldwide ranking of energy hogs (see diagram on next double-page spread). Yet looking at the energy input during the construction stage and the required materials is becoming increasingly important as well. For achieving a truly carbon-neutral footprint of buildings, it will even be necessary to look at their entire lifecycle – from raw material extraction to demolition and disposal of the construction materials used.

This energy input for the production, transportation, storage and disposal of the materials used is called "gray energy." The proportion of gray energy installed in a building may amount to a third of the total amount of energy and emissions during the operation and maintenance stage, depending on the materials and efficiency standard selected. According to the International Energy Agency (IEA), the construction sector on average accounts for five percent of the worldwide energy requirement and ten percent of the global CO_2 emissions. Disposal has to become a focus of attention too. In Germany, for instance, the construction sector causes 53 percent of the total waste generated nation-wide. Some of it is special waste that can be sorted and recycled only with a major effort (including energetic input).

These facts provide an impression of the construction sector's impact on resource consumption, CO_2 emissions and disposal. They show the urgent need of thinking about alternative construction materials with a better carbon footprint. Such innovative solutions are already on the market. The rediscovery of timber as a construction material is a case in point.

Use of renewable raw materials

Timber as a construction material has many advantages. It's renewable, stores CO₂ during the growth phase, and releases oxygen. Particularly important is the fact that wood as well as bamboo are regional construction materials in many countries. Today, timber is already in use for large-scale projects including high-rise buildings and can replace concrete or steel. In 2019 alone, three skyscrapers were completed worldwide with a timber content of at least 75 percent: the Dushan Shuisi Building in China (99.9 meters / 328 feet tall), the Norwegian Mjøsa Tower (85.4 meters / 280 feet) and the HoHo in Vienna (84 meters/276 feet). Others, including a 73-meter (240-foot) high-rise in Amsterdam, are either under construction or in planning. Even such large-scale architectural projects use cross-laminated timber (CLT). Due to the biaxial load transfer of CLT, timber buildings in which it's used can even be erected in earthquake-prone areas.

Generally speaking, timber, besides its carbon friendliness, has other benefits: Weighing less than steel and concrete, it's easier to deliver in prefabricated elements. As a poor thermal conductor by nature, it has good insulation properties as well (the same, by the way, applies in terms of acoustics). Plus, the demolition of timber buildings has a lesser environmental impact than that of conventional ones.



#CO₂EFFICIENCY

Timber is suitable not only for huts but also for high-rises, as the 85-meter (280-foot) tall Mjøsa Tower in Norway proves

Renewable raw materials such as wood fibers, sheep wool, flax, hemp and straw are also suitable for insulating buildings. Many of these materials were used for construction purposes centuries ago and are now experiencing a revival. But just like in the case of timber the question inevitably arises if such raw materials can grow back fast enough to cover the construction industry's enormous material demand. Or at least to such an extent that its climatic impact can be improved significantly by their utilization. At the moment, the worldwide timber market is depleted and prices have risen to new record highs. Even so, the current potential of worldwide wood harvesting can cover the lion's share of a timber-based transformation of construction, provided it's based on the current space requirement, according to a study by the Potsdam Institute for Climate Impact Research.



Timber is a light-weight material and superbly suited for modular construction, like here for the HoHo high-rise in Vienna



Greener building with greenery

Due to its façade greening, the indoor temperatures of this office building in Vienna can be kept cool enough even on hot days so that 45 air conditioning units were disposed of. Such façade greening reduces radiant summer heat by up to 80%. In winter, the heat radiated to the outside decreases by 20%. The constant extraction of CO_2 from the air and filtering of pollutants are further benefits of this insulation that's not green only in terms of its color. In addition, it makes for a more pleasant ambient micro-climate and absorbs sound.

Climate-positive construction materials

The facade of Audi's branch on Trudering in Munich consisting of hexagonal plastic elements is more than a sleek-looking shell - it's a CO₂ storage system, because its manufacturer, a company called Made of Air, extracted more CO₂ from the air than it generated in the material's production process. The basis of such carbon-negative materials is the thermochemical process of pyrolysis during which organic waste such as sawdust, grass, leaves and tree cuttings, as well as industrial waste, are split up under application of oxygen-free heat (400-700 °C / 750-1,300 °F). The process produces biocarbons that – for instance as a petroleum substitute – serve as the basis for a wide variety of materials also in the construction sector. Carbonauten, another company pioneering carbon-negative technology, is planning to use biocarbon – which offers non-combustibility and very light weight as two further advantages – as a base material for concrete, asphalt, brickwork, wall structures, frame profiles, floor, wall and ceiling panels, and even for thermosolar roofs and façades. Every metric ton of biocarbon stores 3.3 metric tons (3.6 short tons) of a CO₂ equivalent, according to the "carbonauts." Plus, the company says that this is not the only sustainability advantage of biocarbon. Both suppliers emphasize that



Share of building construction in worldwide energy consumption and CO₂ emissions

Source: Global Status Report for Buildings and Construction 2020





Biocarbon granulate stores three times more CO₂ equivalent than it weighs and can be used in many types of construction materials – like in the elements of the façade of this car dealership

their manufacturing process produces more energy than it consumes. This surplus can be converted into district heat or green electricity.

Cement-free concrete

Cement production is the "bad carbon dioxide apple" of the construction sector. It alone is supposed to be responsible for seven to eight percent of worldwide CO_2 emissions. During the production of one metric ton (1.1 short tons) of cement around 600 kilograms (1,320 lbs) of CO_2 are released into the atmosphere. But there are some promising innovations in this area as well.

They include "CarbiCrete," another carbon-negative and cement-free construction material from the same-named Canadian startup company that uses ground steel slag to replace cement as a binding agent. The fresh concrete injected with it is cast into molds for hollow concrete masonry units (hollow CMUs) and cured in a carbon dioxide atmosphere that binds more CO₂ than the amount released during the entire production process. Another advantage is that the setting time of the CMUs is reduced from 28 days to 24 hours. The technology is still being tested. However, a rollout to the field might be hampered by the price of the special furnace for the CMUs that's supposed to amount to the equivalent of around two million euros, according to "Deutsche Bauzeitung."

Scientists from the Institute of Industrial Science at the University of Tokyo have developed a method for producing cement-free concrete using alcohol as a binding agent. To obtain a viable end product, the researchers dedicated several years to systematically investigating and determining the right mixing ratio of sand, alcohol, a catalyst and a dehydration agent as well as the suitable heating temperatures and reaction times. Another advantage of this technology is its suitability for the use of desert sand, which is too round for conventional methods.

Dr. Gnanli Landrou, a professor in the department of Sustainable Construction at ETH Zurich, has developed a chemical mixture called Oxacrete. It liquefies mud that can subsequently replace cement as a binding agent for concrete. Since mud is excavated at most construction sites anyway, this technology is supposed to improve not only the carbon footprint but save up to 20 percent of construction costs, according to Landrou – to the delight of builders, contractors and the environment alike.



The author

As a writer with an engineering degree in building physics, **Andreas Kühl** has been dealing with energy-efficient construction, renewable

energies, sustainability and digitalization in the energynet.de blog and freelances for companies and publications in these sectors.

With the wind against the wind

Sailing faster than the wind is no problem. But against the wind? Not even the most modern yacht in the world can manage that. But on the road, it's possible. Teams from all over the world prove that it is, in their self-built headwind vehicles competing in the annual Racing Aeolus event in the Netherlands.

By Daniel Hautmann

A hand just barely fits between the asphalt and the race car. The gap shows that this is all about aerodynamics. And weight. The racer that's largely made of carbon fiber tips the scales at a mere 171.7 kilograms (379 lbs). Its four wheels are as thin as those of a road bike, but its most conspicuous characteristics are the two rotors above the cockpit. The rotor blades are the race car's engine – and the wind is its fuel.

Welcome to Racing Aeolus, a unique kind of race. It doesn't feature a field of roaring twelve-cylinders but so-called headwind vehicles aka wind cars. Essentially, they're wind turbines on wheels. The race is held at Den Helder in the Netherlands. The race track is an asphalted dyke, 500 meters (0.31 mi) in length. A little more than a dozen university teams from all over the world compete in the event. The objective of the race is to drive faster than the wind. That's why it's difficult to state the actual speeds driven - they decisively depend on the prevailing wind speed. In good conditions, it's 40 km/h (25 mph). The race is unique because the cars drive directly into the wind instead of being propelled by tailwind. Amazingly, the faster the vehicle moves, the stronger the apparent wind blows, in other words the sum of the actual wind force and the airflow aboard the vehicle – which increases the propulsive force.

Efficiency leads to victory

Michael Liebl explains how driving against the wind works: "The aggregate of all frictional forces – from the rotor blades to the gearbox to the wheels – must be less than the propulsive force gained from the wind." Liebl is one of the three team principals of the InVentus race team from the University of Stuttgart supported by Schaeffler, where the "Ventomobil" was developed and built.

The idea of being able to driver faster than the wind was purely theoretical for a long time. It wasn't until 2016 that the Danish team DTU proved that it's possible by reaching 101.76 percent of the wind speed prevailing at the time with their vehicle. In 2017, the Canadians from the Chinook ETS team took the lead by achieving 102.45 percent. In 2019, the same team even recorded 113.97 percent – a world record!

The blades of the Ventomobil spin at a rate of up to 1,500 revolutions per minute. "We don't even need half of the acceleration distance to achieve

PPropulsion V13

Shaft for

rotor unit

VVehicle

énergy ¹¹¹¹

Wind

THE REAL PROPERTY OF

113.97%

faster than the wind that served as the only source of propulsion

energy was the speed at which the world record holder drove in the 2019 Aeolus Race – not with tailwind but straight into the wind. The record set by the Canadian Chinook ETS team means that at a wind speed of 40 km/h (25 mph) the highly efficient vehicle (pictured) would achieve 45.588 km/h (28.327 mph).

Rear axle

our target speed," says Liebl. In addition to the percentage-wise speed in relation to the wind, acceleration and innovation are rated in the competition.

Ingenuity and creativity are essential

The commitment of the Stuttgart squad began in 2007 when two students started constructing the first Ventomobil. It was their final project for earning their degrees. The vehicle consisted of a carbon fiber chassis and a rotor that propelled the wheels directly. The effort paid off: in 2008, they won the Boysen Award for the best thesis in the field of environmental engineering. "A project such as InVentus poses a challenge to the budding engineers because knowledge of theory as well as ingenuity and creativity are essential there. You don't learn these skills for your future profession in the lecture hall but in the field," says Professor Po Wen Cheng, PhD, Head of Wind Energy Institute of Aircraft Design at the University of Stuttgart.

Over the years, the Stuttgart-based team developed three different vehicles. The latest generation is a hybrid with two rotors trapping the wind. One of them supplies its torque directly to the rear wheels while the other one drives a generator powering two electric motors on the front axle. With this design, the team exploited the maximum permitted rotor area of four square meters (43 sq.ft), with the maximum rotor diameter being limited to two meters (6.6 feet). Although the hybrid approach entails conversion losses it facilitates the transmission of power from the two rotors. Instead of complex shafts and gearboxes the electrical part of the drive train just requires a cable.

Even so, the team did not claim victory in their last race participation in 2018. "Our purpose-developed power electronics unit was finished just shortly before the race, so we were able to test it only for functionality but not for efficiency," says the then team principal Julian Fial. That's why the squad from Stuttgart raced only with the mechanical drive unit and achieved just 95.6 percent of the wind speed. However, due to having won the innovation award for their hybrid drive, they finished in second place overall anyhow.

VJ=VWind+VVehicle



The InVentus team from the University of Stuttgart supported by Schaeffler deploys the "Ventomobil" to the headwind races. The most recent generation has a second rotor at the front that supplies current to two small electric motors on the front axle "The idea behind Racing Aeolus is to design and build cars, i.e., wind powered vehicles that generate energy while driving against the wind and competing with teams from all over the world. It is a real challenge for the student teams. It requires steadfastness, co-operation, perseverance and fearlessness. They learn how to handle renewable energy. Some of them are really motivated and manage to find a job in this field"

Hans Verhoef, Chairman of Racing Aeolus

Due to the Covid-19 pandemic, there were no races held in 2020 and 2021. "The team, though, did not spin its wheels but used the time to design a number of innovations and improvements some of which still need to be integrated into the vehicle," says co-team principal Liebl. They include a new rotor hub with torque measurement, a new rotor with a triple-blade geometry, a new drive train including new bearings from the team's sponsor Schaeffler, and the new aerodynamic cover of the entire rear end of the vehicle based on a wound flax fiber structure.

Michael Liebl and his teammates are optimistic about the next race: "That's when we're going to show the capabilities of our hybrid drive."







The author

Free-lance science journalist **Daniel Hautmann** has dedicated an entire book to the wind: "Windkraft neu gedacht – erstaunliche Beispiele für die

Nutzung einer unerschöpflichen Ressource" ("Wind power reimagined – amazing examples of the utilization of an infinite resource") is not only about wind turbine systems that generate electric power but presents many other ideas that show how humans can harness the power of the wind for their benefit – without polluting the atmosphere with gases that harm the climate.



Lightweight design and aerodynamic fine-tuning enhance the efficiency of the "Ventomobil" just like in modern cars

Engineering

Mechanical systems, electronics and digitalization are forming more and more synergies in an increasingly automated world.

Rolling through the ages

It's still unclear who invented it and how it evolved. Even so, it's **one of the world's most important inventions** and has been making the everyday lives of humans easier for nearly 6,000 years: the wheel. With its help, the efficiency of hauling goods and construction materials as well as people was enhanced significantly. Rotating potter's wheels are regarded as a possible source of inspiration. For a long time, pictorials created in Mesopotamia around 3500 BC were regarded as the oldest proof of the utilization of wheeled vehicles. More recent discoveries, though, show that chariots were used in many places in Central Europe such as Schleswig-Holstein in Germany and Southern Poland at the same time. Since its beginnings, the wheel has evolved from a stone disc to spoked wooden wheels to low rolling resistance tires of electric cars. However, not all wheeled vehicles – such as the monobike pictured here – gained traction.

#ENGINEERING



The products that can be made by means of 3D printing are becoming increasingly complex. In Amsterdam, the **first pedestrian bridge produced by additive manufacturing technology** has recently been opened. The bridge weighing 4.9 metric tons (5.4 short tons) and measuring twelve meters (39 feet) in length was designed by Imperial College London and produced by the Dutch company MX3D. The printing process took six months. Safety is ensured by sensors monitoring the bridge's stability in real time.



"Pragmatism is not the opposite of perfectionism but the pathway to achieving it"

BioNTech co-founder Uğur Şahin



times Schaeffler was recognized for **top quality** by its customers in 2020 – more often than ever before: a great success for the company because in addition to innovation, manufacturing excellence and strong system knowledge it defines itself by its exacting quality standards. Microrobot

0.8 mm (0.03 in)

3011112211

That's the size of the **world's smallest robots.** Professor Oliver G. Schmidt, PhD and his team at TU Chemnitz spent ten years just on refining the chemical twin "jet engine" of the remote-controlled units the size of a grain of salt that float in liquids. Other features include **a light source and a small gripper**, both of which are supplied with energy using wireless technology. Biosensors and micro-surgery directly in the body are potential uses.



Modern painting

Individuality, speed and sustainability – these factors don't have to be mutually exclusively in industrial automotive painting. PixelPaint technology from ABB is said to be 50 percent faster than conventional twotone painting because it eliminates the need for time-consuming masking and demasking. In addition, the precision of the process reduces paint consumption significantly. The secret behind this is non-overspray technology, which prints the paint directly onto the target area using an inkjet nozzle instead of spraying it with a gun.



Less is more

The operation of machines generates friction, which entails friction losses at the expense of material and efficiency. Experts attribute approximately a fourth of the worldwide energy requirement to these losses: reason enough for delving deeper into this subject that's anything but superficial.

By Volker Paulun & Alexander von Wegner

Humans recognized the phenomenon of friction including its side effects early on – and learned how to put it to use. For instance, to generate heat for starting a fire. Often, though, friction proved to be a hindrance, so the desire to minimize it became the mother of invention even in the days of our ancient forebears: To reduce the physical exertion involved in pulling heavy loads, early tinkerers as far back as in the Neolithic Age 5000 BC came up with rolling logs and using sleds as precursors to the wheel and axle combination. The first machines that generated friction were bow drills and potter's wheels. Pre-Christian finds prove that lubricants were used to minimize friction as far back as in Ancient Egypt and China.

In the Late Middle Ages, the precision of observations relating to friction clearly increased. In the 15th century, Leonardo da Vinci gathered initial scientific findings about static friction, in other words the force that keeps two contacting objects from sliding against each other. For his observations, the universal genius measured the angles of various inclined planes on which solid objects began to slide. In addition, he determined the force that's needed to cause an object to slide on a horizontal plane: dynamic friction. To minimize the force that needs to be exerted, da Vinci placed balls between two plates and so came to be regarded as the inventor of the ball bearing, which he went on to optimize with a cage guide.

Scientists subsequently described various physical laws around friction. Sir Isaac Newton (1643-1727), for instance, investigated the adhesive force that's generated by molecular interactions of the interfacial layer of surfaces. This adhesive force causes a protective film to stick to the display of a cellphone, for example. The Swiss Leonhard Euler (1707-1783) with the coefficient of friction µ defined a key characteristic that describes the ratio between frictional force and contact force. During the same era as well, Charles Augustin de Coulomb described the frictional resistance of rolling wheels in proportion to the load and inversely proportional to the radius: The higher the load the higher the frictional resistance and the larger the wheel the lower the friction. In addition, he elaborated the differences between static (excitation of the sliding action) and dynamic (preservation of the sliding action) friction. In this context, Coulomb observed that in the case of sliding the frictional force is nearly independent of the relative speed of the friction pairing, unlike, for example, in the case of air resistance.

Friction as a science in its own right

Even though the research of friction began more than 500 years ago, the scientific term for it, tribology, wasn't coined until the nineteen-sixties. Tribology derives from "tribein," an Old Greek word for rubbing and wearing. The term tribological system describes the interaction of surfaces in relative motion to each other, which serves to perform specific technical functions. That sounds complicated – and is, in fact, a highly complex subject. "As the study of friction, lubrication and wear, tribology is a cross-sectional technology of macroeconomic importance. It enables energy efficiency and sparing use of resources by reducing friction and wear," says Prof. Dr.-Ing. Tim Hosenfeldt, Senior Vice President, Corporate Research and Innovation & Central Technology at Schaeffler and Honorary Professor of Surface Technology and Tribology at University of Erlangen-Nuremberg.

Engineers today distinguish between the following terms for friction, depending on the state of contact: solid friction, boundary friction, mixed friction, fluid friction and gas friction. In this context, scientists not only look at the tribological





Even long before the birth of Christ rolling logs were used to reduce friction, like the Egyptians did for building pyramids as shown here. Universal genius Leonardo da Vinci is regarded as the inventor of the ball bearing. Depicted here is a replica based on original drawings (above right)



This picture from a microscope proves the scratches that AM-III inflicted on the surface of a diamond



Vickers hardness (HV) is achieved by a carbon-based glass recently developed by researchers at Yanshan University in China. The material called AM-III is 30 times harder than stainless steel and can even scratch diamonds (10,000 HV). In addition, AM-III is semi-conductive and therefore suitable as a viable silicon alternative in the field of photovoltaics.

objects rubbing against each other, namely the base body and the mating body, but also investigate the elements acting between the surfaces such as lubricants, particles and even air. The ambient medium, be it liquid or gaseous, is decisive as well. The ambient air, for instance, produces chemical effects that promote lubricant aging. To be considered as well are aspects such as viscosity and aging of a lubricant that evaporates under excessive loads. Furthermore, service parameters affect tribological behavior: the type of motion, load, speed, temperature and duration of friction. Plus, there are some other factors. Scientists investigate tribological phenomena on macro-, micro- and even on nano-scale levels.

Enormous efficiency potential

What purpose does all this research ambition serve? Even in a single component assembly – for instance in a passenger car, a commercial vehicle or a train – significant friction losses can be measured. That raises the question of how massive the total effect of all friction losses must be, considering that such products are used day in day out in hundreds of millions or even billions of units worldwide. A scientific engineering study calculated these effects in 2017. The figures are impressive: Tribological contacts account for 23 percent of the world energy consumption of which 20 percent serves to overcome friction and 3 percent to recondition components and spare parts that are worn in the process. In terms of absolute numbers, this 23 percent corresponds to 119 exajoules (EJ). That's 33,055 billion kilowatt hours (kWh), in other words nearly ten times the primary energy consumption of Germany.

"There is a clear trend toward customdeveloped multifunctional and sensorial coatings"

Tribology expert Prof. Dr.-Ing. Tim Hosenfeldt, Senior Vice President, Corporate Research and Innovation & Central Technology at Schaeffler

This incredible amount of energy requires high capital expenditures, is produced in complex ways, has adverse effects on the environment and climate - and is ultimately lost to friction. And the smallest part of that is intentional, for instance due to applying the brakes. Kenneth Holmberg and Ali Erdemir, the academic authors of the aforementioned study, performed further calculations showing that friction and wear could be reduced in the long term by up to 40 percent by means of new surfaces, materials and lubrication solutions, which roughly equates to potentially improving the global primary energy requirement by 8.7 percent. The transportation sector accounts for a fourth of these savings and energy production for a fifth, according to the study. Both of these are areas in which Schaeffler is intensively involved with its Automotive and Industrial divisions. The following figures are impressive as well: With forward-thinking tribological technologies, the study found, 3,140 metric megatons (3,460 short megatons) of CO₂ and and 970 billion euros could be saved in the long term, according to Holmberg and Erdemir.

"Surface technology is a key enabling technology"

Not least in view of these figures, Schaeffler, as a global automotive and industrial supplier, intends to use its tribological know-how to minimize friction with the objective of enhancing efficiency as well as increasing the service life of products through wear protection and corrosion protection. As early as in 2007, the Group opened its "Surface Technology" competence center at its headquarters in Herzogenaurach and has successively been extending the development capacities at the site. The researchers and developers there are highly motivated, telling us that surface technology is no less than one of the key enabling technologies in industrial countries. That assumption certainly sounds plausible if for no other reason than the aforementioned figures.

Due to its expertise in coating technologies and in the fundamentals of tribology and nanotechnology, Schaeffler has acquired a position of worldwide leadership in functional surfaces and coatings. This field has long ceased to be strictly about optimizing the surfaces of heavy-duty rolling bearings, for instance in wind turbines or aircraft engines, with innovative coating technologies. In fact, coatings from Schaeffler have already made it into automotive powertrains, for instance in the engine's valve train. And the performance of bipolar plates in fuel cells and electrolyzers for the utilization and production of green hydrogen applications is raised to new levels by the tribological know-how of the automotive and industrial supplier as well. Many other fields of application are emerging and will be addressed later.

Diversity is an advantage: Schaeffler has developed a Coating Toolbox enabling the company to offer its customers tailored solutions. The toolbox covers these five main requirements: corrosion protection, wear protection, friction reduction, current insulation and sensors, as well as any intersections between them. "These surface modifications have to be designed for the relevant application and should be considered as early as in the system's design phase. Consequently, the coating should by all means be seen as a valuable



Up to 80 percent less dry friction compared to steel: Triondur-coated barrel rollers in a spherical roller bearing from Schaeffler

key areas of tribological research and development in the field of thin-film technology

- Innovative coating methods and processes
- Tribological and corrosionprotection coatings for mobility and energy
- Coatings for sensorial and bionic applications
- Coatings for optical and electronic applications
- Coatings for energy storage devices and converters

design element that is necessary for achieving the best possible success," says Professor Tim Hosenfeldt, who is in charge of the competence center.

One of Schaeffler's fortes is the transformation of complex niche applications into mass production with corresponding requirements such as first-rate reproducibility to meet exacting quality standards and, of course, in consideration of strict cost requirements. The extremely thin application of the heavy-duty layers is an art in itself, considering that we're talking about ultra-fine layer thicknesses, often in the nano range. All the more astonishing is their robustness: Schaeffler offers so-called Triondur coatings that easily withstand heat of up to 600 degrees centigrade. In terms of hardness, peak values of more than 4,000 Vickers hardness (HV) are currently achieved. For comparison: standard bearing steel peaks at 700 HV and diamonds as the hardest natural mineral reach 10,000 HV.

The future: plasma coatings and multifunctional surfaces

In addition to electrochemical techniques (galvanic), painting and thermal spraying, plasma-assisted


chemical vapor deposition (PACVD) and physical vapor deposition (PVD) are playing increasingly important roles also at Schaeffler, especially with multifunctional thin-film coatings. The plasma surface technology is truly a multi-talent with a performance range far exceeding the areas of friction reduction and wear protection. This technology, for instance, can be used to clean and activate surfaces for enhanced adhesion of paints and adhesives or for icing prevention. Furthermore, it enables the provision of surfaces with additional optical, electrical or chemical functions.

"There is a clear trend toward using precise layer systems as design elements with multifunctional and mechatronic properties," says Prof. Tim Hosenfeldt. Here's another number that underscores the importance and diversity of tribological plasma technology: plasma is utilized in 14 of the 17 "Future Fields" identified by the German Federal Ministry of Education and Research, ranging from the hydrogen economy to medicine to biotechnology.

That's because PVD and PACVD have a crucial advantage: The technologies are suitable not only for use with metals but with most polymers and even with many organic substances as well. Highly effective membranes or individual fibers can be treated with plasma technology too, for instance to produce specialty yarns. Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, for instance, has developed a plasma-polymeric coating for sealing elements made of rubber. The coating reduces friction and wear of such seals that serve to prevent lubricant oil leakage. Schaeffler was involved as a partner in this project called "Poseidon." In tests on a model test bench, the scientists were able to reduce friction by 23 to 55 percent - depending on the oil used and its additives. With fully additive-enhanced production lubricants in wheel bearings, the coefficient of friction in laboratory tests was reduced even by up to 71 percent.

Coatings with sensory properties enable experts to determine and analyze the in-service wear behavior of components to improve products or better yet: to directly and proactively intervene to prevent wear. In addition, such data make it possible to calculate residual service life precisely, thereby optimizing lifecycles and maintenance



99%

of the universe is plasma. The Sun, like all stars, consists of plasma, as do natural phenomena such as polar lights and thunderbolts. **Plasma is one of the four fundamental states of matter besides solids, liquids and gases.** The addition of a sufficient amount of energy to gas results in a mixture of particles consisting of ions, free electrons, and typically neutral atoms or molecules as well, which is called plasma. Unlike gases, ionized plasma is conductive.

intervals, which saves resources. At the same time, unplanned downtimes can be minimized. Ideally, surfaces regenerate their friction-induced substance loss automatically and tribologists are already working on such wear- and friction-reducing "healing processes" as well. So, the subjects of surfaces and friction will continue to inspire our ingenuity – just like they did with our forebears thousands of years ago.

Steel with a shade of green

It defines large parts of our everyday lives: Cars, buildings, wind turbines, bridges – none of these would be conceivable without steel. Every year, some two billion metric tons (2.2 billion short tons) of it are processed, so the carbon footprint of this sector is correspondingly large. Steel production is responsible for eight to ten percent of worldwide carbon dioxide emissions, so it's time to make some changes: with green hydrogen and new technology approaches.

By Oliver Jesgulke

The history of steel is not completely clear and varies depending on the source. Frequently mentioned is the Middle Eastern tribe of the Chalybes that invented wrought iron as a precursor to steel around 1800 BC and used it to make weapons. Around 500 BC, the Chinese developed headhigh blast furnaces in which they produced cast iron. In both methods, iron ore as the raw material was infused with carbon by mixing it with charcoal. The reducing agent extracts oxygen from the iron ore, thereby producing pig iron - the stage preceding steel, which Indian blacksmiths are assumed to have invented around 400 BC. In addition to adding charcoal, they mixed the iron ore with a few other suitable ingredients (glass shards and green leaves, among other things, according to literary references) and smelted it in crucibles. The resulting alloy called wootz with a carbon content of 1.5 percent is regarded as the first steel and became an export hit. In Damascus, Syrian blacksmiths refined the alloy from the east to create the famous Damascus steel swords. Equally feared were the melee weapons from Toledo, Spain, that were forged from Indian wootz. With them, the Romans conquered an empire.

Nearly 2,000 years passed until steel production took its next decisive step. In 18th century England, "ironmen" used baked coal instead of charcoal and heated their iron mix not in crucibles but in smelting furnaces. The steel quality of the resulting blocks was a quantum leap. Even so, there was still room for improvement. Especially the plants that heated iron to make steel in their redhot furnaces became increasingly efficient. In the 19th century, steel became a mass product. Currently, more than 2,500 standardized grades of steel are available worldwide, all of them produced predominantly from pig iron in blast furnaces by blowing in coal dust. For every ton of steel, nearly half a ton is needed as a reducing agent. That's a fraction of what was required a few hundred years ago, but still too much because two tons of CO₂ are emitted per ton of steel. Even the steel corporations have realized that this technology is not sustainable going forward and are thinking about departing from the archaic "blast furnace route" as it's referred to in technical jargon. Their ambitious goal is to replace carbon by hydrogen to produce green steel. After all, climate protection makes exacting demands on the industry and in the end the quality of the product is the same. By 2050, CO₂ emissions are to decrease by 80 percent compared to 1990, according to the Paris Agreement.

Innovations from the steel mill

By the same year, Thyssenkrupp, the steel company with a long history from Germany's Ruhr region, plans to stop using coked coal and is working on respective concepts. So far, the tradition-steeped steel giant has been known primarily for its "Carbon2Chem" project in which carbon dioxide generated as a process gas is converted into basic chemical substances such as ammonia and methanol by means of water electrolysis to produce fertilizers or fuel from them. A steel mill consists of a coking plant, blast furnace and converter steel plant, plus auxiliary and processing facilities, and is a real energy hog. On the road toward a climate-neutral steel mill, the conversion of the process energy from fossil to renewable sources such as wind and solar power is just one of the smaller obstacles.

"We are abolishing coal, not the steel mill"

Dr. Arnd Köfler, CTO Thyssenkrupp

Especially the mammoth blast furnaces with their humongous coal consumption contribute to the bad carbon footprint of steel mills. This is precisely the area the steel company targets: In a new process, green hydrogen - i.e., hydrogen produced with renewable energy - is blown into the blast furnace, thereby replacing part of the PCI (pulverized coal injection) coal which results in steam instead of CO₂. The advantage: There's no need for new plant technology. Minor modifications of the existing infrastructure are sufficient. The hydrogen can only replace coke at this stage of the production process proportionally but, at least, CO₂ emissions can be reduced by 20 percent in this way. Consequently, this approach is only an intermediate technology.

Going forward, the company will be rolling out new technology – "Blast Furnaces 2.0" – that operate completely climate-neutral and are called direct reduction plants. Thyssen's competitor Salzgitter, as well, is pursuing this approach that can be integrated easily into steel mills. In direct reduction plants, oxygen is extracted from iron ore by means of a reducing gas. This process takes place under overpressure and at 1,000 °C (1,830 °F). It no longer produces liquid pig iron but solid sponge iron as an intermediate product that's smelted in an electric arc furnace together with steel scrap and refined into new steel. The technology doesn't really break new ground and has been anything but climate-neutral due to the previous use of natural gas. This is where the "Salzgitter Low CO₂ Steelmaking" project comes in. The plan is to successively replace the share of the fossil energy source by green hydrogen produced from green electricity and to thereby reduce CO₂ emissions by up to 95 percent.

With a wind farm and an electrolysis plant, the steel giant is already independently producing green hydrogen for this purpose. In addition, the company is working on increasing the efficiency of producing green hydrogen and tested a high-temperature electrolyzer as part of a research project. At a temperature of around 150 °C (300 °F), this method uses steam generated by waste heat – as a by-product from steel production in a manner of speaking. However, no manufacturer has



Schaeffler bearings in steel production

The operating conditions of rolling bearings in the steel industry are characterized by high temperatures, high rotational speeds, and considerable exposure to dirt and water. **Schaeffler offers bearing solutions for all points of support in plants producing and forming steel and non-ferrous metals.** Due to decades-long collaboration with plant manufacturers and operators, Schaeffler has extensive know-how in this field. Hundreds of steel mills benefit from the quality of tailored solutions. Solutions with which increasing production speeds can be achieved economically and with maximum reliability.



The production facilities of a steel mill (shown here is an electric arc furnace) are as large as blocks of residential buildings

developed green steel production to industrial marketability yet. The conversion to low-carbon production has to be economically secured because a ton of green steel today costs about two thirds more than its conventional counterpart at the same level of quality. Even so, there's demand for green steel already – for instance, in the context of carbon-free supply chains.

Steely startups

The automotive industry is one of the biggest customers of the steel industry worldwide. In Germany, for instance, it accounts for 26 percent. Together with its steel suppliers, Mercedes-Benz is pursuing the goal of a green steel supply chain and is planning to launch various vehicle models made of green steel starting in 2025. Today, a sedan from the premium brand consists of 50 percent steel on average, so this material accounts for about 30 percent of CO₂ emissions in the manufacturing process. To underpin their plans, the Stuttgart-based manufacturer has joined other renowned investors in the H2 Green Steel startup. The young Swedish company is planning to establish a greenfield steel mill including hydrogen production at a giga scale, with a mammoth 800-megawatt electrolyzer as its core. Electric power is supposed to be supplied by surrounding hydropower stations and wind farms. The raw materials are supposed to consist of 60 percent scrap and 40 percent iron ore. The facility is planned to start producing five million metric tons (5.5 million short tons) of steel per year in 2030. BMW, as well, is investing in a startup that's developing a method for carbon-free steel production.

Boston Metal is ringing in a new era in metallurgy using an electrolysis cell powered by renewable energy to produce liquid iron that will subsequently be processed into steel. Under a NASA tender around 15 years ago, its founder, Donald Sadoway, a chemist, had come up with a solution for extracting oxygen from the Moon's surface. It produced molten metal as a by-product which inspired the researcher to adapt the approach to alternative steel production. In the coming years, the young company is going to establish demo plants for its technology in order to further develop it for industrial-scale use.



The author

As a young person, our author, **Oliver Jesgulke**, always felt that the Ruhr region with its skyline of chimneys was a place he

wanted to get away from quickly. Today, though, it's become a discoverer's paradise for him, where a lot is happening even without coal.

High tech in the fields

NEW HOLLAND

Efficiency and sustainability play a central role also in farming. They're achieved by the deployment of ultramodern machinery. "Precision Farming" or "Farming 4.0" are keywords in this context.

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By Lars Krone

Farming is facing major challenges. The growing population on Earth is hungry for more and more food. On the other hand, climate change and growing environmental awareness call for efficient, energy-saving and eco-friendly production methods. Moreover, many countries are increasingly confronted with the problem of labor shortage. Incumbent agricultural machinery manufacturers and startups are developing various approaches to tackling these challenges. In the agricultural machinery sector the development is split: On the one hand, large machines such as those used for grain harvesting are becoming more economical and increasingly efficient due to modern technology and on the other, small multifunctional, autonomous machines that can operate in a swarm for seed-sowing, fertilizing or plowing are intended to replace conventional farm tractors, so saving energy and labor. Increasing digitalization dubbed "Farming 4.0" is common to both of these segments. By means of cloud-based, app-controlled networks agricultural machines are monitored in real time while their utilization is continuously optimized. Their routes in the fields, for instance, are planned for particularly soil-conserving and energy-saving operation so that the machines are always running within their optimal performance range. Precision farming is another key element. Here the utilization of drones that continuously monitor the condition of plants plays an important role. As early as in 2018, nearly one in ten farmers in Germany used drones - there's no other sector

The record mower

Model New Holland CR10.90

Category Combine harvester

Field of application

Suitable for different types of grains, regarded as the world's fastest combine harvester with an entry in the Guinness World Records (797.656 metric tons / 879.265 short tons) of wheat in eight hours).

Technology

16-liter common-rail diesel engine delivering a maximum of 700 hp that, thanks to AdBlue injection, meets Euro V introduced in 2020, one of the world's strictest emission standards for mobile machinery; proactive automatic systems selecting the best possible setting from 280 million options in mowing operations; controlled traffic farming (CTF) enables carefully planned lane guidance and minimizes soil damage; grain tank with 14,500-liter (3,830 gal) volume.

Charged up

Model SLC Tom and Dick

Category Weedkiller

Field of application

Approach to combating consistently growing weed problems, eco-friendly and automated destruction of undesirable plants without using controversial herbicides.

Technology

Robots autonomously acting in tandem. Tom (small and orange), thanks to AI and high-resolution video technology, identifies weed infestation with centimeter-level accuracy. Data are transmitted to Dick that systematically kills weeds with an 8,000-volt electric shock (small picture). All this happens fully automatically and 24/7 if necessary.



Schaeffler in land technology

Land technology is under high pressure to increase productivity. With the reliable components and system solutions from Schaeffler, manufacturers can reduce their total costs. The range of standard bearings is correspondingly sophisticated. Customized solutions complement it in useful ways – some of them unconventional, but amazingly simple, and always focused on effective sealing and ease of installation. All this is backed by a powerful service network – from the nearby consulting engineer to modern calculation tools to lubricant and coating know-how.



Learn more at schaeffler.com

Giant with centimeter-accuracy

Model

Case ICH Quadtrac 620

Category

Tractor

Field of application

A powerful and – in spite of a length of 7.6 meters (25 ft) but thanks to a small turning circle – nimble tractor for heavy-duty field work; gentle on the soil due to minimized ground pressure and slip of the four track units; GPS-controlled steering system eases the burden on the driver.

Technology

12.9-liter six-cylinder turbo diesel engine with 692 hp; Quadtrac units with articulated steering for small turning circle; digital operation management with telemetry enables real-time access; controlled traffic farming defines permanent lanes, dedicated network guarantees reliable repeatability year by year, plus lane-tolane accuracy of up to 2.5 cm (1 inch).



Good vibrations

Model Sicma F3 140

Category Vibration harvester

Field of application

Time-consuming and labor-intensive harvesting of tree fruit is done automatically without damaging the plants. Harvesting fruit from a tree only takes

a few minutes, up to 99 percent of the fruit is collected and can be processed immediately.

Technology

Tree trunks are caused to vibrate by means of a two-stage joystick-controlled gripper, fruit is caught in a folding umbrella with load-bearing capacity of up to 400 kilograms (880 lbs).





On a long leash

In contrast to the passenger car market, electrification is still playing a minor role in the farming machine sector. The main reason is that the high level of capacity utilization there entails the need for a large onboard energy storage requirement that current battery systems cannot cover. John Deere has presented an approach to solving this problem in a project called GridCon, in which autonomous tractors are supplied with electric power by a cable with a length of up to three kilometers (1.9 miles) attached to them. This, by the way, is an idea that was used in the USSR (see below) as early as in the 1950s but did not catch on.



Powerhouse

Model Krone BiG X 1180

Category Forage harvester

Field of application

The currently most powerful farming machine delivering 1,156 hp is used in grass and corn harvesting. With a fresh weight throughput of 400 metric tons/hour (440 short tons), the Krone is extremely powerful and, thanks to its PowerSplit function, features adjustable engine characteristics so that the 24-liter engine always runs in the optimal rpm range and therefore more efficiently.

Technology

Numerous assistance systems ensure optimal harvesting: a steering system for automatic lane keeping, photo optical cells for capturing the ripeness level of the plants and automatic adjustment of the chopping length, depending on the type and amount of harvested mass to be collected. Fully automatic speed adjustment to reduce diesel fuel consumption and easing the burden on the driver; automatic online calibration of yield data acquisition is a first in terms of eliminating the need for vehicle scales.



Aerial perspective

Model

DJI P4 Multispectral

Category

Monitoring drone

Field of application

The health condition of plants is monitored in detail from a bird's eye view. Thanks to precision farming problems such as pest infestation or lack of nutrients and water can be treated in the affected areas as needed, so saving fertilizers and water. In addition, drones can localize animals before mowing work starts.

Technology

An RGB camera attached to a 3-axis gimbal and five spectral cameras, battery-operated with 27 minutes of flying time, real-time data transmission over a distance of up to 7 kilometers (4.3 miles) thanks to image transmission technology; app-controllable.



Swarm intelligence

Model

Fendt Xaver

Category

Seed-sowing robots

Field of application

Can be used for seed-sowing 24/7. A swarm of six of the robots, each the size of a riding lawn mower, manages 3 hectares (7.4 acres) per hour and consumes around 70 percent less energy than a tractor doing the same work – silently and with zero emissions. The robots perform the work of heavy-duty machinery that might cause damage especially on soft or wetter soil and thus reduce yield.



Technology

Automatically cloud-controlled based on input parameters, lane guidance system ensures most efficient route with centimeter-level accuracy, lithium-ion battery with 2.6 kWh capacity, robot self-charges, seed tank with 20-liter volume is sufficient for 0.5 ha (1.2 acres) at 90,000 kernels/ha (36,500 kernels/acre).

In touch with the stars

The flying observatory SOFIA is arguably the most efficient way of looking into space. It combines the far-reaching vision of satellite-based telescopes with the comparably easy maintenance of ground-based observatories, plus very high versatility. At the heart of it is a reflecting telescope with a diameter of 2.7 meters (8.9 feet) and a Schaeffler bearing.

13.7 km

(45,000 ft) is the altitude at which SOFIA flies. There, at the lower edge of the stratosphere, 99% of the water vapor in Earth's atmosphere is below it and the infrared rays from space can reach the telescope unhindered.

3–4 times

per week. This is how often SOFIA normally embarks on its observing missions. The flights last 8 to 10 hours. SOFIA's home base is NASA's Armstrong Flight Research Center, Building 703, in Palmdale, California. But missions have also departed from New Zealand, French Polynesia and Germany.

Elizabeth Ruth ist the only woman in SOFIA's pool of pilots. The NASA employee has been flying the observatory jet since 2016

SOFIA

(870 km/h; 540 mph)



SOFIA's major discoveries

- In 2017, SOFIA confirms the existence of a solar system that resembles ours. It's 10.5 light years away.
- In 2015, thanks to its flexibility, SOFIA is on the spot when, during a rare occultation, Pluto throws a fleeting shadow onto the Pacific, and gathers new findings about the small planet.
- Astronomers use SOFIA to investigate the magnetic field in the middle of our Milky Way and begin to understand the differences between active and quiet black holes.
- In 2019, thanks to SOFIA, the existence of the helium-hydride ion in space is proven for the first time. Our entire idea of the evolution of chemical elements and life the way we know it is based on the existence of this type of molecule in the universe.
- In 2020, SOFIA discovers water bound in the Moon's surface in an area exposed to sunlight that is 120 °C (248 °F) hot. The amount of water discovered corresponds to the contents of an 0.33-liter (12-oz) can dispersed on a football field.



The former lower passenger cabin accommodates the workstations of the astronomers and an area for guests (a maximum of 30 persons in total). Discernible in the tail section is the bulkhead separating the open telescope area from the cabin, including the telescope's mounting bracket (blue) and the flangemounted measuring instrument in front of it

> SOFIA's base jumbo jet was put into service in 1977 as a PanAm airliner. In 1997, NASA took over the jet. It's one of only 45 747SP types ever built. The "Special Performance" version with a length of 56.4 meters (185 ft) is 14.6 meters (48 ft) shorter than a standard jumbo jet. As a result of this shrinking, the short version can fly at higher altitudes than any other wide-body iet

approx. €1.5 billion

is said to be the costs that have been incurred so far for the Stratospheric Observatory for Infrared Astronomy, which is SOFIA's full name.

SOFIA's heart

The 17-metric ton (18.8-short ton) telescope in the tail section is the most important passenger on board. It was made in Germany. 1 A tri-mirror system (primary mirror diameter: 2.7 m/8.9 ft), weight: 750 kg/1,650 lbs.) that 2 is mounted in a carbon fiber cage captures infrared radiation from space and deflects it to 📀 the flange-mounted measuring instrument. Variations between six different instruments are possible, depending on the research purpose. A pressure bulkhead separates from the cabin the mirror elements exposed to the atmosphere. 4 A ring with 24 pneumatic spring-damper elements isolates the mounting bracket of the telescope from the aircraft's vibrations. The actual bearing **5** is a hydrostatic, spherical plain bearing from Schaeffler (diameter: 1.2 m/3.3 ft), weight: 600 kg/1,323 lbs.). It provides isolation as well and ensures movability. In addition, twelve motor segments help orient and track the telescope so that external disturbance forces are compensated for. The whole interaction works so well that a laser pointer mounted to the telescope could accurately target and hit a coin on the ground from an altitude of 12 kilometers (39,370 ft).



Future Life

Higher sustainability, speed, comfort and convenience – that's how technological progress shapes everyday life and helps master the challenges of major forward-thinking topics such as urbanization and demographic change.

The bicycle capitals of the world Percentage of distances in major cities covered completely or partly by bicycle.



Source: Deloitte City Mobility Index 2019

I want to ride my bicycle

A classic is turning into the spearhead of urban mobility transformation: the bicycle. The consulting firm Deloitte expects the number of regular bike riders to double from 2019 to 2022 worldwide. The number of commuters pedaling on a daily basis is supposed to double as well, globally from one to two percent. That doesn't sound like a lot but, projected to 1.5 billion commuters worldwide, it would amount to an increase from 15 to 30 million people. Plus, the larger the number of people that move to conurbations (expected to account for 68% of the world population by 2050) the larger the number of potential bicycle users. Electrification of the drive unit has given this mobility classic a special boost: Even today, more than 200 million electric bikes, and heavily counting, are supposed to be in use. Thanks to electric motor assistance there's no reason for any commuter to fear arriving at work in a sweaty business outfit. Plus, at an average speed of 22 km/h (13.7 mph), e-bikers are not only faster than conventional bike riders (15 km/h / 9.3 mph) but even nearly as fast all other urban means of transportation. Schaeffler is now presenting the next e-bike evolution: a chainless "Bike-by-wire" drive – an all-new riding experience without a mechanical connection between the drive shaft and the rear wheel.



18 million

people worldwide work in the energy sector, 12 million of them in the area of fossil fuels. By 2050, their number is predicted to increase to a total of 26 million, but 84% of them in the field of renewable energy.

Source: European Institute on Economics and Environment

Efficient cancer screening

The e-nose developed by research scientists at the University of Pennsylvania delivers up to 95-percent accuracy in sniffing out vapors from blood samples. "It's an early study but the results are very promising. The data shows we can identify these tumors at both advanced and the earliest stages, which is exciting. If developed appropriately for the clinical setting, this could potentially be a test that's done on a standard blood draw that may be part of your annual physical," said Charlie Johnson, a co-author of the study. Thanks to nanosensors the artificial olfactory organ is a lot more sensitive than the human one. Specially trained dogs, however, have managed to sniff out cancer as well.

"A year from now you may wish you had started today"

Karen Lamb, Communication scientist

Everything under one eco-roof

Västerås, a city with a population of 120,000, some 100 kilometers (62 miles) west of Stockholm, is going to receive a **pioneering mobility center.** Buses, long-distance and local trains, taxis and shared mobility services are to become efficiently interlinked in a central location starting in 2025. Shopping opportunities, parks, wide bicycle and pedestrian paths enhance the quality of the travelers' stay at the facility. At the same time, the design of the planners from the renowned architectural firm Bjarke Ingels Group (BIG) is **focused on high energy efficiency.** The distinctly curved and partly greened roof will have solar cells that are supposed to cover up to 70 percent of the building's annual energy demand. In addition, the mobility center will have a rainwater collection system and be kept at pleasant temperatures with energy-efficient floor heating and cooling systems. Skylights and ample glazing of the façade allow plenty of daylight to enter the building, thereby reducing electricity consumption.



Amazing 24/7 assistants

A fleet of autonomous service vehicles has embarked on a journey of revolutionizing the workplace and everyday life. That's a huge step in the direction of greater efficiency because these automatic assistants can work around the clock. Read on to learn more.

22

52

3

32

By Björn Carstens

Autonomous driving is a concept that causes the imagination of car manufacturers and consumers alike to run wild. Finally, it will be possible to use the time spent in an automobile in meaningful ways: for working, reading, surfing the internet or sleeping instead of staring at the road and the cars in front for miles on end. However, the problem is that here we're talking about automation Levels 4 (car is in control, driver can fully focus on other tasks) or 5 (no steering wheel and pedals



in the car anymore). At the moment, we're in the transition stage from Level 2 to 3: cars can operate autonomously in defined situations (e.g. using traffic jam assist) but the person at the wheel must be able to intervene at all times. Although more automation is already possible in terms of technology, there are other questions to be clarified such as liability in case of a crash. Consequently, it will be a while before computers take full control of cars. Level 4 may be achievable starting in 2025, according to expert estimates, and Level 5 not before 2030. In other areas, a mass rollout of



Load carrier

This cobot from a French startup company is a **smart automatic carrying aid** (up to 500 kg/1,100 lbs). When someone taps its touchscreen, EffiBOT will automatically follow them through the factory like here at the SEAT plant in Martorell, Spain. Thanks to its sensors permanently scanning the environment for 360-degree readings it doesn't need any further assistance even if people or objects cross its path.



Sweep-o-bot

This device made by a Finnish company looks a little like an oversized robotic vacuum cleaner. And in a way that's what it is. As an **electric street sweeper**, this 3.50-meter-long (11.5-ft) and 2.30-meter (7.5-ft) wide XXL version drives fully automatically through Helsinki's streets at night at a maximum speed of 10 km/h (6 mph). In addition to several cameras whose pictures are analyzed by means of Al image recognition technology, the street sweeper uses LiDAR (Light Detection and Ranging) to achieve precise object recognition and flawless contact avoidance.



U-robot

The SeaClear project currently being tested at the Hamburg port is focused on **getting rid of macroplastics at the bottom of the sea.** The mission of a "team" of uncrewed underwater robots, a ship, and a drone is to localize the waste, classify it as such and to finally collect it using a combination of suction and gripping devices. Once initiated, this process is supposed to be run fully automatically. Unfortunately, there's plenty of disposal work to do. An estimated 26 to 66 million metric tons (29 to 73 short tons) of waste are polluting the oceans, more than 80 percent of it on the seafloor.



Refueling drone

For the first time, the U.S. Navy has managed to use a **drone for in-flight refueling of a fighter jet**. Just six meters (20 ft) of hose separated the drone from the jet. In future missions, Boeing's MQ-25 Stingray is said to be able to carry up to 8,525 liters (2,252 gallons) of fuel for in-flight refueling of several jet aircraft. The drone, though, can be used not only for refueling aircraft but also for reconnaissance and surveillance purposes. the technology will be achievable sooner. Tobias Wessels, for instance, is convinced that this will be the case because "In delivery trucks for the last mile the technology currently makes more sense than in passenger cars," says the CCO of U.S. startup Udelv that's planning to launch up to 35,000 self-driving delivery vehicles by 2028. Why does Wessels see things this way?

Machines are immune to distraction

The world is in delivery mode. During the coronavirus lockdown it seemed like there were more delivery heroes with their parcel vans, pizza cars or messenger bikes in the streets than pedestrians. All of these vehicles are still operated by humans but, provided that reliable people can be found in the first place, they cost a lot of money, need to take breaks, and occasionally are unavailable due to leave or illness.

Autonomous service vehicles on the other hand do not get tired or sick, are immune to distractions, recognize hazardous situations earlier thanks to their connectivity, and are simply safer. "Autonomous service vehicles of all kinds can be used 24/7 and therefore very efficiently," emphasizes Klaus Graf, member of the management board at Schaeffler's subsidiary Paravan, that in the form of Space Drive drive-by-wire technology (see page 93) supplies a redundant electronics interface for controlling the steering wheel, accelerator and brake as an important basic component for achieving autonomous mobility.

The highly sophisticated systems of a robo-car react faster than a human ever could – in 0.1 instead of 1.4 seconds, according to relevant calculations. Around 90 percent of traffic accidents are attributable to driver mistakes, according to the consulting firm McKinsey. They could be reduced by automated vehicles.

Closed-off areas as ideal training grounds

The fact that unlike human passengers, parcels have no concerns about the absence of a human driver at the wheel is another advantage of self-driving delivery vehicles, which makes them superbly suited for accelerating developments in the area of autonomous driving and finding

"In a predefined area, autonomous service vehicles will be gaining ground relatively soon"

Klaus Graf, member of the management board, Schaeffler Paravan

new solutions especially in the important setting of urban mobility. Factories have been regarded as perfect test beds for years: separate areas with reduced speed, the same recurring routes, and hardly any other traffic are an ideal environment for learning autonomous driving - just like electric trolleys, forklift trucks and other fully automated robots have been doing for years: driverless and fully autonomously, they detect obstacles and crossing workers by sensor systems using 3D cameras, lidar, ultrasound and laser sensors as well as radar eyes. Klaus Graf: "I think that in other predefined areas autonomous vehicles can become an integral component of everyday mobility relatively soon as well." Kiosk robots on wheels, for instance on campuses, pharmacy cabinets on wheels in low-traffic neighborhoods, or autonomous street cleaners washing the streets at night. Uses are emerging in areas other than streets and roads as well: in the form of self-diving underwater cleaning robots in port facilities, drones that fly banked blood back and forth in cases of emergency, or autonomous ferries shuttling passengers many things are possible and some are already being tested (see examples in the sidebars of these pages).

Space Drive as a key technology

"All of these autonomous vehicles on water, in the air or on the road will require redundant brake-bywire and steer-by-wire systems such as our Space Drive. That's why we regard it as a key technology for future mobility," says Klaus Graf.



Driverless parcel delivery

Field testing of self-driving technology. In the UK, automaker Ford and delivery service Hermes are investigating how other road users behave when encountering **a seemingly driverless van** that's equipped with all the typical sensors of a fully autonomous vehicle. The idea behind it is that the driver in the field has a range of tasks such as sorting, loading and handing out parcels besides operating the vehicle. In this test, the "invisible" driver remained totally passive. Couriers called the delivery vehicle via an app, and voice messages and monitors guided them to the parcel box intended for them.



High-tech delivery service

Smart, self-driving high-tech robots delivering supermarket or fast-food orders – testing of **the automated future of door-to-door delivery services** has been underway for years. Robot manufacturer Nuro in the U.S. has deployed the R2. Equipped with lidar, radar and cameras, it navigates its way around the maze of city streets at up to 40 km/h (25 mph). After entering a code, customers just take their shopping out of a refrigerated compartment.



Kiosk on wheels

A vending machine arriving at your doorstep. Network operator Vodafone and food retailer Rewe are currently testing a self-driving project vehicle that delivers snacks and beverages. The snack-mobile continuously travels in a loop across a commercial campus in Cologne at 6 km/h (3.7 mph). All it takes to cause the vehicle to stop is to briefly beckon it. Roof-mounted cameras and sensors recognize the hand signals. That's truly a foretaste of connected road traffic of the future.



Road-approved people mover

Hanseatische Fahrzeugmanufaktur has deployed Busbee, an autonomous electric bus currently operating on a test route in the North German lowlands, albeit with a driver. **The bus is controlled with a joystick** using drive-by-wire technology from Schaeffler's subsidiary Paravan. Busbee is the only road-approved people mover, which means that in manual mode it can also operate off the test routes. Graf knows how the development can be further accelerated: "Vehicle control and the interaction of systems must be imagined beyond the current state." Fast and secure data communication using the 5G network plays a crucial role in this context because, ultimately, a drive-by-wire system only executes control commands, and the more data the creation of such commands can be based on the safer autonomous driving becomes.

The vehicles need to learn how to communicate and have to absorb information in a dialog with other vehicles (car2car communication), non-motorized road users, the traffic infrastructure, or with other information sources such as radio traffic service and weather forecasts (car2x communication). And why shouldn't a school warn approaching traffic of an impending break and the resulting higher risk of children potentially running into the street. So, the connected vehicle literally peeks around the corner and even through walls. It recognizes hazards early and in doing so becomes an early warning system for the traffic behind it. All in all, these are good prerequisites for assuring us that not only our goods are in safe hands in a self-driving vehicle but that we will soon be too relaxing and leaning back in our seat and making sensible use of our time on the road.

Restaurant helpers

Peanut, **the robotic waiter**, may not be of huge help in serving meals to patrons but clearly shows which way things in the restaurant business may be headed, considering the severe shortage of labor there. Using lidar technology, the robo-waiter autonomously takes tableware from place A to place B. However, it's unable to autonomously set tables nor truly work together with people. Albeit, what's already possible in industrial settings should soon work in restaurants too.





With the production-level Rolling Chassis, Schaeffler presents a modular platform for the city of the future with universal usability for hauling passengers and goods

The pathway to autonomous mobility

With Space Drive 3 Add-ON, Schaeffler is presenting the next generation of the steer-bywire system, the key technology for autonomous driving with multiple redundancy. For Schaeffler, this step marks the company's entry into low-volume production.

In Generation 3, the system based on the automotive open system architecture (AUTOSAR) standard allows a direct connection to the vehicle electronics as well as communication and network architectures, which enables integration into existing advanced driver assistance systems (ADAS). "Space Drive 3 marks a major milestone for us," says Viktor Molnar, President of the Chassis Business Division at Schaeffler.

"With it, we're able to offer our customers a production-level steer-by-wire system with maximum scalability and flexibility. In addition, all steering parameters can be recorded, which enables feedback communication to ADAS in vehicles operating in automated driving modes," says Molnar.

Moreover, by presenting the **Rolling Chassis** (pictured right) at IAA Mobility 2021, Schaeffler demonstrates what innovative drive and chassis technologies might look like going forward – as flexible, scalable platforms for new, driverless mobility solutions for hauling passengers or goods or for specialty applications such as street cleaners.

The modular platform shows the wide variety of technologies from Schaeffler and offers a flexible architecture: for the steering and drive systems, diverse versions can be implemented, depending on customer requirements – from simple drives via an e-axle and a central steering unit to the utilization of four **Schaeffler Corner Modules**. The Corner Modules, each enabling a steering angle of up to 90 degrees, have been further developed toward production level and scalability. They encompass the wheel hub motor, the wheel suspension including air springs enabling the vehicle to be lowered for ingress, the actuator for the electromechanical steering system, and a brake.



The Line

How a city is supposed to grow 170 kilometers (106 miles) into the desert and secure the future of Saudi Arabia, and what European experts think of the plan.

Car-free **residential level** with green and recreational areas

Supply and support level with shops, services and motorized short-haul transportation

Besides Hyperloop highspeed systems, freight and regional trains are planned to travel on the **third level**

By Rosa Grewe

What can be seen here so far is stones, mountains and water galore, but soon the Saudi Arabian side of the Red Sea is supposed to become home to an urban landscape in an area that could accommodate New York City thirty-three times. The Arabian Peninsula is no place for skeptics, as the construction boom proves on its eastern coast, in Abu Dhabi and Dubai. Even so, it's hard to believe what the Crown Prince of Saudi Arabia, Mohammed bin Salman Al Saud, is planning as the city of the future in the middle of the desert and has named Neom. A sub-project of Neom is The Line, a green linear city for which the vision of Neom has been fed concretely into a master plan since February 2021.

"Neom and the linear city 'The Line' are more than mere PR. They're realistic because the Crown Prince is driving the country's transformation," says a person who knows what he's talking about. Professor Rainer Schmidt, a town and country planner from Munich, used to teach at the universities of Beijing and Berkeley, and planned and implemented numerous large-scale urban and landscaping projects, including some in the The Line is supposed to be **energy self-sufficient** and carbon-neutral

380,000

Forward-focused jobs are supposed to be created by The Line.

1 million

Residents are planned to be distributed to the consecutive urbanizations of The Line. Arabian world. He's been familiar with the region, the project plans, the developments and the decision-making structures on the Arabian Peninsula for decades. He knows that Neom and The Line are not utopian delusions of grandeur but the beginning of necessary social and economic change in the region – for a prospect of life without oil and with more personal freedom, as Rainer Schmidt says: "The people there are raising their voice."

Sebastian Sons shares this view. He's an expert on Saudi Arabia with the German Council on Foreign Relations and in a "Deutschlandfunk" radio broadcast said: "Saudi Arabia has been undergoing fundamental social change for years." For him, too, the Saudi Arabian urban utopias are "a signal to us, to the West, to portray Saudi Arabia as something that it never before has been perceived as, that is as a country striving to enter modernity."

Utopian or feasible?

The Line is a linear city of 170 kilometers (106 miles) in length connecting the Saudi Arabian desert with the Straits of Tiran in the northern part of the Red Sea. The location is strategically attractive. Across from it, on the opposite side of the coast, is Sharm el Sheik, one of the most important and high-revenue tourist resorts in the Middle East, just a few hours away from Europe by plane and located in Egypt, a political ally. This is where Saudi Arabia, by forging links with Egypt not just figuratively but also architecturally, wants to establish a closer connection to the West and demonstrate its fitness for the future around the world. The satellite towns of The Line are planned to be carbon-neutral and self-sufficient using "clean" energy. To achieve these objectives, the Line with its districts arranged like a pearl strand will organize itself on three layered levels. Intended uses and space are supposed to be interlinked as efficiently as possible in this way: an above-ground level with residential, green and recreational areas. The level below it is planned to accommodate underground shopping malls with stores for everyday needs, plus a network for autonomous short-distance travel. The project promises a maximum walk of five minutes from home to all everyday destinations, because The Line is supposed to be car- and even road-free, at least above the ground. On the third and lowest level, autonomous vehicles will haul people and goods in several tubes across medium distances.



According to the plans, a Hyperloop train will cover the entire 170-kilometer (106-mile) distance in a maximum of 20 minutes, which calls for a speed of more than 500 km/h (310 mph). As a smart city, data about all processes are supposed to be captured and enhance the efficiency of the infrastructure by means of artificial intelligence.

The Spanish architect Vicente Guallart, a planner of several low-traffic and " CO_2 -absorbing" cities, voiced criticism during a broadcast of the

"It's impossible to build a city with such a huge underground infrastructure"

Vicente Guallart, Spanish architect and city planner German cultural TV program "Aspekte": "The Line will never be built, simply because it's impossible to build a city with such a huge underground infrastructure." Rainer Schmidt has a different view: "The mobility structure with the Hyperloop, for instance, is evolving and certainly possible."

Water and soil management for the desert

The environmental dimension is another issue raised by critics: 170 kilometers (106 miles) of area planted with greenery in the middle of the desert seems to be wasteful and inefficient in view of extremely scarce water resources. Rainer Schmidt counters this point as well, reporting about the success of a forested park in Riyadh he'd planned: "With efficient irrigation systems, with water and soil treatment – by enhancing soil with bacteria, for instance – sustainable greening of the desert is possible." Plus, he refers to the afforestation project of

Short distances are gaining ground

The reconstruction of Europe after the Second World War inspired planners as a major opportunity for change: As more and more people became motorized, cities were planned in more spacious style, and seemingly efficiently and functionally divided into spheres of living, working, shopping and transportation. However, many of the satellite districts that emerged in the process proved neither pedestrian-friendly nor vibrant and atmospheric. Because these suburbs with their mono-structures had little capacity for change they were highly crisis-prone when confronted with changing social and economic developments and turned into socially deprived neighborhoods. In many areas, the anticipated efficiency of functional division was thrown into reverse. Since the middle of the nineteen-nineties, if not earlier, the mixed, concentrated city has been the ideal again – in Paris, for instance. Its mayor, Ann Hidalgo, proclaimed the "city of the 15 minutes": Similar to the plan in The Line, all things of everyday life – including work – are supposed to be accessible on foot or by bike within a few minutes in Paris' neighborhoods by the end of the decade. The coronavirus elevated the idea of self-sufficient sub-centers onto the desks of many urban planners, where the Sahara (see also page 40) that not only is feasible but even sensible and necessary for environmental reasons in order to increase the water storage capacity of the soil and to prevent the spread of the desert. Water management and greening of dry regions could in the long run enable the necessary water supply and high-yield local farming in growing urban areas in Africa and the Arabian region, according to Schmidt. Critics on the other hand fear that exactly the opposite is true: The Line might tap into the valuable ground water reservoir that formed some 25,000 years ago when the Arabian Peninsula was still a green savannah and is among the largest ones on Earth. The entire region, especially Jordan, benefits from this non-renewable resource.

Cosmopolitan and pioneering?

Irrespective of the environmental considerations, the question arises whether The Line will be able to attract enough people and investors from all over the world in the first place. After all, the Saudi Arabian legal system and the degree of freedom for ethnic or other minorities, critics and women clearly differ from those of democratically ruled countries from which many of the investors, guests and future residents might hail. And they are essential, as Rainer Schmidt points out: "Financing of the project strictly by earnings from the petroleum sector is not realistic." So, will the project boost social change in Saudi Arabia, in terms of democracy and a pluralistic and liberal society? Sebastian Sons puts the answer in perspective: "That has its limits and the limits are where the conservative clergy, the religious scholars, are massively affected, because Saudi Arabia is based on a very conservative and strict interpretation of Islam, which cannot be upended just like that." That's why, more than likely, says Schmidt, a free trade zone with a separate legal status for Neom and The Line would be inevitable. Should the project become a technological, environmental and social success it might be able to drive development in other desert regions, especially in Africa, with transferable solutions for water management, farming and urbanization. So, aside from the hype, The Line engenders a lot of hope for the future.



The Author

Rosa Grewe is a journalist specialized in architecture, construction technology and urban development. She loves cities and finds

especially the non-perfect ones just perfect. The ones that keep changing with their people and their times. The ones that in their smallest free spaces surprise you with ample space to breathe. Living in a perfectly organized planned city? That wouldn't be her cup of tea.

people's homes turn into safe havens and life is supposed to take place within immediate proximity. But critics of such decentralized concepts have been raising their hands as well. The journalist Alice Delaleu, for instance, wrote in the "Chroniques d'architecture" online magazine: "By creating the 'city of the 15 minutes' Paris is building new walls and descending into egoism," particularly with regard to segregating poorer neighborhoods on the outskirts. Other critics fear that less mobile segments of the population such as senior citizens or people with disabilities will be disadvantaged.

Riding the wave

Half airplane, half ferry: Wing-in-ground (WIG) craft efficiently "surf" an air cushion and are poised to play an important part in interurban mobility. The principle, though, has been around for a while.

By Volker Paulun

The western world is shocked. In the middle of the Cold War, in September 1966, U.S. satellites are taking pictures of a well, what ...? Is it an airplane floating in the harbor basin of a Soviet naval base? Or a new boat class? Well, it's a hybrid of both, a wing-in-ground (WIG) craft. And it boasts such mammoth dimensions that U.S. intelligence officials reverentially dub it "Caspian Sea Monster." The behemoth is 100 meters (328 ft) long, while the biggest Boeing 747 merely measures 78 meters (256 ft) in length. Its takeoff mass of 550 metric tons (606 short tons) is around 100 tons (110 short tons) higher than that of a jumbo jet. But what worries western military experts most is the fact that as a WIG craft it flies at a maximum altitude of 14 meters (46 ft), literally under their radar – at a speed of up to 500 km/h (310 mph).

Surfing a "rolling air cushion"

Today we know that their fears were unfounded. The Sea Monster was built only once and finally The Seaglider from U.S. manufacturer Regent is supposed to cost half as much as a comparable airplane and be six times faster than a ferry

> At a top speed of 290 km/h (180 mph), the Seaglider is supposed to achieve a range of 290 kilometers (180 miles), twice as much as that of a comparable electric aircraft

A little bit of air beneath the fuselage: the closer to the surface a WIG craft flies, the more efficient it is

sank in 1980 after a pilot error. The few WIG craft that were to succeed it can only be found in museums today. Engineers in other countries pursued the idea as well, albeit a major commercial success has not materialized so far, even though these "wingships" are epitomes of efficiency due to the ground effect they use. As a result of this aerodynamic effect, a "rolling air cushion" forms underneath the wings and the fuselage on which the WIG craft can ride in an energy-saving way. Another efficiency benefit is the fact that, unlike normal aircraft, a WIG craft is not affected by wake turbulence. In total, the ground-effect gliding is supposed to be up to 40 percent more efficient than flying at higher altitudes.

This inevitably raises the question why this principle has not caught on so far. A decisive reason is that the higher the ground effect the lower the craft flies. Altitudes of clearly less than one meter (3 ft) are ideal in terms of efficiency. Such low flying altitudes practically exclude the use of WIG craft on land, which typically bristles with all kinds of obstacles. But even water is not always perfectly



"The electrification of aviation enables new and revived concepts such as WIG craft. Power density and reliability of the electric propulsion units play a major part in this context. Due to the development expertise that we have accumulated over many years in the automotive sector and the high industrialization know-how at Schaeffler, we are open-minded toward such developments. However, the time of their market launch depends not only on the maturity of the propulsion technology itself but on the necessary infrastructure and social acceptance of these new concepts as well. Schaeffler will continue to monitor and evaluate these technologies and the still very young market very carefully in order to support our customers with an extended product portfolio as appropriate"

Dr. Peter Glöckner, Director R&D, Engineering and OEM Sales Schaeffler Aerospace

smooth. Waves, buoys, ships, offshore wind farms or bridges – a lot of things can get in the way of a WIG. The air cushion rolling in front of these gliders can also cause severe storm damage, plus flying extremely close to the surface used to have some pitfalls.

Buoyed up by new conditions and technologies

All in all, a plethora of disadvantages caused the efficiency advantage over airplanes to melt away, especially since aircraft fuel was cheap. Climate change and the resulting stricter emission limits, plus rising energy costs, now seem to buoy up the WIG idea again.

WIG craft have a major advantage: Thanks to their higher efficiency they're clearly better suited for switching to battery-electric propulsion systems than airplanes. In addition, the important self-regulating stabilization programs have become increasingly better and cost-efficient due to technological progress.

Projects around the world

Brittany Ferries in France has recently signed a letter of intent for zipping across the Channel with Seagliders starting in 2028 at a top speed of 290 km/h (180 mph) and with up to 150 passengers on board. Regent, the Boston-based manufacturer of the flying boat, is even planning to start



As early as in 2017, the Airfish8 from Wigetworks in Singapore was deployed on a test flight to the Malaysian tourist resort Langkawi

regular service with a smaller version in 2025. However, both companies said that the project raised "many technological, practical and regulatory questions." Jonathan Ridley, Head of Engineering at the renowned Warsash Maritime Academy, commented to the BBC that in spite of all obstacles the plans were "really quite viable." Equally convinced of the idea is U.S. billionaire Mark Cuban, the owner of the Dallas Mavericks basketball team, who is a member of a group of companies and investors that were leading the most recent financing round for Regent. "The efficiency of coastal transportation will be 100 times greater with Regent. There is no other way to describe it. The idea of having to get between two coastal points is always stress-inducing. Regent changes all that and makes it fast and easy." It's conceivable that Cuban has set his sights on coastal points such as Los Angeles, San Francisco, New York and Miami.

Tallinn, the capital of Estonia, might also be one of such coastal points. In 2019, Sea Wolf Express, a company based there, announced that they would establish a high-speed connection across the Baltic Sea to Helsinki. Their WIG craft that comes from Russia is supposed to zip across the Gulf of Finland at 200 km/h (125 mph). This is another project that's still in the planning stage and the company is in the process of exploring regulatory issues with the relevant government authorities. At least the Finnish side is open-minded toward the plans, according to a government spokesperson, but particularly safety issues such as flying over frozen water still require basic clarification.

In Singapore, the Airfish8 WIG craft from Wigetworks is being prepared for launch and completed initial test flights as early as in 2017. In the same year its Chinese counterpart, Xiangzhou 1, took off for initial test glides. The U.S. manufacturer Regent is in negotiations with several transportation companies. In addition to Brittany Ferries, they include a provider from the Bahamas, a U.S. charter airline with bases in New York, the Hamptons, Miami and the Virgin Islands, and the Croatian ferry operator Split Express, so there are many indications that new vehicles will be navigating ocean routes in the near future.

A giant between water and the sky: the "Caspian Sea Monster" was 22 meters (72 ft) longer than the biggest jumbo jet and was able to glide across water at up to 500 km/h (310 mph)



Smarter living

Thanks to digitalization many things that used to take hours can now be taken care of with just a few clicks. Even so, we have – at least subjectively – less and less time. Yet with a few simple tricks for work and leisure we can make more time for ourselves again.

By Andrea Neumeyer



Fighting time sinks digitally

In his book **"Digital Working für Manager"** ("Digital Working for Managers"), digitalization expert Thorsten Jekel advises readers to use sensible technical tools: smart filing systems – preferably in a cloud – avoid version conflicts when sending documents with a large distribution list back and forth. Eliminating time sinks is another step: with address management, to-do lists and calendars that are synchronized on all mobile devices, and to which all team members have access, unnecessary emails and further questions can be avoided, and meetings planned more effectively.

Outwitting procrastination

Procrastination, the term for postponing things that should not be postponed, derives from the Latin word "crastinum," which means tomorrow. To avoid procrastination, we should heed Benjamin Franklin's advice: "Don't put off until tomorrow what you can do today." The following two "minute-rules" can be of help in this context.

The two-minute rule advises us to tackle a simple task that can be done in two minutes on the spot and on our own – for instance, entering an address in a database. Delegating this task would take more time than doing it ourselves right away.

The ten-minute rule in turn targets those of us who tend to put off unpleasant jobs: Starting a task and allocating a limited period of time to it, and subsequently re-evaluating it, helps fight habitual procrastination. The advantage is that after ten minutes we may have already finished the task or at least found a beginning that will boost our motivation to pick up later where we left of.





Prioritizing tasks

Former World War II General and U.S. President Dwight D. Eisenhower would sort tasks into four groups by applying the criteria "important" and "urgent." A-tasks (important and urgent) he'd handle immediately. B-tasks (important, but not urgent) he'd put on his calendar. C-tasks (urgent, but not important) he'd delegate. D-tasks (neither important nor urgent) he'd occasionally just drop. **The Eisenhower Matrix** still works today. Ideally, it cuts our own to-do lists in half in next to no time.

Effective need not be efficient

We're effective when the result achieved matches or at least comes very close to the desired result. Here's an example: If I want to get from A to B walking may be effective. However, the time spent on a walk may be very long, depending on the distance, so driving would be more efficient. If only the time invested mattered, the fastest car would be the most efficient way to go. If the financial or energetic investment mattered more than time, a bicycle could be the better choice. However, all vehicles would be effective. "Smart working does not mean working more, but doing the right things and using new technologies so that work is practically like a product that flies off the shelf"

Thorsten Jekel in his book "Digital Working für Manager"

Motivation with a countdown

Having problems getting started? Motivational speaker Mel Robbins recommends to outsmart ourselves with a little trick. Just do a simple countdown: **5 ... 4 ... 3 ... 2 ... 1 ...** the psychological push triggered on zero can be reinforced by a physical act like reaching for a tool or putting on a pair of sneakers. It's worth a try!

The 80/20 rule – or when is "good" good enough?

Sometimes it's worth asking ourselves how much work we should invest in a project before we're satisfied with the result. Using the **Pareto method** (achieving 80 percent of the result with a 20-percent investment) can definitely save time. Here's a case in point: When painting a room, the large walls are finished quickly thanks to wide rollers and thick brushes. 80 percent of the work is done in 30 minutes. All that's missing is the clean edge and some touching up that's still required in a few places due to lacking opacity – these final touches take another two hours. And then the wall will disappear behind a closet. We could have saved the 80 percent for the remaining 20 percent. Needless to say, there are exceptions. Or would you like to fly with an airline that performs maintenance of its aircraft according to this principle?



of our productive time – according to experts – is lost due to poorly prepared meetings, floods of unnecessary emails, badly organized processes, and distractions of all kinds.

Decluttering life

A very important step toward leading an efficient life is to declutter it. Decluttering has become a global trend word. Japanese author Marie Kondo is the guru of the decluttering community. Her book "Magic Cleaning" has been sold in millions of copies around the world and translated into 30 languages. The most important rule of her **KonMari method** is to ask yourself: Does this thing spark joy? Because it's useful, or simply because you feel it's beautiful. If it does, it can stay. If it doesn't, it gets ditched. Perhaps we should use this rule for entries on our calendar – at least our social ones – as well. By replacing "sparks joy" with "important for work" we can also apply this method to our own desk or the whole office.

#EVERYDAY LIFE

Learning properly

As far back as in the late 19th century, the German psychologist Hermann Ebbinghaus described correlations between learning and retaining. His most important finding for efficient learning: We can remember things for longer periods of time by taking breaks during our learning processes. Ebbinghausen called this the **spacing effect.** Although we'd expect exactly the opposite to be true, the brain keeps using new nerve cells during consecutive learning phases. But when we expand the spaces between learning phases nerve cells previously used for them will be reactivated. This causes them to increasingly interlink and boosts their capacities. Many neuroscientists have confirmed the spacing effect, although the exact reasons why slow learning is the better form of learning still remain a mystery to them.

Assessing risks properly

You're susceptible to Murphy's law ("Anything that can go wrong will go wrong") cramping your style? Then you might try using the **premortem method** like, for instance, Google's employees do. Prior to launching a new project, they usually meet for a "brainstorming session of doom" where, in an informal setting, they discuss potential scenarios that could impede or prevent a successful outcome, followed by analyzing the risks: which ones are improbable, and which relevant ones could be minimized and how? With that, all the demons have been named and stopped from haunting the project. Even if Murphy's law should materialize, the premortem method prepares us for and enables us to counteract negatives. In other words, even after making wrong choices we can take corrective action to minimize the resulting damage. Knowing this helps overcome obstructions to decision-making.





Higher efficiency = more free time: field trial in Iceland

A large-scale trial in Iceland has shown how much potential there is in eliminating waste of time and energy on the job. Between 2015 and 2019 the working hours of 2,900 public sector employees were reduced from 40 to 35 or 36 per week – with no reduction in pay. The results were positive across the board: Productivity remained at the same level as before or even increased. Team members and supervisors reported that they were enjoying a better work-life balance due to having more time for family and hobbies. At the same time, a range of actions were taken to compensate for the shorter working hours: Tasks were organized more efficiently or delegated, meetings were held in shorter and more compact formats or even replaced entirely by emails.

Going forward, Bjarkey Olsen Gunnarsdóttir, a member of the Icelandic parliament, said, "We should continue on this journey, and I believe the next step is to reduce working hours to 30 hours per week." Like the Icelandic government various companies have been testing new working hour models. At Microsoft in Japan, for instance, productivity increased by around 40 percent after the corporation had introduced the four-day work week.

Masthead

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