Creating Chemistry

BASF'S SUSTAINABILITY MAGAZINE

ISSUE 10 ▸ 2021

A new look at energy

Our hunger for energy continues to grow. How can we meet increasing demand while simultaneously protecting the climate?

BASF
We create chemistry

Dear readers,

The coronavirus pandemic has governed our lives in recent months and forced us, all over the world, to face up to previously unknown questions. At the same time, we cannot and must not neglect fundamental challenges such as climate protection. More and more countries throughout the world are working to implement the aims of the Paris climate protection agreement, and the European Union has used its Green Deal to formulate the climate goal clearly for the continent: to be climate-neutral by 2050. This plan is very ambitious, and will require more creativity, innovation, and international cooperation than ever. Energy supplies that are obtained from renewable sources will play a key role in this. Our cover story examines how the switch from fossil fuels to renewables can succeed.

For us, as BASF, climate protection and energy have long been very important topics. As part of the chemical industry, we are indeed using our innovative products to lay the foundations for a low-carbon future. However, our own carbon footprint is still too big, and that is something we aim to change. For this reason, we are working hard on fundamentally new, low-carbon production processes to enable us to significantly reduce greenhouse gas emissions. In this issue, we explain why we need large quantities of renewable energy at competitive prices in order to achieve this. This requires policymakers to urgently create the framework for a successful transformation in the industry.

We also need to work faster on digitalization; the coronavirus pandemic is making that very clear. Up to 40,000 BASF employees have worked temporarily from home, and this made things a lot easier during the crisis. In this issue we also discuss how mobile working is making long-term changes to the way we cooperate with each other. By adopting an open attitude to modern technologies, I am sure we will be able to achieve ambitious climate protection goals while at the same time increasing our value creation.

I hope you enjoy reading Creating Chemistry!

Dr. Martin Brudermüller
Chairman of the Board of Executive Directors,
BASF SE

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PHOTO: BASF SE

Energy in focus

The future of energy is renewable, and that's good news for the climate. How ambitious targets aim to increase production and reduce consumption.

By 2030

→ **57 percent** of the energy mix in the E.U. will be made up of renewables, according to predictions. In 2018, the figure was 32 percent.

→ **50 percent** of power generated in Africa is set to come from renewable sources. In 2018, it was 20 percent. Excluding hydropower, it was 5 percent.

Power for all

According to the United Nations' Sustainable Development Goals, **100 percent of humanity** should have access to affordable, sustainable energy by 2030.

72 percent of the world's newly built power capacity in 2019 was based on **renewable sources**.

This means that in 2019 the capacity for power generation from renewable sources increased to **176 gigawatts**.

Sources: International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations

Energy in focus

Development is impossible without **energy**. But it needs to be clean, for the climate's sake. The only thing is – how? **Page 06**

Find the whole **world of energy** in our infographic, along with many interesting figures. **Page 16**

BASF's Creation Centers are designed to inspire innovation and creativity. We take a look inside. **Page 48**

"Moving waste up the waste hierarchy creates jobs."

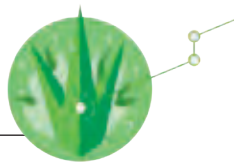
Professor Linda Godfrey manages South Africa's governmental Waste Research Development and Innovation Roadmap Implementation Unit. Hers is one of five different perspectives on the issue of waste. **Page 32**

The sun is a life-giver but its rays also damage the skins and surfaces of people, objects and animals. How do we protect them? **Page 26**

Working digitally from home but still all together on site - can this work? Experts are sure that virtual reality will make it possible. **Page 40**

PHOTOS: PAUL LANGROCK; LEMRICH STUDIO; GETTY IMAGES/DSIGN; GETTY IMAGES/EVA-KATALIN; CSIR

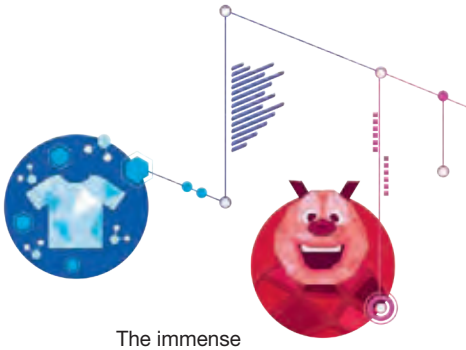
Contents



Focus

Science & environment

Technology & society



The immense computing power of **supercomputers** helps in many areas. **Page 46**

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PHOTOS: GETTY IMAGES / ISSARAWAT TATTONG; ILLUSTRATION: MATHIS REKOWSKI

Focus

Infographic
How nature supplies us with more and more energy.
Page 16

Interview
How can the world's poorest gain access to clean, reliable energy?
Page 18

Europe

Gwynt y Môr

Wales, United Kingdom

▸ WIND POWER

At this offshore wind farm in the Irish Sea, 160 turbines currently meet the energy needs of about 400,000 British households. Sea-based wind power is becoming increasingly competitive. According to the International Energy Agency, $1 trillion could flow into offshore projects by 2040.

Asia

Gaoyou project

Chuzhou, China

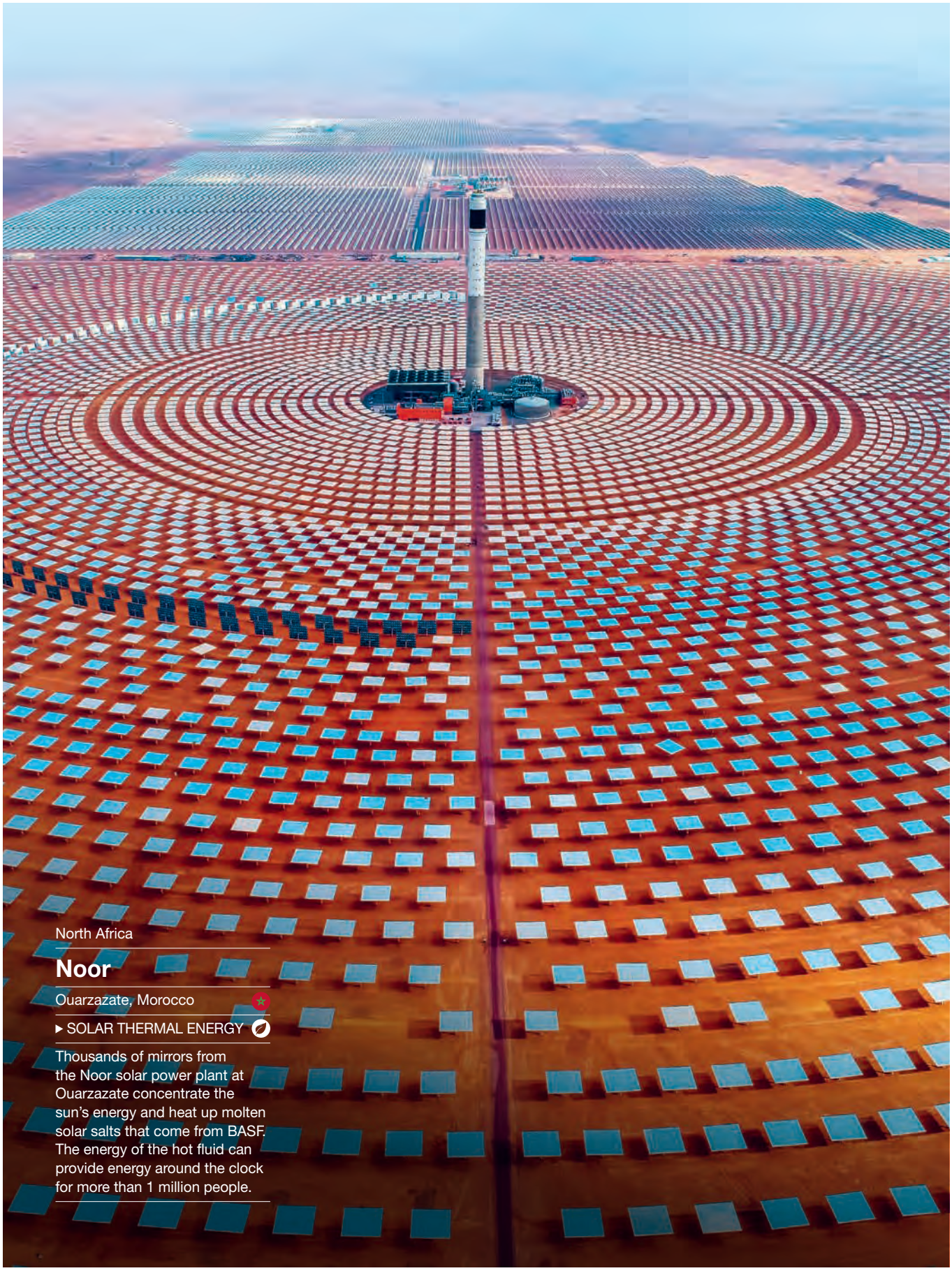
▶ PHOTOVOLTAICS (PV)

Land-saving solar farms such as this, built on Gaoyou Lake, the sixth-largest freshwater lake in China, are still rare. One advantage is that there is less shade out on the lake. The Rethink Energy consultancy estimates the global market for such floating PV plants at 62 gigawatts by 2030.

Energizing the world

We are facing a twofold energy challenge: meeting growing demand while also lowering emissions. This decade will be decisive for the transition from fossil fuels to renewables.

PHOTOS: PAUL LANGROCK; GETTY IMAGES/VCG/SONG WEIXING



North Africa

Noor

Ouarzazate, Morocco

▸ SOLAR THERMAL ENERGY

Thousands of mirrors from the Noor solar power plant at Ouarzazate concentrate the sun's energy and heat up molten solar salts that come from BASF. The energy of the hot fluid can provide energy around the clock for more than 1 million people.

PHOTO: PICTURE ALLIANCE/PHOTOSHOT

There will be light: 90 percent of all people have access to electricity.

Source: Energy Progress Report 2020

PHOTO: GETTY IMAGES / CATHERINE FALLS COMMERCIAL

Rows of mountain peaks, covered in snow for 150 days of the year – an idyllic winter picture-postcard scene in Zhangjiakou. Some competitions of the 2022 Winter Olympics are due to take place in this city of millions in China's Hebei Province. The aim is to offer more than just sporting superlatives: Beijing is promising "climate-friendly winter games." A strategy for the next 30 years, developed by Zhangjiakou with organizations including the International Renewable Energy Agency (IRENA), is to show the city the way to switch to renewables. Its mountainous, water-rich region offers excellent geological conditions for pumped-storage power plants and an estimated 30 gigawatts of solar power and 40 gigawatts of wind energy, according to the strategy. Zhangjiakou is intended to set an example for other cities in the country, as China looks for a sustainable way to manage rapid urbanization in the coming decades. Zhangjiakou became China's first National Renewable Energy Demonstration Zone in 2015, and forms part of the energy revolution that was enshrined in 2016 in the 13th five-year plan for the development of the Chinese economy. "The goal is to develop a clean, low-carbon, safe and efficient energy system by 2050," says Wang Zhongying, deputy director-general of the China National Renewable Energy Centre and a co-author of the strategy paper. ▸

The façade of the International School at Nordhavn in the C40 city of Copenhagen boasts 12,000 photovoltaic panels. These are intended to cover more than half the building's energy needs.

01

Energy production

From fossil fuels to renewables, energy systems are being transformed not only in China, but all over the world. Increasing the use of renewable energies such as solar and wind power is one of the central elements in achieving the Paris climate goals. This is because fossil fuels, such as oil, natural gas, and coal, are the biggest source of greenhouse gases resulting from human activities and lead to global warming. To limit global warming to less than 2 degrees Celsius, countries in the European Union are seeking to reduce their net carbon dioxide (CO_2) emissions to zero by 2050. Cities and regions all over the world are hurrying ahead with even more ambitious targets. Den Haag is planning to become climate-neutral by 2030, Reykjavik by 2040. Copenhagen has set the goal of becoming the world's first CO_2-neutral capital by 2025. It already has wind turbines supplying a large proportion of its energy.

The Danish capital is one of the C40 cities – a network of 97 major cities, from Addis Ababa to San Francisco to Karachi, that have come together to implement the Paris Agreement goals at local level. For example, since buildings are responsible for about half of all emissions in cities, it is planned that all newbuilds in New York and other C40 member cities should be able to operate on a climate-neutral basis from 2030. Since 2019, it has also been a requirement in New York legislation that all new buildings should be fitted with solar cells or have roofs covered with grass or other vegetation. The mayors of 35 cities, including Birmingham, Oslo and Tokyo, have committed themselves to order only emission-free buses from 2025.

Trend toward electrification

The share of electricity in overall energy demand will continue to rise significantly in the future, especially for the major energy guzzlers: mobility, heating, refrigeration. This presents the world with a dual challenge: people need more and more electricity as the hunger for energy grows at the same pace, while greenhouse gas emissions need to fall in parallel. The change that has happened in 2020 may be only short-term. "The coronavirus crisis did initially lead to a fall in CO_2 emissions on a scale we have not seen since the Second World War," says Professor Manfred Fischedick, Scientific Managing Director of the Wuppertal Institute for Climate, Environment and Energy, Germany. However, he adds, economic recovery and catch-up effects mean that pre-pandemic emissions levels will probably be reached again within just two years. The scientist demands a "consistent change of course toward clean energy systems," so that CO_2 emissions can fall on a sustained basis and effective measures to limit climate change can be implemented as quickly as possible.

"The measures that are taken in this decade will be decisive in determining whether climate protection succeeds or fails," warns Lord Adair Turner, Chairman of the Energy Transitions Commission (ETC), a global association of prominent figures from business, finance and society. The aim is both to reduce emissions quickly in order to limit the increase in CO_2 in the atmosphere and to achieve net zero emissions in the energy and industry sectors by mid-century. "To achieve this, energy efficiency must be improved and the use of carbon-based energy sources in electricity generation must be reduced. In addition, as much of the economy as possible must be

PHOTO: ALAMY/OLIVER FÖRSTNER

New York City lights its park on the East River in Brooklyn with solar power.

PHOTOS: GETTY IMAGES / ISTOCK / JAY LAZARIN; INETECONOMICS; ILLUSTRATION: JÖRG BLOCK

“The measures taken this decade will decide whether climate protection succeeds.”

Lord Adair Turner
Co-Chair of the Energy Transitions Commission, London, England

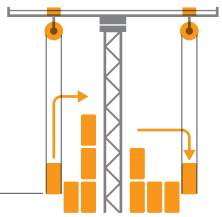
electrified with electricity from renewable sources,” explains Turner.

More renewable energy for the chemicals industry

This goal has been on BASF’s agenda for a long time. In its carbon management research and development program, the company is researching fundamentally new production technologies to enable energy-intensive industrial processes to be switched to a renewable energy supply. For instance, an interdisciplinary research team is working on projects that include the development of an electric-powered steam cracker. Naphtha is split into olefins and ▸

Energy storage: new ideas for more flexibility

Heavyweight storage facility
Gravity keeps us on the ground – and is also what makes possible a futuristic storage idea from the Swiss start-up Energy Vault. An automatic crane uses surplus energy from wind and solar power to lift large concrete blocks. The huge prototype energy storage facility is tapped when the weights are lowered to the ground again and run a generator.



Artificial atolls as energy islands
The concept of an artificial island off the coast of Denmark as an energy storage facility came from the Danish architecture firm Gottlieb Paludan in Copenhagen. If surplus energy is available, water is pumped out from the middle of the island. If energy is needed, it flows back and powers the turbines as it does so.

Liquid air for storing energy
Not magic, but physics. Air cooled to minus 196 degrees Celsius becomes liquid. In cryogenic energy storage systems, as they are known, surplus energy from renewable sources is stored temporarily in liquid air. When electricity is required, the air – already warmed and returned to a gaseous state – drives a turbine, which generates electricity. Highview Power in England is building a cryogenic battery with a 50-megawatt liquid-air storage system on a commercial scale for the first time.

London's biggest pedestrianized area, Broadgate, was temporarily covered by a surface that converted the footsteps of up to 60,000 people a week into energy. That energy was used for lighting.

Human beings as an energy source

Human body heat + gelatin = electricity
With this seemingly simple formula and years of tweaking, a team from the Southern University of Science and Technology in Shenzhen, China, managed to achieve output power of 5 microwatts (0.000005 watts), which is promising for possibly supplying medical sensors, for example, with power from body heat.

Producing power while chewing gum?
It may sound odd, but this was actually researched in 2014 at the École de Technologie Supérieure in Montreal, Canada. To do this, the scientists fastened a chin strap made of piezoelectric fiber composites (PFCs) to electric ear protectors. The movement of PFCs creates electric tension. However, the chewing of gum for 60 seconds generated output of only 18 microwatts (0.000018 watts).

Do not read on if you are easily disgusted
Researchers at the Delft University of Technology, Netherlands, have developed a toilet that uses human excrement to produce energy. Feces and urine are dried, converted into synthesis gas, and fed into a fuel cell.

aromatics – important building blocks for all chemical products – at temperatures of 850 degrees Celsius in petrochemical facilities. "If we succeed in converting the cracker from natural gas to renewable electricity, we could save up to 90 percent of the resulting CO_2," says Dr. Andreas Bode, manager of the carbon management research and development program at BASF in Ludwigshafen, Germany. The challenge is that the new steam cracker has to have a reliable supply of very large amounts of electricity, and at competitive prices. "For the steam cracker alone, we would need the electricity from more than a hundred large wind turbines," Bode says. "This also requires policymakers to make the big decisions to ensure that this works."

Differences in the electricity mix

In 2018, renewables accounted for 32 percent of the electricity mix in the European Union, 26 percent in China, 19 percent in India, and about 17 percent in the USA, Russia and Japan. Despite all the green rays of hope, global energy-related CO_2 emissions continue to rise. China demonstrates the dilemma: although the country invests the most in renewable energies of any country in the world, the energy hunger of this huge nation also makes China the global leader in coal consumption. Head of State Xi Jinping wants to change this in the long term and announced that his country will be climate-neutral by 2060. In the foreseeable future, however, China will continue to rely on electricity from

PHOTO: PAVEGEN

In 2017, the Swiss retailer Coop launched the world's first hydrogen-powered truck, with a maximum weight of 34 metric tons. It is helping to save about 70 to 80 metric tons of CO_2 a year, says the Association pro H_2 mobility Switzerland.

PHOTO: COOP

One metric ton of hydrogen contains, chemically, 33.3 megawatt-hours of energy.

Source: German Ministry of Education and Research

coal. The situation is similar in the USA, Japan and India, which rank second to fourth in the list of the world's biggest coal consumers. In 60 countries worldwide, including Bangladesh, Vietnam and Indonesia, coal-fired power stations with a capacity of around 580 gigawatts were at the construction or planning stage in 2019, according to recent calculations by 30 environmental and climate protection organizations for the Global Coal Exit List project. This is equivalent to an increase in installed capacity of about 30 percent of the amount of electricity presently available from coal.

Hydrogen is one source of hope in the energy transition, as no CO_2 emissions are generated in its production. Hydrogen is not merely a substance to power the future of the transportation transition. It also supplies energy in industry and is used in substantial quantities as a reaction partner in the chemical industry. The production of hydrogen currently releases large amounts of CO_2. "There is great potential for reducing CO_2 emissions in hydrogen production," Bode says. The subjects of BASF's research here include new, emission-free processes for producing hydrogen.

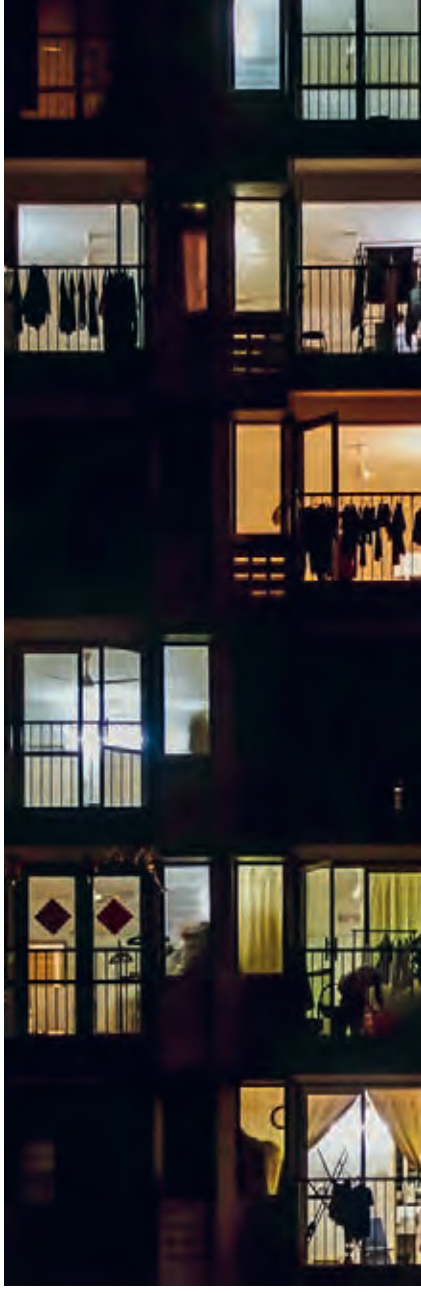
Increasing importance of long-term storage

Hydrogen is not only usable in industry or transportation, but can also be stored long-term in large quantities. In the future, this could be a solution to one pressing question relating to renewables: How can the surplus energy created on sunny and windy days be stored and then made available flexibly for those times when conditions are cloudy and windless? As well as hydrogen, stationary batteries are also suitable for the long-term storage of energy from renewable sources. The two technologies have different areas of application. Whereas hydrogen is suitable as an energy source for a period of several months, batteries are used as a long-term storage facility for energy for up to 12 hours. One tried-and-tested technology here comes in the form of NAS® batteries (sodium-sulfur batteries with high energy content). These are particularly suitable for the integration of renewable energies into power grids and can also support a constant supply of power in locally demarcated power networks known as island grids. BASF New Business is cooperating globally in their distribution and in the development of a new generation of NAS batteries with NGK Insulators Ltd., a leading Japanese company.

Producing emission-free energy and having it constantly available in the necessary volume is one side of the ▸

The global hunger for energy will grow by 25 percent by 2040.

Source: International Energy Agency 2018, scenario taking account of existing and planned laws.



02

Energy consumption

A lot of energy is needed – not just for digitalization, but also to make rooms livable. This makes energy efficiency all the more important.

coin. The other is energy consumption. How can we use less energy for the same or even bigger tasks? “The smart way,” says Jatin Nathwani, Professor of Sustainable Energy Policy at the Canadian University of Waterloo: “Advances in information and communication technologies are making it possible to build a networked world with a much smaller ecological footprint than today.” One practical example of the digitalization of the energy transition is the smart grid, which has been trialed since 2012 in the desert nation of Qatar. It is composed of networked computers that communicate with each other, managing electricity demand and automatically drawing on energy storage facilities. Small-scale digitalization could also help with the United Nations goal of finally including the 10 percent of people worldwide who are still living without electricity (see interview on page 18). “Digital technologies like mini-grids will bring electricity to rural, poorer communities without the need to invest in a huge centralized grid,” says Nathwani.

There are two sides to digitalization

We cannot win the fight against global warming without digital solutions. But at the same time, digital technologies have an immense hunger for energy. Intelligent networks, cloud applications in business, and the streaming of movies and music all mean that the daily volume of data handled is growing inexorably. According to a study commissioned by the U.S. International Data Corporation (IDC), every person with internet access in the Europe, Middle East and Africa economic area will by 2025 be using digital data in some form about 5,000 times a day, or once every 18 seconds – and every click consumes electricity.

PHOTOS: GETTY IMAGES/E+/FREEMIXER; GETTY IMAGES/EYEEM/CHUN CHEUH TANG

Which items use and produce how much power

To make units of measurement easier to understand, we have combined them with consumption values* – but these depend on many factors and vary by model and manufacturer. The averages and approximate values are therefore intended only as a rough guide.

1 watt

20 Wh
Smartphone
(10-watt power supply)
charged for two hours

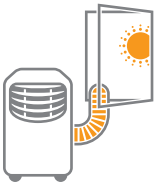
28 Wh
0.25 liters of water in a kettle brought to boil

Around 20 watts
Power of the **human brain**

1 kilowatt = 1 thousand watts

1 kWh
Ironing **15 shirts**
(one hour)

For 1 kWh
to be generated by a **dynamo**, you would have to pedal for 8–10 hours



600 kWh
a **mobile air conditioner** running 8 hours a day in summer for 30 days

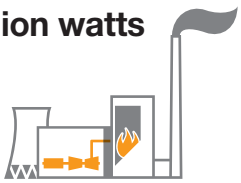
1 megawatt = 1 million watts

3.2 MWh
Electricity consumption per German household (2 people) 2018

1 gigawatt = 1 billion watts

451 GWh
Direct and indirect electricity consumption by Netflix in 2019

1 terawatt = 1 trillion watts



2 TW
Capacity of coal-fired power plants installed worldwide in 2019

1 petawatt = 1 quadrillion watts

24.7 PWh
Worldwide electricity consumption in 2018

* One watt-hour (Wh) is the amount of energy used by one watt of electric power over a period of one hour.

This means efficiency will become ever more important. According to Koomey's law, the energy efficiency of computers has doubled every 2.7 years since 2000. A similar trend is being observed in data transmission networks.

The problem here is that, in the past, the growth in use was greater than the gain in efficiency. Although processors are indeed yielding better and better performance with lower consumption, more and more people are simultaneously using more and more energy-intensive services. "To prevent this rebound effect, we have to raise the question of what is the correct amount – meaning, sufficiency," Fischedick says. In relation to digital technology, this means counteracting overconsumption – not constantly buying the latest smartphone, occasionally clearing your device's memory, and not letting your usage get out of hand.

The obstacle to energy-saving

The economical and sensible use of energy accordingly places a responsibility on the consumer. In theory, energy-saving can be as simple as taking a shower instead of a bath, cycling or using a carpool instead of driving on your own, and buying an efficient refrigerator but not continuing to use the old one in the cellar. Although people know all this, they find it hard to change their behavior, says Fischedick. Hardly anybody will give up cherished habits, convenience or time savings just for the sake of cutting back on energy. "Present-day societies actually change only once the pressure is already very great – when there is, in effect, hardly any alternative course of action left. However, in the light of the coronavirus crisis, climate protection may at last become a higher priority," hopes the Managing Director of the Wuppertal Institute. The team of the international consortium Affordable Energy for Humanity Global Change Initiative around co-founder Professor Nathwani focuses on participation for behavioral change: "Technological solutions for a sustainable energy supply are not enough; they must work in the respective cultural context." This means: take your time, listen to local people, and work together to find possible solutions. ■

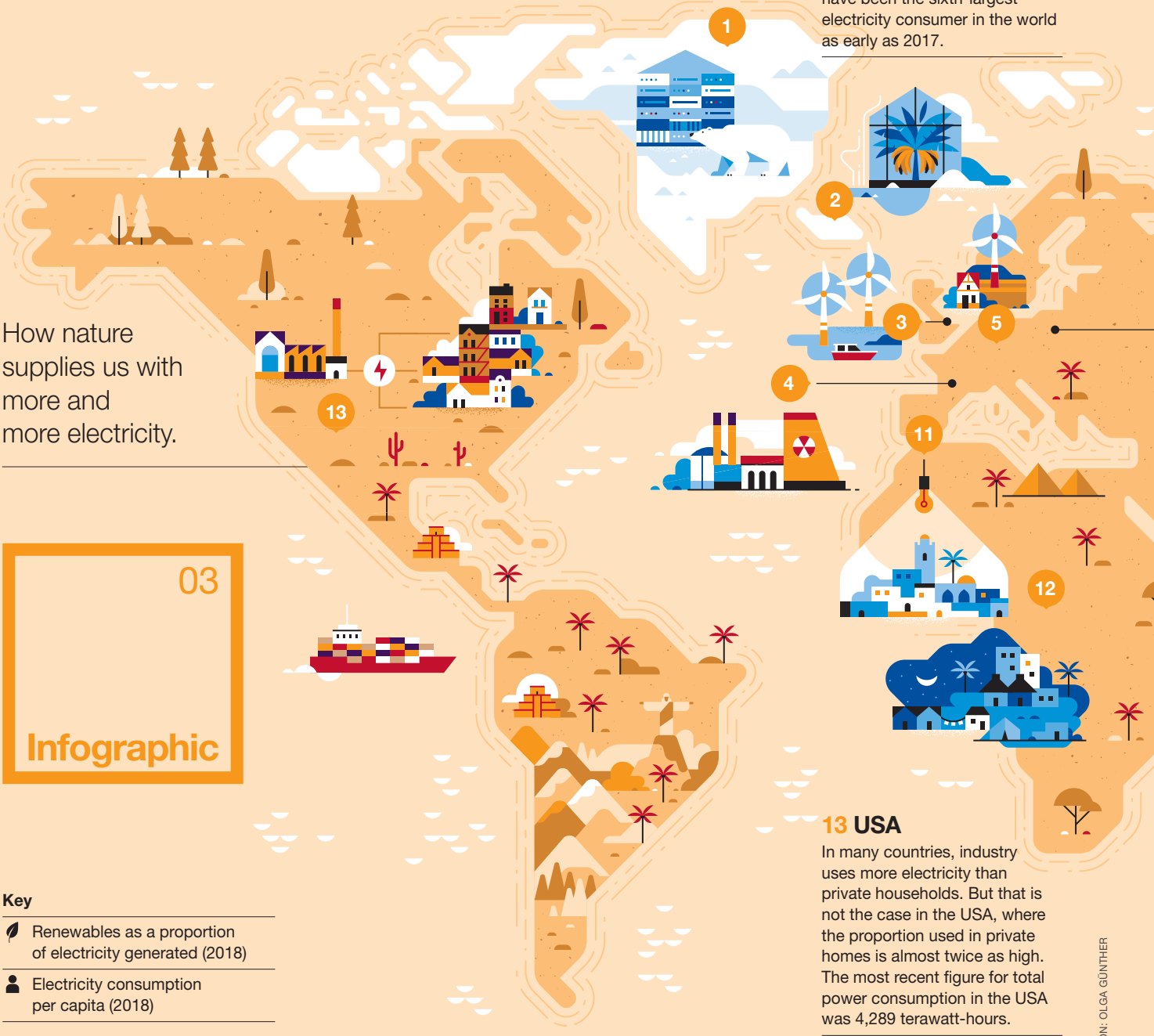
ILLUSTRATION: JÖRG BLOCK

The world as an energy producer

How nature supplies us with more and more electricity.

03

Infographic



1 Arctic Circle

Server farms are found more and more frequently in places such as Iceland, Norway or Alaska, where the cold conditions mean less electricity is used to cool the units. Nevertheless, digitalization requires a lot of energy. If the internet were a nation, it would have been the sixth-largest electricity consumer in the world as early as 2017.

13 USA

In many countries, industry uses more electricity than private households. But that is not the case in the USA, where the proportion used in private homes is almost twice as high. The most recent figure for total power consumption in the USA was 4,289 terawatt-hours.

- 17%
- 13.1 MWh

Key

- Renewables as a proportion of electricity generated (2018)
- Electricity consumption per capita (2018)

Sources:
International Energy Agency (IEA), International Renewable Energy Agency (IRENA), Greenpeace, REN 21, Endcoal

ILLUSTRATION: OLGA GÜNTHER

2 Iceland

The island nation has by far the highest per capita electricity consumption level in the world, mainly due to the aluminum industry. However, Iceland's electricity is completely climate-friendly, generated solely from hydroelectric and geothermal energy. Geothermal heat also enables bananas to grow despite icy temperatures – in greenhouses heated by hot water from underground.

100%
54.6 MWh

3 United Kingdom

Dogger Bank is due to become the world's largest wind power project, with what will also be the world's tallest wind turbine, at 260 meters, due to be in operation from 2023. According to the IEA, sea-based wind power is becoming increasingly competitive. Global capacity could triple to 65 gigawatts by 2024 and then account for almost 10 percent of the world's wind power production.

33%
4.9 MWh

4 France

The French obtain about three-quarters of their electricity from nuclear power stations – more than any other country in the world. That proportion is due to fall to 50 percent by 2035, with wind and solar power being significantly expanded.

20%
7.1 MWh

5 Germany

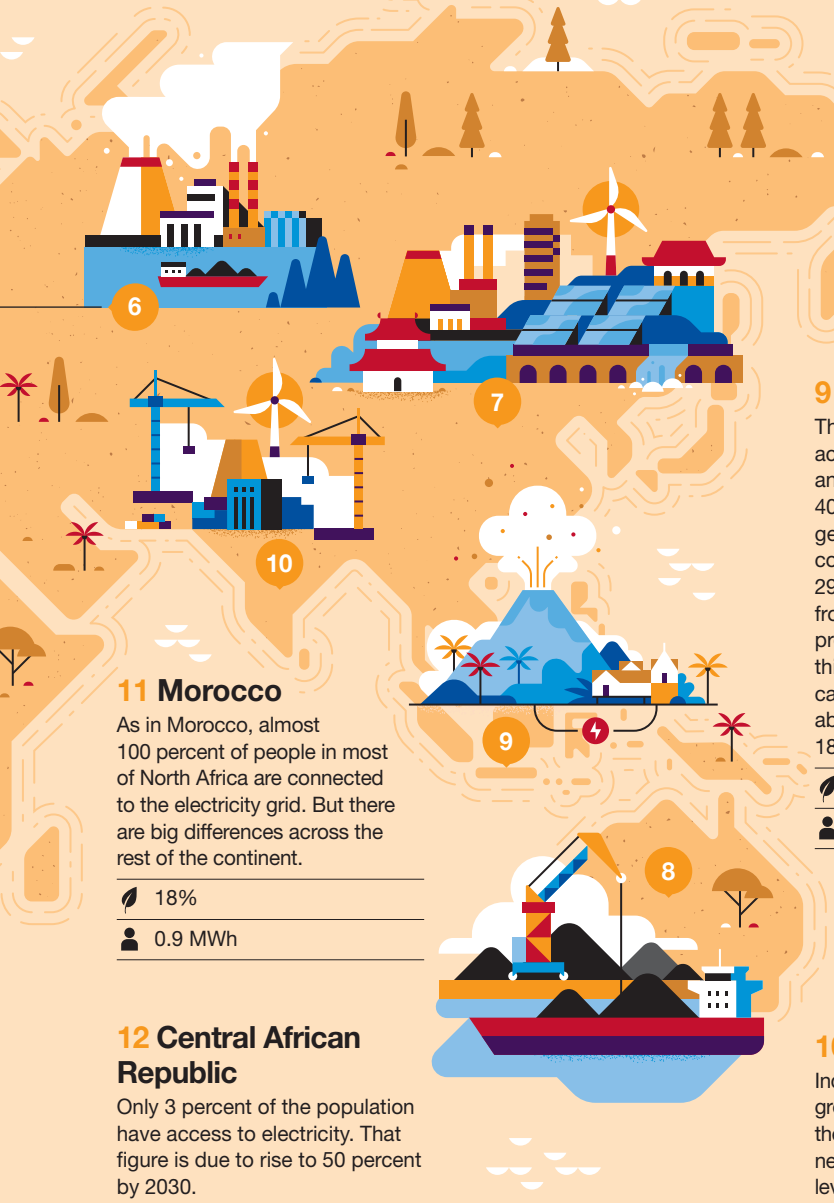
Globally, hydroelectric power is the dominant source of renewable energy production. In Germany, however, more than half comes from wind power. Regarding global wind power capacity, Germany ranks third – after China and the USA – in terms of megawatt-hours produced.

35%
6.9 MWh

6 Poland

Warsaw has so far rejected the European Union's goal of becoming climate-neutral by 2050. About 70 percent of its electricity comes from coal, which is used mainly by private households. That proportion is due to fall to 50 percent by 2050.

13%
4.3 MWh



7 China

China is the biggest producer and consumer of electricity, and the world leader in terms of installed capacity for renewable energy. At the same time, two-thirds of the world's new coal-fired power station capacity was commissioned here in 2019.

26%
4.9 MWh

8 Australia

Australia is the world's biggest exporter of coal, ahead of Indonesia, and at the same time also uses it to produce around 70 percent of its own electricity.

17%
9.9 MWh

9 Indonesia

This country has about 130 active volcanoes, more than any other. This gives it around 40 percent of the world's geothermal potential. Indonesia could probably obtain up to 29 gigawatts of energy a year from geothermal heat. At present, less than 10 percent of this is used. Globally, geothermal capacity is expected to rise by about 30 percent by 2024, to 18 gigawatts.

17%
1.0 MWh

10 India

India's hunger for energy is growing rapidly. According to the IEA, the amount of energy needed will double from today's level by 2040.

19%
1.0 MWh

11 Morocco

As in Morocco, almost 100 percent of people in most of North Africa are connected to the electricity grid. But there are big differences across the rest of the continent.

18%
0.9 MWh

12 Central African Republic

Only 3 percent of the population have access to electricity. That figure is due to rise to 50 percent by 2030.

Unknown
Unknown

Clean energy powers progress

How can the world's poorest people access the energy they need for health, education and economic progress? Rachel Kyte makes the case for an integrated approach that puts the needs of end-users first.

PHOTO: WEBB CHAPPELL

Rachel Kyte

Dean of The Fletcher School of Law and Diplomacy at Tufts University, Medford, USA

Kyte has spent many decades arguing the case for clean, reliable and affordable energy in developing regions.

She served as special representative of the United Nations secretary-general and chief executive officer of Sustainable Energy for All, an organization created to support the goal of universal access to sustainable energy by 2030.

Prior to that, she was World Bank Group vice president and special envoy for climate change.

Today, 840 million people around the world still do not have acess to electricity, and 2.9 billion people, more than one-third of the population, must burn wood, coal or agricultural waste to cook and heat their homes, according to the latest data from the World Bank. Lack of access to clean, reliable energy has a profound impact on health, welfare and economic prospects. Can the world find a way to close the energy gap?

Creating Chemistry: Why is energy such an important topic for developing countries?

Rachel Kyte: Ban Ki-moon, when he was secretary-general of the United Nations, described energy as the "golden thread" that runs through every other development goal. It is difficult, if not impossible, to deliver any form of development without energy. You need energy to provide healthcare, you need energy to heat, cool and light schools, and energy for the industry to make the things and create the jobs that we need. Yet in many developing countries, the centralized electricity grids perform poorly and do not reach large parts of the population. ▸

How are countries addressing these long-standing problems?
Rather than taking the traditional top-down approach to energy infrastructure planning, a few countries with large energy access gaps have been able to flip the question and ask, "Who doesn't have access to energy, and what access do they need in order to be productive within the economy?" Instead of spending millions of dollars to push extra gigawatts into a grid that loses lots of energy – and probably doesn't reach those end users anyway – you start to think about mixed solutions with a combination of centralized and decentralized approaches. Decentralized systems use local generation, often from renewable sources – mini and micro-grids for communities and institutions down to solar home systems at the household level. Sometimes these provide the only source of energy for communities beyond the grid, and can also offer resilience alongside grids, especially for low-income and vulnerable communities. Countries that have adopted that approach have made rapid progress.

04 Interview

Which countries have made the most progress?
Ethiopia is an interesting example. The last few years were dominated by the construction of mega-dams on the Nile. But the Ethiopians realized that a large number of their citizens, particularly in rural areas, don't have access to the energy they need. So now Ethiopia is building out ambitious plans using decentralized renewable energy in those parts of the country.

Another good example is Kenya. In 2002, less than 20 percent of the country's population had access to electricity. By 2018 that figure had reached 70 percent, depending on the data source. By any measure, that is great progress. It did that by embracing geothermal, wind and solar power at scale. Kenya has also benefited from its well-established "mobile money and electronic payment" systems. The country has become the world's crucible of learning for decentralized home solar systems and microcredit, where you pay by the unit of energy using your mobile phone.

Which other regions are adopting innovative approaches?
There are examples of new approaches all over the world. Chile and Argentina have both run very substantial programs, bidding out energy contracts that have been won by renewable energy contractors. That has allowed them to expand the availability of reliable, affordable, clean energy. Bangladesh has used a different model, with rural electrification agencies, which provide households with small-scale solar power systems at low cost.

Will the developing world's energy systems evolve differently from those elsewhere?
Yes. I believe there are several trends that will shape the development of these energy systems. First, there is decentralization, which will help with the provision of energy to remote communities, to large rural communities and even to shanty towns on the edge of major urban areas. ▸

Kharzanir, Bangladesh
Bangladesh has one of the biggest domestic solar energy programs in the world. In a country where more than one-fifth of the rural population lacks access to electricity, small-scale solar home systems have been installed in 5.8 million households. Solar energy is also used to power streetlights, cookers and irrigation pumps.

"It is difficult, if not impossible, to deliver any form of development without energy."

PHOTO: VISUM / PANOS PICTURES / ARGOS / LAURENT WEYL

Lake Turkana Wind Power Project, Kenya
Africa's largest wind farm has 365 wind turbines. It provides reliable low-cost energy to Kenya's national grid, making up approximately 17 percent of the country's total installed capacity.

Those systems may operate independently of the grid, or may work as a complement to it, improving the resilience of the energy system.

Then you have digitalization, which allows you to provide energy at greater levels of efficiency and enables you to take an Internet of Things approach, using devices and appliances that adapt automatically to changes in the price and availability of power. We are already seeing a lot of interest in developing countries in those types of technologies.

What about pollution?
That is the third big trend. These countries want to enable access to energy, but they don't want to have the air-quality and pollution problems that the developed world has. The good news is that the prices of solar and wind power have both tumbled over recent years, and the price of storage is now falling too. Countries are asking whether they can leapfrog from their fossil-fuel powered, centralized energy systems to grid-connected, scaled modern renewables.

With storage and the huge renewable energy resources that many of these countries have, they could become energy exporters. Morocco is already exploiting concentrated solar power in solar thermal power plants. It doesn't just deliver a high level of energy provision within the country. It also positions Morocco as a strategic exporter of energy.

As both the developed and developing worlds decarbonize their energy systems, will they use different technologies?
I think there will be some important differences. The Indian support for the International Solar Alliance, for example, is driven by the vision of exploiting solar energy in the tropics, which is where the most intense sunlight is available. They are looking at a range of different ways of capturing that energy. Another important topic is to find effective ways of using solar energy for cooking, both at large scale and at the level of the individual household.

Beyond electricity, do countries also need to focus on the availability of other types of energy?
Certainly. The availability of cleaner cooking fuels is one important area. And whereas sustainable transport in the developed world tends to focus on the electrification of private cars, in the developing world it is trucks and buses that are far more important for moving people and goods around cities.

PHOTO: GETTY IMAGES/AFP/SIMON MAINA

Muara hydropower plant, Bali
The first mini hydropower plant in operation in Bali, Indonesia. Two 1.15 megawatt turbine generators produce electricity by harnessing the power of the river.

Maibarara geothermal power plant, Philippines
Geothermal fields supply about 12 percent of the nation's energy. With large untapped sources of volcanic heat, the plan is to double that figure.

steps do not need to cost an exorbitant amount. Prioritizing the delivery of reliable, affordable energy into healthcare settings would be a great place to start.

What actions should those bodies take over the long term to promote clean, accessible and reliable energy?
Countries should take care of their regulatory frameworks, so providers of decentralized energy technologies can operate alongside the centralized electricity grid. I would like to see countries creating integrated energy plans, with a real focus on the needs of the end user. Such plans would help countries to direct the big investments, such as large-scale renewables or improvements to national and international grid connections. They would also help the allocation of resources at the local level, in distributed energy programs, energy-efficiency measures and low-tech climate-resilient architecture. The significance of those smaller-scale efforts should not be underestimated. They do a lot to improve resilience and they create a lot of jobs. And that is exactly what the world needs as it charts its recovery from the current crisis. ■

Finally, there is a pressing need for cooling technologies that are hyper-efficient, hydrofluorocarbon-free and reasonably priced. With a rising population, increased urbanization and a hotter planet, cooling will be the difference between life and death in places such as Southeast Asia and West Africa.

What do you see as the most urgent energy priorities for governments, development agencies and other stakeholders?
The coronavirus crisis has revealed how poor energy provision creates a lack of resilience in societies and economies. You can't protect your population if your clinics don't have power, or if you can't keep vaccines cool. I think governments – even the poorest – are recognizing the need to invest in their energy systems. First

"I would like to see countries creating integrated energy plans, with a real focus on the needs of the end user."

PHOTOS: BASARA HYDRO; GETTY IMAGES / AFP / NOEL CELIS; WEBB CHAPPELL

Energy transition at BASF

BASF is serious about climate protection and intends to make increasing use of emission-free wind and solar energy at its sites. Fluctuating production volumes and high electricity procurement costs are just some of the challenges that still have to be overcome.

05

On the ground

The BASF site at Schwarzheide in the German state of Brandenburg, located in the Lower Lusatia lignite-mining region, has what it takes to become a laboratory for the energy transition in the chemical industry. One wind turbine after another extends its blades into the sky north of the BASF site, not far from this landscape dominated by open-cast coal-mining. More than 360 megawatts of capacity from renewable energy sources have now been installed in and around Schwarzheide, and another 300 megawatts are planned. This means much more renewable energy is being produced than consumers in the region are using – and in some cases it is actually more than the grid can take. “Our situation is a glimpse into the future,” says Dr. Robert Preusche, Head of Renewable Energy Transformation for BASF at Schwarzheide. “The proportion of renewables in the electricity mix around Schwarzheide is already at levels that the German federal government is seeking nationwide by 2030 or 2040.” However, a

PHOTO: BASF SE

The BASF site at Schwarzheide is aiming to use renewable energies on an industrial scale with security of supply.

PHOTO: BASF SE

few technical and political challenges still have to be overcome before BASF can use energy from renewable sources on a large scale at Schwarzheide or other sites.

Verbund sites need a lot of energy

Even if there is a lull in the wind or thick cloud cover, the quantities of electricity from renewable sources that are needed for production will still have to be available in the future. BASF's six major Verbund sites worldwide, in particular, need a lot of energy. These include Ludwigshafen, Germany, where more than 200 production facilities, energy supply, logistics, and infrastructure are intelligently integrated and connected with each other. In this Verbund system, one plant can, for example, use another plant's waste heat as energy and use by-products as raw materials for making other products. Energy at Verbund sites is currently produced as far as possible in BASF's own highly efficient gas and steam power plants, which emit around 50 percent less CO_2 per megawatt-hour of energy produced than the electricity mix in the public grid.

"We can restructure our internal energy supply to enable us to use electricity from renewable sources instead of natural gas, but the volumes of electricity that the site will then need are not yet available in the region and cannot yet be transported to Ludwigshafen through the existing power networks," says Markus Scheuren, Head of Energy Verbund Management & Legislation at BASF in Ludwigshafen.

Grid charges and levies increase the procurement cost of green electricity

High grid charges and levies for electricity procurement are another major obstacle to using more green electricity in production in Germany. "As soon as we buy in electricity, whether it is green or grey, from outside, we have to pay levies on top of the regular electricity price," explains Dr. Roland Merger, who is responsible for renewable energy for BASF worldwide. "If we produce the electricity locally in the existing facilities at our own sites, those network charges and levies do not apply. We can only produce competitively by using our own electricity." He adds that usually there is simply not enough space to produce large quantities of green electricity ourselves at BASF sites.

For this reason, Jürgen Fuchs, Chairman of the Management Board at BASF Schwarzheide, stresses that "we need renewable electricity at competitive prices in order to be successful. Only then can we implement our plans in Brandenburg and really make use of renewable energies – in particular, for the new facility for making battery materials from 2022."

Despite all the challenges that still have to be met, a total of 23 locations in Europe, North America and Asia were already being supplied with emission-free electricity in 2019 – either through the direct purchase of renewable electricity or through renewable electricity certificates. For example, in Canada, BASF and Bullfrog Power, a large Canadian renewable energy provider, entered into a partnership in 2018. Since then, BASF has been using renewable electricity for its Canadian headquarters and other production facilities based in the country's most carbon-intensive provinces, thereby decreasing its national carbon footprint by 50 percent in Canada. By the early summer of 2020, BASF had reduced its CO_2 emissions by about 6,000 tons.

BASF developing low-emission production processes

Every one of these steps is closely connected with BASF's sustainability strategy, which has climate protection as a central component. "The path leading to the energy transition is a huge challenge for the energy-intensive chemical ▸

"We are approaching the energy transition with determination and are building a climate-friendly chemical industry."

Dr. Martin Brudermüller
Chairman of BASF's Board of Executive Directors

A steam cracker powered by green electricity could save up to 90 percent of CO_2.

Source: BASF

The heart of the Verbund site at Ludwigshafen is the steam cracker. It will be switched to renewable energies from about 2030.

sector in particular. This makes it especially important for us to approach this challenge with creativity and determination and build a climate-friendly chemical industry," says Dr. Martin Brudermüller, Chairman of the Board of Executive Directors at BASF. In recent decades, BASF has already significantly reduced its CO_2 emissions by optimizing its energy generation and its production processes. To reduce greenhouse gas emissions even further, BASF researchers are currently working to develop fundamentally new, low-carbon production processes, which are due to come into use from about 2030, as a matter of high priority. "We are concentrating here on the production of basic chemicals, since these are responsible for about 70 percent of the chemical industry's greenhouse gas emissions," Brudermüller says. "With electrification and new processes involving power from renewable sources, we may be able to produce those basic chemicals with almost zero emissions in the future. This will roughly triple our electricity demand at Ludwigshafen alone."

Schwarzheide investing in the energy transition

At the Schwarzheide energy-transition laboratory, meanwhile, BASF's in-house gas and steam-turbine power plant is already being modernized. BASF is investing €73 million to enable it not only to generate electricity and steam with an even smaller carbon footprint in the future, but also to use wind and solar power to supply its production facilities. "We aim to use our pilot project to prove that renewable energies can be used on an industrial scale despite the chemical industry's great need for security of supply," Management Board Chairman Fuchs explains. The modernized power plant at the BASF site will be better able to absorb fluctuations and to be powered up or down within minutes, depending on whether or not enough electricity from renewables is available.

In addition, a plan is currently being worked out to test two different battery storage systems. The first involves stationary NAS® batteries, which are based on tried-and-tested sodium-sulfur technology from Japanese manufacturer NGK Insulators Ltd., and are being distributed and refined by BASF subsidiary BASF New Business. For the second, BASF's Intermediates division is supplying one of the two electrolytes for organic redox flow batteries from the energy storage company JenaBatteries. It is intended that the tests of battery storage systems will use renewable energies to ensure a stable and reliable supply. "It is important that we at Schwarzheide act here and now to set a course and to try out integration, because the chemical industry in the future will be based much more firmly on electricity from renewable sources," Fuchs stresses. ■

PHOTO: BASF SE

Hydrogen

H

Atomic number
1

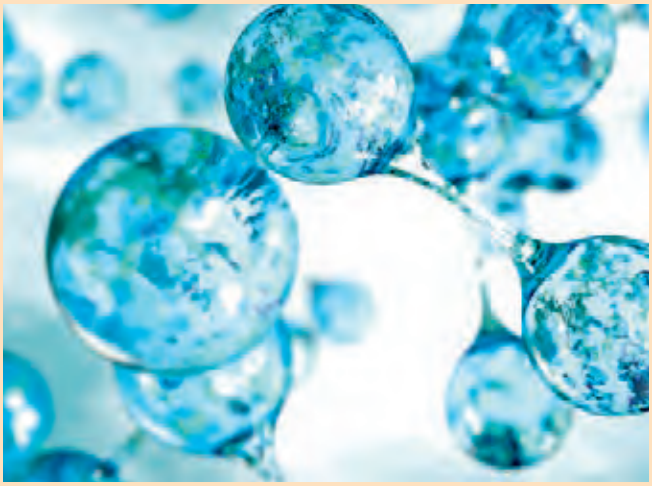
Physical state
Gaseous (H_2)

Atomic mass
1,008 u

Occurrence
93 percent of all atoms in the universe are H atoms

Year discovered
1766

The most common element in the universe is also the lightest, with an atomic mass of just 0.000000000000000000000000166 grams. Hydrogen is very volatile and highly flammable and therefore very high-energy. Its great advantage is that it burns without emitting CO_2. When used in power plants or fuel cells to generate electricity, this source of energy produces pure water as a by-product. The challenge is that it occurs on Earth only in bonded form, such as in the H_2O water molecule. A lot of energy is required to split this compound of hydrogen and oxygen. Only then can hydrogen provide clean electricity.



All the things hydrogen can do today

Fuel
Oil refineries use hydrogen to lower the sulfur content of gasoline and diesel. However, the gas is itself also a fuel for electric vehicles with fuel cells, or for rockets.

Foodstuffs
Hydrogen is an important helper for the food industry. The element is used, for example, to produce sugar substitutes or hardened fats.

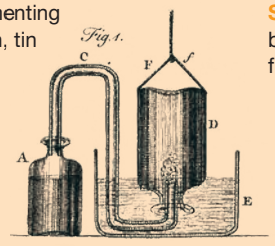
Energy storage
Electricity from solar and wind power can break water down into its chemical components and be stored temporarily in hydrogen. Devices such as fuel cells convert this back into clean energy.

Fertilizer/chemicals
Hydrogen is used to make ammonia, an important precursor for fertilizer. The element is, in general, a central reaction partner in chemical production.

Milestones in the history of hydrogen

1766

Henry Cavendish discovers hydrogen while experimenting with zinc, iron, tin and acids.



1838

Christian Friedrich Schönbein builds the first fuel cell.

Since the 1950s

Hydrogen has been used as **rocket fuel**.

1966

The first **fuel cell vehicle** comes onto the market.

Everything under the sun

The sun is essential for life, but overexposure harms people, animals and the materials we use to build our world. Protection comes in some surprising forms.

PHOTO: DAVID BEHAR

How not to waste waste
A panel of experts give their views on how to tackle waste.
Page 32

Freshly printed
How 3D printing is boosting people's health.
Page 38

Damage from UV exposure is cumulative.

"The sun never repents of the good he does," said Benjamin Franklin, one of the Founding Fathers of the USA. "Nor does he ever demand a recompense." It rises every day and we think nothing of it, but without the sun our planet would be uninhabitable.

The sun, a giant nuclear reactor, provides us with the heat and light that are essential to all life on Earth. Its rays also help our bodies make vitamin D, which in turn helps us absorb calcium and phosphate from our diet – minerals that are important for healthy bones, skin and muscles. It boosts our immune systems and releases mood-enhancing serotonin. But too much exposure to the sun's ultraviolet (UV) radiation is detrimental to everything on Earth – humans, animals, plants and objects. Dermatologists say there is no such thing as a "healthy" tan. Tanned skin is damaged skin.

Ultraviolet radiation from the sun reaches us in wavelengths between 100 and 400 nanometers (billionths of a meter). Around 5 percent of UV radiation is UVB, which only penetrates into the epidermis, while 95 percent is UVA. This can penetrate far deeper, though both UVA and UVB rays can cause skin cancer. And it's not just humans that need protection – animals do too. In Cambodia, rats trained to sniff out deadly landmines need to have their ears covered in sun-block to allow them to carry out their life-saving work.

The reason for reddening

General awareness about the risks of sun exposure is growing, but it was only in the last decade that researchers, led by Professor Richard Gallo, Chair of ▸

When the UV index is very high, not only sunscreen but also hats, sunglasses, long clothes and umbrellas can be needed for protection.

The six skin types

Developed in the 1970s by U.S. dermatologist Thomas Fitzpatrick, the Fitzpatrick scale remains the recognized guide to how likely skin is to suffer sun damage. It is even used as the basis for skin color in emojis.

Type I
Skin: pale white, often with freckles, burns easily and does not tan
Eyes: blue or green
Hair: blond or red

Type II
Skin: fair, sometimes tans but usually burns
Eyes: blue or green
Hair: blond

Type III
Skin: light brown, tans easily but still burns
Eyes: hazel or light brown
Hair: dark blond or brown

Type IV
Skin: light brown or olive, tans easily and seldom burns
Eyes: brown
Hair: brown

Type V
Skin: brown, tans easily and burns very rarely
Eyes: brown
Hair: brown or black

Type VI
Skin: deeply pigmented dark brown or black, becomes darker with UV exposure, does not burn
Eyes: brown
Hair: black

the Department of Dermatology at UC San Diego, USA, discovered why our skin reddens.

It is part of a process to alert the body that it is in danger. When skin cells are damaged by UV rays, it causes a type of ribonucleic acid (RNA) within those cells to break up. Our bodies become aware of the damage to the RNA because it is detected by what are called receptor molecules in neighboring cells. The receptor molecules instruct the body to inflame the skin around the damaged cell – which is what we experience as sunburn. “The reason for the inflammation is to clear away the sun-damaged cells,” says Gallo. “But it’s not only clearing, it’s actually alerting the body that the damage has occurred so you can have the appropriate response.”

As well as tests on human skin cells, the team carried out a study in mice and found that those without the receptor molecules did not have as much of a redness response. “At one point everything became predictable as a pathway,” says Gallo. Thanks to the research we now know that the receptor molecules are part of a process that warns us that our skin has been exposed to too much sunlight.

The right protection

While countries like Australia are doing a good job of getting sun safety messages across, others have a great deal of work to do, Gallo believes, with tanning still widely associated with exercise and outdoor activity. Cancer Research in the U.K., for example, has found a 150 percent rise in skin cancer deaths since the 1970s. “There’s this common misperception that tanning is healthy. But it’s very clear that there’s damage going on,” says Gallo.

Sunscreens to protect us from this damage have developed considerably since the first widely available product, developed by Austrian Franz Greiter, went on sale in 1946 with a sun protection factor (SPF) of just two. Getting the UV filters exactly right, however, can still be a

PHOTO: STOCKSY / BISUAL STUDIO

difficult balancing act, as products need to protect against the different kinds of UV rays while still feeling pleasant on the skin.

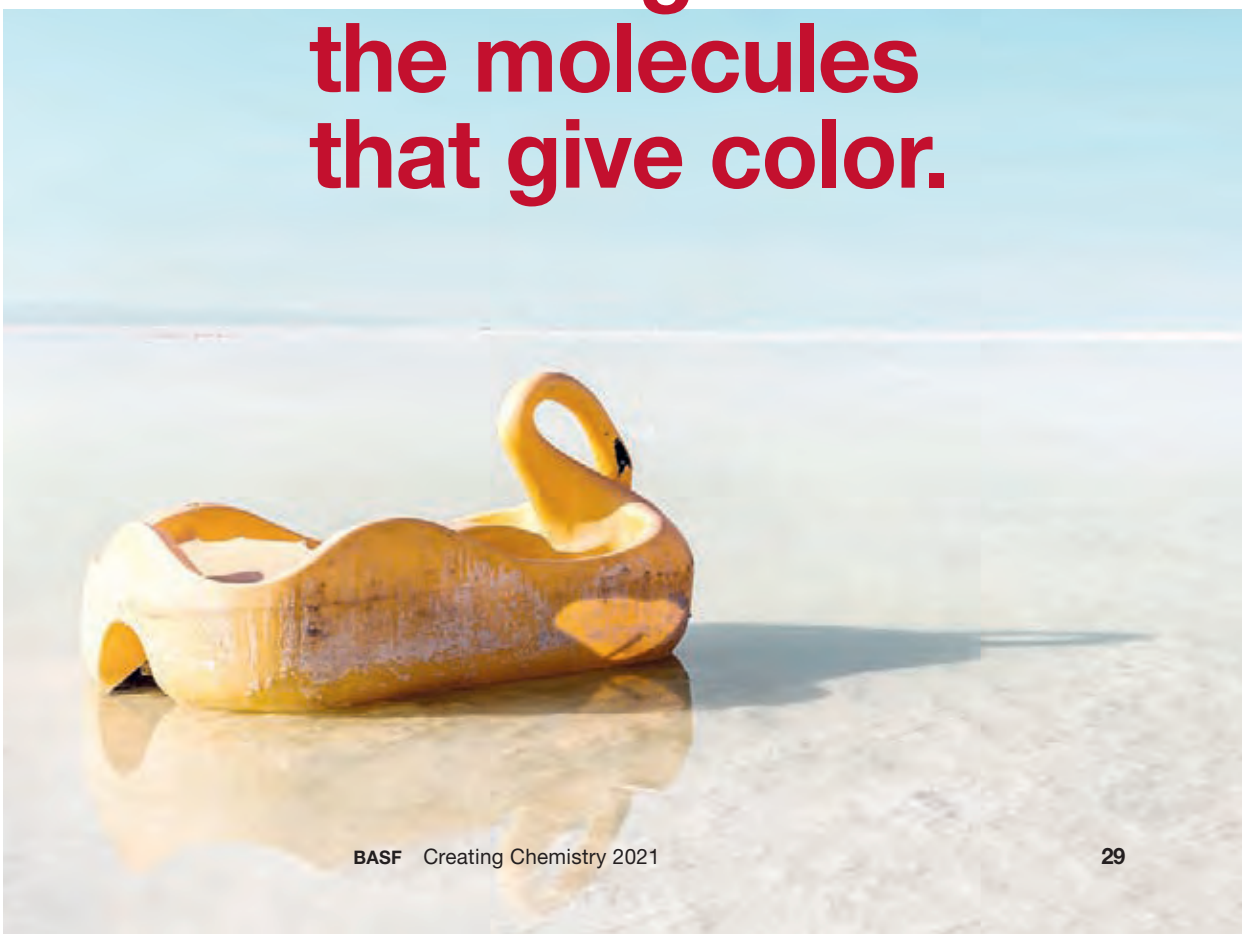
There are two types of UV filter: organic filters based on carbon, and inorganic filters based on zinc and titanium oxide. Organic compounds absorb UV light while inorganic particulates not only absorb but reflect and scatter the light. One organic example is BASF's Tinosorb® M. Around 90 percent of its action is via absorption and the rest through scattering. "We've chosen the most efficient molecules – an SPF 50 formulation absorbs 98 percent of the incoming UVB light, which is incredible with such a thin film," says Marcel Schnyder, Head of the Global Technical Center Sun Care at BASF in Grenzach, Germany. Sunscreen products made with it have a light texture and dry feel, while meeting the UVA protection guidelines of the European Union.

These improvements, along with growing awareness of the dangers, have led to growth in the use of sunscreen products. But there is also a cost. A 2015 study estimated that up to 14,000 tons of sunscreen end up in the world's oceans every year, potentially damaging coral reefs and marine life. This led BASF to launch the EcoSun Pass, which provides a comprehensive and transparent environmental evaluation of sun care products based on eight internationally recognized criteria including aquatic, terrestrial and sediment toxicity. "We created an algorithm that calculates the environmental impact of a sunscreen formulation, taking into account these eight parameters for each UV filter," says Schnyder. The EcoSun Pass value for a given formulation is normalized for its sun protection factor. This is to prevent sunscreens being rated "poor" because of their high efficacy and filter concentration. The higher the EcoSun Pass value for a formulation, the more environmentally friendly it is. "Customers are given a comprehensive evaluation of their product's filter systems, and manufacturers can develop sunscreens with the highest degree of environmental compatibility without compromising performance," says Schnyder.

Crumbling and cracking

But it is not just our skin that needs protection. The sun's radiation also affects everyday objects, weakening adhesives, causing colors to fade and reducing durability. Materials particularly at risk are polypropylene and polyethylene, which are found in a wide range of products, ▸

UV rays cause fading by breaking down the molecules that give color.



When a plastic surface is subject to the sun's blaze for long periods, it begins to "chalk," or whiten. This is the polymer surface starting to crack.

PHOTO: GETTY IMAGES/DOMINIKA ZARZYCKA/NURPHOTO

“Like any outdoor paint, the sculptures are going to fade.”

Julie Wolfe
Associate Conservator,
J. Paul Getty Museum,
Los Angeles, USA

Outdoor sculptures at J. Paul Getty Museum in Los Angeles are treated to protect them from the sun.

including plastic containers, clothing, cabling and machine parts. These things can crack or even disintegrate under the sun’s glare unless they are protected by light stabilizers.

“Bottle crates that stand in the sunlight begin to degrade in weeks. Then you can’t use them. But if you stabilize them you can use them again and again, for years,” says Daniel Müller, Head of Competence Center Film & Tape at BASF in Kaisten, Switzerland. “It’s the same with garden furniture. When it starts whitening, that is usually degradation of the polymer on the surface. With a stabilizer you can prevent this and prolong the lifetime.”

BASF produces two kinds of stabilizer – Ultraviolet Light Absorbers (UVA) and Hindered-Amine Light Stabilizers (HALS). HALS trap free radicals, which prevents surface cracking and helps maintain gloss. The best results are often achieved by combining the two. BASF’s Tinuvin® range comprises UV stabilizers for a variety of plastics, preventing color fading and other ageing signs. “With Tinuvin we provide protection and also repair of the polymer when it starts to degrade,” says Müller.

Exposed to the elements

It is frustrating when garden furniture fades, but the stakes are far higher with valuable artworks. The damaging effects of UV rays are something museums have to contend with all the time. At the J. Paul Getty Museum in Los Angeles, USA, outdoor bronze sculptures are protected with wax at least annually, with lacquers often added on top of that.

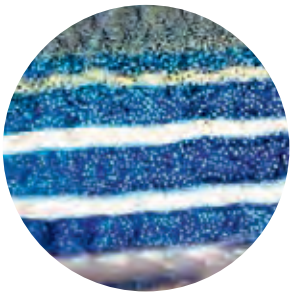
One of the main challenges is protecting a piece without compromising it. Julie Wolfe is Associate Conservator at the museum. “Right now, I’m focusing on the artworks of Roy Lichtenstein, who made painted outdoor sculptures,” she says. “The paint he originally applied was something he created using industrial automotive and artist paints. Like any outdoor paint, they’re going to fade and need to be repainted. Now that he’s no longer here, we have to try to recreate his technique.”

Learning how thick the brush strokes should be, replicating the exact shade of color from a faded one – that takes a lot of time and research. “If he’d painted swatches and stored them in a dark, protected space, it would be perfect,” says Wolfe. “But that rarely happens with artists!” ■

PHOTO: GETTY MUSEUM / JULIE WOLFE; ALAMY / ROBERT LANDAU

Natural protection

It's not just humans that need to be careful in the sun. Animals do, too. Some protect themselves using sand or dust, while others have developed more surprising methods.

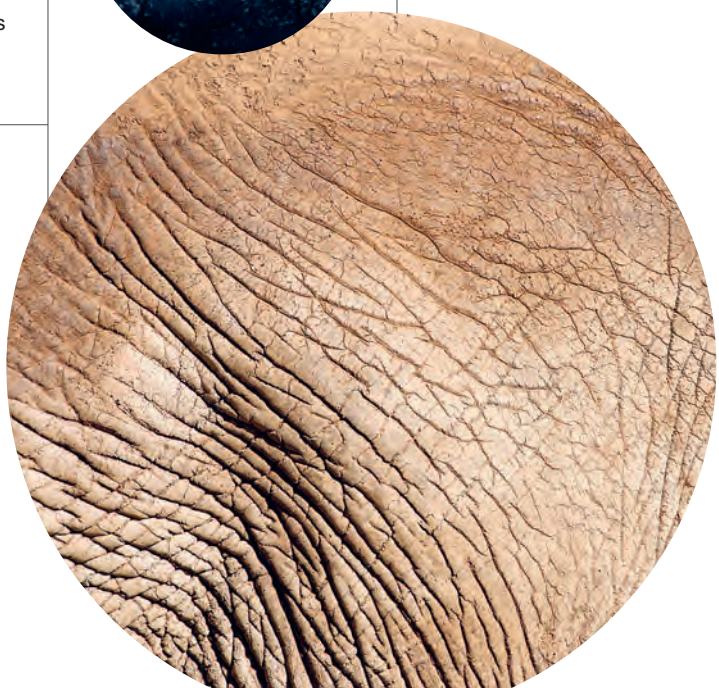


Fishing for protection

Although water absorbs UV rays, this is not the case in the first few meters. Freshwater **zebrafish** – a type of minnow – are able to produce a chemical called gadusol, which serves to protect them from UV penetration. The compound is found in shrimp and sea urchins' eggs. Reptiles, birds and amphibians are also thought to be able to produce it.

Whale of a time

Whales are susceptible to sun damage, and their defense is similar to our own. Researchers found that **fin whales** have high levels of melanin, the pigment that provides darker skinned people with protection from UV, while those with less melanin, like **blue whales**, are more prone to sun-related harm.



Don't sweat it

Hippopotami secrete a thick, gelatinous reddish orange "sweat" that acts as a natural sunscreen. While the red pigment contains an antibiotic to prevent infections, the orange helps to absorb UV rays. The pigments maintain their color for several hours before they polymerize into brown solids.

Muddying the waters

As well as regularly seeking shade, **elephants** coat themselves with mud. When the mud dries it becomes a thick and effective protective barrier against the sun's rays.

Tip of your tongue

Giraffes also have melanin – in their tongues. The first part the animal's extremely long tongue is much darker – purple or almost black. This is thought to be a result of higher levels of melanin that offer sun protection as the giraffe sources food. The part that is less frequently exposed to the sun is much pinker in color.

How not to waste waste

We have become all too familiar with growing mountains of waste across the globe, from overflowing landfills to plastics in our oceans. How can thinking of waste as a valuable resource inspire innovative ways to manage it effectively?

According to the United Nations, our global material footprint – the total amount of raw materials extracted from nature to meet human consumption demands – has increased by 70 percent since the year 2000. And the rate of extraction is accelerating, growing faster than population growth and economic output.

We are not using these resources effectively enough. Increasing food waste, throwaway fashion, the obsolescence of electronics and the burning of fossil fuels are symptoms of economies that do not recognize the value in end-of-life materials. This leads to the depletion of non-renewable resources and contributes to increased carbon emissions, climate change, environmental degradation and loss of biodiversity.

To work out how to tackle this problem, we talked to a range of experts who challenge us to rethink the very idea of waste and how we approach it, identifying system failures and developing new ways to capture its value.

PHOTO: GETTY IMAGES/RICHARD DRURY

From the bin to the shelves

Creating Chemistry: ReTuna is famous as the world's first shopping mall for used goods. Can you explain the concept?
Sofia Bystedt: We want people to enjoy coming here and experience shopping as though it was a designer mall. This is how the Circular Economy works in real life. ReTuna was set up in 2015 by the Swedish municipality of Eskilstuna as part of its commitment to finding innovative solutions for reducing environmental impact and creating sustainable social benefit. Local inhabitants drop off anything they don't want and we sort it into things that could be upcycled or send it to the municipality's recycling facility. ReTuna has 5,000 square meters of floor space that houses 13 upcycling shops. The shops pay rent for the space and receive free access to the goods donated. It's then up to them to find creative and profitable ways of adding value. We are a platform to inspire people and show the world that it is possible to sell reused goods at a profit. This year Ikea is opening its first ever second-hand shop in our shopping mall.

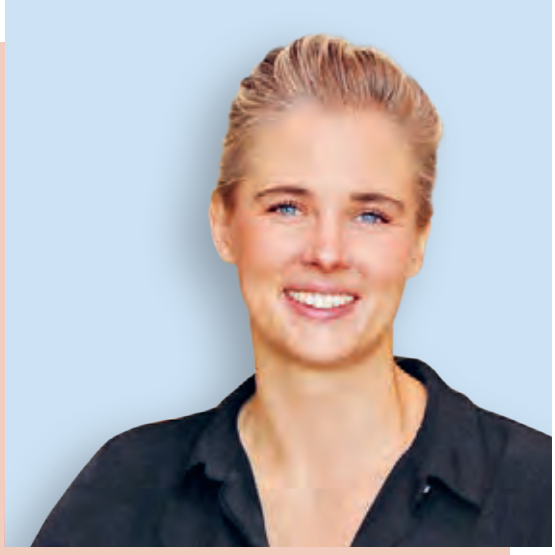
What kinds of things are recycled, and which are the most popular?
The most popular are electronics, followed by clothing, interior design and sports equipment. Home renovations have been popular during the Covid-19 pandemic, so we've had a lot of fridges, bathtubs and building waste. Working together to organize what goes where has been one of the key challenges of the project, but we have learned a lot!

Which are the most difficult items to resell?
We are overwhelmed with clothes. We run swapping events, catwalk shows and designer competitions; it's a real challenge for the sorters and upcyclers. Things like tube TVs or underwear are passed on to commercial recyclers. Cultural attitudes and economics are both important factors in reuse and upcycling – people here would rather buy new underwear, and they can afford to.

Have you developed other strategies to change consumer behavior?
We host conferences and events, run repair workshops and school programs. Our latest venture is working with ten kindergartens, encouraging pre-school children to think that reusing and recycling things is as normal as brushing their teeth every morning.

How do you measure your success?
First, the business model is working. We had a turnover of 14.9 million Swedish krona [€1.45 million] in 2019, and we have created over 50 jobs. We have, on average, over 700 visitors a day, from locals to tourists and climate change activists who travel here to visit us at the weekend. We hope to work with the Swedish Environmental Research Institute (IVL) to evaluate our workshops and outreach programs because it's very difficult to develop metrics for changing attitudes.

What advice would you offer other cities seeking to establish a similar system?
You can't just cut and paste this model somewhere else; you have to think about local markets, cultures and geographies. You also need a huge investment to start with, and a long-term commitment to support it. We are now an important institution in the town, and have set the benchmark for the values the municipality cares about. ■



Sofia Bystedt

Sofia Bystedt is the manager of ReTuna shopping mall for upcycled goods in Eskilstuna, Sweden. She has a background in communications and retail and a bachelor's in behavioral science from Stockholm University.

PHOTOS: GETTY IMAGES/TAHREER PHOTOGRAPHY; IKEA/HENRIK MILL; GETTY IMAGES/BILL DIODATO

Waste is a design flaw

Don Norman

Professor Don Norman is director of The Design Lab, University of California, USA, with academic degrees and industry experience in engineering, psychology and design. He is a member of the National Academy of Engineers and author of *The Design of Everyday Things* and *Emotional Design*. He is one of the founders of the field of human-centered design.

Creating Chemistry: Why do we produce so much waste, and why do we not manage it better?
Professor Don Norman: Many designers focus on the technical problems of recycling and seldom think about the people and wider systems involved. But recycling problems are just symptoms of manufacturing in the wrong way in the first place, like things that can't be reused or are difficult to fix. We also deliberately design stuff not to last for more than a couple of years, like smartphones. Often recyclable materials are stuck together in ways that make it impossible to separate them later.

What would be a better approach?
We should approach the problem from a human perspective. Human-centered design means solving the core problem not the symptoms, thinking about all the people involved, understanding the whole system and how people interact with it, and constantly prototyping potential solutions. Current waste management systems in the USA are an excellent example of the lack of human-centered design: it is almost impossible for consumers to understand how they should recycle everyday goods and packaging.

What design approaches are most useful for keeping products and materials out of the waste stream?
The three most important approaches are reparability, extendibility and reuse. Take cars, for example. Why can't I upgrade my old car and integrate new safety features? Why can't it later be sent back to the factory for the reuse of its parts? Because the business model of the car industry is to make profits by selling new cars. It's a system problem.

With whom must designers collaborate in order to achieve sustainable design outcomes?
With everyone! Plastic comes in such a wide variety of materials that knowing what can and cannot be recycled – where each recycling location follows different rules – is a mess. Notice that the soda and beer industries adopted aluminum cans, which are easy to recycle, and designers learned over the years that you could make them thinner and thinner, as the liquid inside creates outward pressure and keeps the aluminum under tension. In this case, designers, manufacturers, transporters and retailers all worked together to develop improvements.

How can design add value to the things we live with so that we treasure them for longer?
Design is not only about aesthetics, it's also about emotions. There are three levels of emotional response to something: visceral, which is our immediate response to a shape or surface effect; behavioral, our expectation of how the thing will act in response to us; and reflective, which includes our conscious thoughts about past, present or future projections. But you can't design things to be loved; that requires memories and stories to build up through use and time. ■

PHOTOS: GETTY IMAGES/TAHREER PHOTOGRAPHY; UCSD/LAURA TILLINGHAST; GETTY IMAGES/EYEEM/SILKE ENKELMANN; GETTY IMAGES/FOTOGRAFIABASICA

Waste is a valuable resource

Creating Chemistry: Your work focuses on the role of the waste sector in transitioning South Africa to a green economy. How can the country capture more value through recycling?
Professor Linda Godfrey: We need a paradigmatic shift to thinking about waste as a valuable resource, especially for a post-mining landscape. In 2014, we sent 17 billion rands [€900 million] worth of resources to landfill: polymers, nutrients and metals all lost to the economy. Economies of scale are required to make recycling successful, but we must avoid creating opportunities for overseas dumping. One area for unlocking incredible innovation is greater local recycling of electronic waste.

What do you consider the primary challenges to effective waste management in Africa?
First, we need to bring waste under control. Over 90 percent of solid waste is disposed to dumpsites and often burnt in the open. We need to extend collection services and transition to engineered waste disposal facilities for residual waste. Second, with growing consumption rates across Africa, packaging waste, in particular plastics, is causing increased environmental pollution. Third, we need to deal with the dumping of waste, especially hazardous electronic and chemical waste, in Africa by developed countries.

How can these issues be tackled?
We need willingness and leadership to address the waste issue at the highest possible level across all African countries, and partnerships among government, business and society. We must raise citizens' awareness as consumers and generators of waste, and partner with business as both producers and developers of end-of-life solutions.

What initiatives are being developed at the community level?
Many social innovations are emerging. Trash Out is a citizen science project alerting South African authorities to local dumping. Where there are inadequate local services, apps such as Wecyclers or Waste Bazaar in Nigeria link waste generators to private services. Some waste streams can be successfully decentralized, such as collecting organic waste to produce compost or biogas. One of the biggest innovation challenges is how to deal with plastics in a decentralized way and get communities involved. Many African countries want to ban single-use plastics because they don't see any way to deal with it. We must find solutions to reduce plastics consumption in Africa while improving end-of-life management options. This could include finding decentralized ways of dealing with recycled plastic at scale, for example by developing local 3D-printing facilities.

Why do you believe that waste can be a tool for development?
There is already a large informal reuse and repair sector across Africa, so we've been driving a circular economy for decades without calling it that. Investing in waste management moves resources out of dumpsites and into local economies. It improves public health, retains control of national resources and supports a green economy. The higher we move waste up the waste hierarchy away from landfilling and toward prevention, the more jobs are created in the reuse, recycling and recovery industries. ■

Linda Godfrey

Professor Linda Godfrey manages South Africa's Waste RDI Roadmap Implementation Unit, a strategic governmental initiative. Her research focuses on the economic, social and environmental opportunities of innovative waste strategies in developing economies.

PHOTOS: CSIR; GETTY IMAGES / DOUGLAS SACHA; STOCKSY / YAROSLAV DANYLCHENKO

Waste is food

Creating Chemistry: Many believe we must reduce consumption to conserve resources and reduce waste. Why do you prefer to talk about an abundance of resources?

William McDonough: As a child, I lived through water shortages in Hong Kong, but spent summers in Washington State, with its abundance of trout, salmon and oysters, and vast areas of forest. So I went from scarcity to abundance. I always ask how we can look at things from the opposite point of view and reframe the debate. What if we can redesign systems that deplete sources in nature and instead design ways to turn them into resources to keep them circulating in positive, healthy ways? That is how nature creates abundance.

How does that apply to waste?

We must eliminate the concept of waste; in nature there are only nutrients that feed the next cycle of growth. Biology shows us that life is created through the energy radiating from the sun combining with carbon in the atmosphere. Healthy growth depends on having sources of income, like solar energy and carbon, and on an open system of chemicals operating to the benefit of the organisms and their reproduction.

If waste is just a resource in the wrong place, can we think of carbon in the same way?

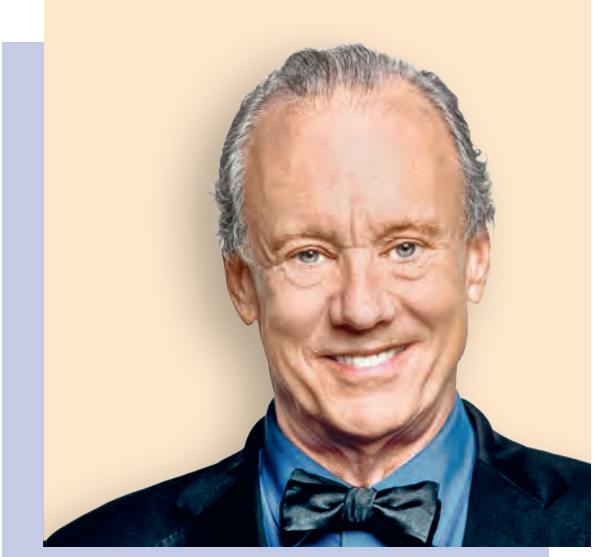
Many societies have now "demonized" carbon, but life is based on carbon. Atmospheric carbon emissions are effectively a toxin, a material in the wrong place, at the wrong dose and wrong duration. In the right place, carbon is a source of life and a resource and a tool. It is unusual in that it can be both a material and a fuel. In order to bring countries across the world together to solve climate change, we need to include economies based on hydrocarbons and give them a common roadmap to managing carbon cycles in regenerative and circular economies.

What exactly do you mean by "carbon in the circular economy"?

We need a new language of carbon that identifies three categories: living carbon, flowing in biological cycles, providing food, forests and soil, which is "carbon positive"; durable carbon, locked into stable solids such as coal or limestone, or recyclable polymers that flow in technical cycles, which is "carbon neutral"; and then there is fugitive carbon, such as CO_2 from burning fossil fuels, deforestation, industrial agriculture and much urban development, which is essentially "carbon negative." We need to develop tools to keep both living and durable carbon in circulation. Synthetic chemistry, for example, is crucial to organize hydrocarbons and plastics into durable polymers that are recycled so that the carbon doesn't become fugitive. This is how we avoid plastic bottles ending up in the ocean and is a good example of integrating durable carbon in the circular economy.

What might waste management look like in the city of the future?

The city of the future does not see waste; it sees nutrient management. For example, if food waste is seen as biological nutrient management, it will have compostable food containers and avoid hybrids of materials that can't be separated or recovered. It will have mechanical and chemical recycling of polymers. A city that recycles at the level of base monomers is coming. Everything's an asset and everything's designed for reuse. ■



William McDonough

William McDonough is an architect and global leader for sustainable development and design. The co-author of *Cradle to Cradle: Remaking the Way We Make Things*, he is a pioneer of the concept of Circular Economy and is now advancing a carbon management framework integrating actual decarbonization of the atmosphere, as well as recarbonization of the biosphere and technosphere.

PHOTOS: GETTY IMAGES/PETER DAZELEY; GETTY IMAGES/LANCHELES; COURTESY OF WILLIAM MCDONOUGH

It's all about changing mindsets

Talke Schaffrannek

Talke Schaffrannek is Director of Circular Economy at BASF, Ludwigshafen, Germany. Her previous responsibilities include applied sustainability, business development in Asia, diversity and inclusion, and product management. She has an MBA from Mannheim Business School, Germany, and Tongji University Shanghai, China.

The core of a circular economy, for me, is to decouple growth from resource consumption. We need to shift to smarter growth models that do not rely on finite resources and instead turn waste into raw materials. Together with my team here at BASF, we recently launched a circular economy program with concrete actions in three areas: new circular feedstock (recycled and renewable); new material circles (direct recycling loops and enabling circularity); and new business models (digital and service-based).

We have set ourselves the target of using 250,000 tons of recycle-based feedstock by 2025, thereby replacing fossil-based input. A significant contribution to this will come from our ChemCycling™ project, in which we manufacture high-performance products such as, for example, parts for the automotive industry, from feedstock derived from tires or mixed plastic waste on an industrial scale. In addition, sustainable bio-based feedstock will increasingly replace finite raw materials.

We also want to close direct recycling loops for the products we sell. Let's take polyurethanes for foam mattresses or battery materials for electric cars. Chemical innovations will play a key role in enabling circularity for these products. Internally, we have set up a co-funding program to stimulate ideas within the business units. Here, we provide financial support and coaching to incubate new circular project ideas. So far, we have supported more than 20 global projects. Most of the circular business models are only feasible because of digital solutions such as tracking and tracing or optimizing complex logistics. Here, we work together with start-ups and value-chain partners and are always looking for new collaborations.

Discovering opportunities

A perfect example for partnerships is our "waste-2-chemicals" project in Nigeria. With great entrepreneurial spirit, colleagues are working with local NGOs in Lagos to collect mixed plastic waste, which is then thermochemically transformed into pyrolysis oil, a high-quality feedstock. It is a small project but with a big impact locally, because it offers income opportunities for the waste pickers and helps to keep plastic waste streams out of the environment.

For BASF, circular economy offers many opportunities, not only in closing direct loops but also by contributing to much more efficient resource use.

These approaches can only work if we stop thinking in terms of "take-make-dispose," and if we have the courage to try out new business models with many unknown variables. The circular economy is not just about technology, nor is it just about marketing or waste collection. More than anything, it is about changing mindsets. Worldwide, we have to find solutions that decouple growth from resource consumption. I think that the chemical industry, and BASF in particular, can lead the way in this transformation. ■

PHOTOS: BASF SE; STOCKSY / YAROSLAV DANYLCHENKO

Freshly printed

Resin thread, metal and even cells – developments in 3D printing enable custom products to be made from the most varied materials. We explain how this innovative technology helps people's health and show you what the future holds.

Looking for innovation you can finally sink your teeth into? Forward AM by BASF is collaborating with Origin, a company in San Francisco, USA that is pioneering the concept of Open Additive Manufacturing to develop dental models with improved accuracy – a deviation of 1.7 percent or 0.00001 millimeters from the original. For traditional 3D printing, the deviation is 20 percent. At the same time, labor costs and material waste are reduced, all with faster process time. The key to the development of optimal dental part performance is a combination of material formulation, workflow process and precision hardware and software. Origin's advanced 3D printing technology, Programmable Photopolymerization, together with BASF's Ultracur3D® high-performing material, increase throughput.

BASF is also involved in another pioneering technology: 3D printing of skin models. BASF Care Creations® and CTI Biotech from France recently succeeded in making reconstructed human skin with a variety of cell types. The 3D models enable researchers to develop and test biological agents for skin care.

forward-am.com
ctibiotech.com

Help from BASF out of a 3D printer

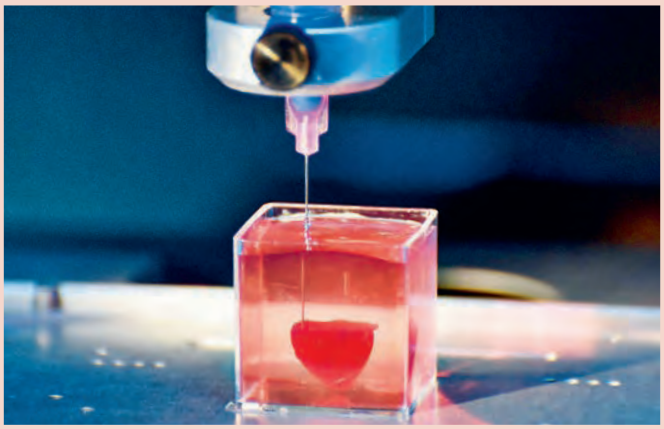
Rows of teeth made to measure: These tooth models are printed in 42 minutes, highly stable mechanically, and very precise.

3D skin model: Its uses include helping in the development and testing of new cosmetic agents.

Artificial heart

Israel It is still barely bigger than a cherry, but has everything it needs: blood vessels, tissue, cells and chambers. In 2019, researchers from Tel Aviv University became the first in the world to produce a complete heart from human cells by 3D printing. However, the cells cannot yet contract synchronously, and this means that the heart does not beat. Scientists expect that it may take many more years before such a biocompatible organ from a printer will perform its function in a human body – and thus make organ donations unnecessary.

bit.ly/heart-printer



Artificial bones

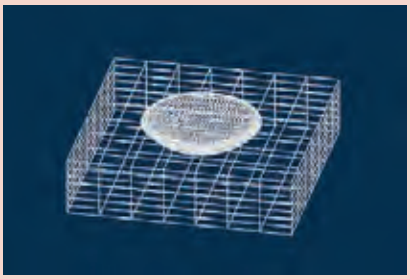
Scotland For bones, this is already a standard procedure: A scan provides the plan that is used for the precision manufacturing of implants using 3D printing. The materials are usually plastics, metals or ceramics. It has been possible to do this with human stem cells only since 2017, when scientists from Glasgow succeeded in using them to print bone grafts. The idea is that these grafts will themselves form bone tissue and fuse with the body. “We tried it out on a dog, and within six weeks it was running around on its repaired leg,” says Matthew Dalby, a professor at the University of Glasgow. Trials on human beings are due to begin before the end of this year.

bit.ly/bone-printer

Corneas for a clear view

England In 2018, a team of researchers from Newcastle University printed the first cornea from human cells using a bio-ink from stem cells, alginate and collagen. By scanning the patient’s eye, they could make the cornea to match the individual. However, before it can actually be transplanted, it is still necessary to investigate whether the cell-gel mass could melt at some point, and whether the printed cornea really does enable the eye to see clearly.

bit.ly/cornea-printer



Individualized tablets

USA Epileptics find it very hard to swallow pills. For this reason, the Ohio-based pharmaceutical company Aprecia has developed a 3D-printed drug that is constructed in layers. This creates a tablet with a very porous structure, which dissolves quickly in the mouth. In 2016, the Spritam epilepsy drug became the first 3D-printed pill to be approved by the U.S. Food and Drug Administration.

spritam.com

Technology & society

The digital boost

The coronavirus pandemic has changed the world of work. Companies and employees are harnessing the transformative power of digital technologies.

Venturing into new worlds
Supercomputers and what their immense computing power is already offering today.
Page 46

A space to stretch the imagination
BASF's Creation Centers foster innovation.
Page 48

Support on the ground
Bringing high-tech solutions to farmers in Egypt
Page 54

Not just for the future: avatars of BASF employees interact in digital spheres. To achieve this, the company piloted a platform where employees could come together in virtual form during the coronavirus lockdown.

PHOTO: BASF SE

Early morning, Coralie Adam sits in a Los Angeles suburb and opens her notebook to steer her space probe a few meters closer to Bennu, a slightly rugged-looking asteroid some 321 million kilometers from Earth. It is all done very professionally. "Directing a real spacecraft from my own home is something completely different from sitting at a games console," admits Adam, a flight navigator for the U.S. aviation and aerospace company KinetX. This is especially true now that her team are not sitting together in the control center, as they normally would, but are working dispersed throughout the USA because of Covid-19. However, thanks to digital technology and a lot of organization, Adam's team were ultimately able to take rock samples – and to complete their mission for NASA's OSIRIS-REx project after all.

The discovery that location-independent working is far from rocket science is an experience that Adam has shared with employees, as well as school and college students worldwide. While offices, factory floors and educational institutions were abandoned during the first wave of the global pandemic, work colleagues and students swiftly linked up with each other virtually from their living rooms or kitchens using video conferencing, chats or messengers. At BASF, for example, a total of one-third of the global workforce switched to working from home. People coped with this unprecedented situation better than one might have thought possible, thanks partly to internal campaigns to support digital working. "Actively using and experiencing digital working methods ▸

does something to you. The courage to do new things and to approach matters differently has grown significantly," says Martin Stork, who heads Workforce Enablement at Global Digital Services, BASF, Ludwigshafen, Germany.

This positive experience has been echoed by many companies. In an internal survey conducted by McKinsey in the USA, 80 percent of employees questioned during the pandemic indicated that they liked working from home. More than two-thirds said they were more productive at home than in the office, or at least as productive. For this reason, tech giants such as Google and Facebook are going to rely entirely on working from home for the foreseeable future. Facebook CEO Mark Zuckerberg expects that half of his employees will not return to the office at all after the pandemic is over. And what about BASF? "We won't launch ourselves into a purely virtual future, but into one that is flexible," Stork says. "Personal contact will remain an important driver of our innovative strength."

Several companies that regard digital as part of their DNA and have spent years testing methods for enabling people and machines to interact in the future acted swiftly and unbureaucratically at the height of the pandemic to make these methods widely available. One of them is TCS iON, the globally active IT subsidiary of India's Tata Group, known to many as a steel and automotive giant. TCS iON long ago became an agile smaller craft accompanying the big industrial tanker. TCS iON has been active for years in digital learning in schools and universities.

Transforming learning

This past year, the free Digital Glass Room has enabled millions of Indian schoolchildren to continue taking part in lessons despite the coronavirus lockdown. "This digital learning platform," TCS iO chief Venguswamy Ramaswamy says, "is more than just a temporary solution. The tool has the potential to fundamentally transform teaching and learning." Instead of continuing with face-to-face teaching using digital tools, teachers and students could open up virtual possibilities in these digital rooms, depending on the subject and the format.

There, they can hold discussions, compose blogs, organize quizzes, and much more. Group sizes can be chosen freely, as can the time when the work is done. It is also intended to support teachers in developing a approach tailored to each student.The TCS iON CEO also plans to make the digital tools available to the entire company in order to offer tailor-made talent development for some 453,000 TCS employees worldwide.

New digital tools and ways of working are creating headaches for company strategists around the world, because even though working from home and mobile working have started up very smoothly in their companies, the drawbacks of constantly having the same form of screen-based communication are also slowly becoming apparent. The expression "Zoom fatigue" is already in circulation, describing a mysterious exhaustion that grips regular participants in video conferences. "The constant direct eye contact and the sense of being watched back through webcams have made participants feel

"Actively using digital ways of working also gives you the courage to approach matters differently."

Martin Stork
Head of Workforce Enablement at Global Digital Services, BASF, Ludwigshafen, Germany

Conferences with colleagues – in the future they could be held digitally from home more often.

Impromptu, informal exchanges over coffee have become harder during the pandemic.

PHOTOS: BASF SE; GETTY IMAGES / CHEE GIN TAN; GETTY IMAGES / WESTEND61

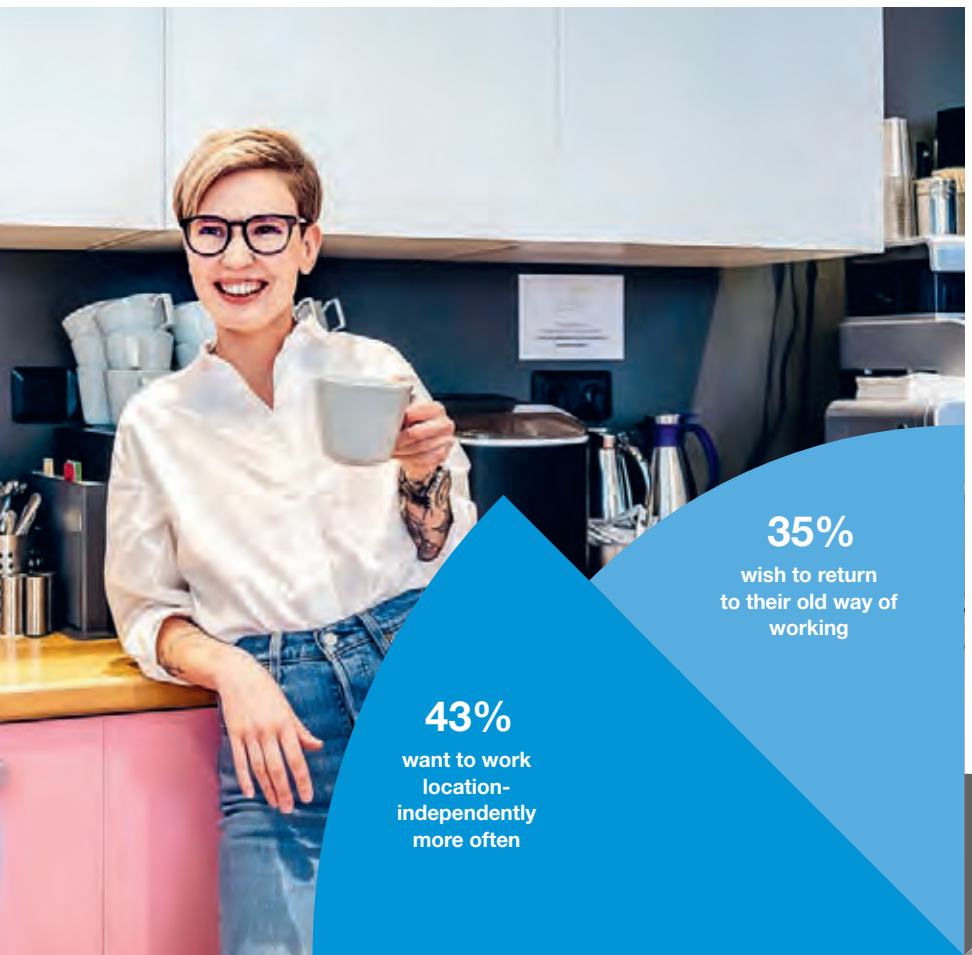
Eighty percent of U.S. employees like working from home.

Source: McKinsey

under pressure, like on a stage," says psychologist Janine Hubbard, Adjunct Professor at Memorial University of Newfoundland, Canada. Does this mean that online meetings have become an instrument of relentless observation, from which humans almost instinctively look for ways to escape? There are now apps that let employees lighten the mood by inviting real llamas or goats into Zoom meetings. The animals even join the conference by video.

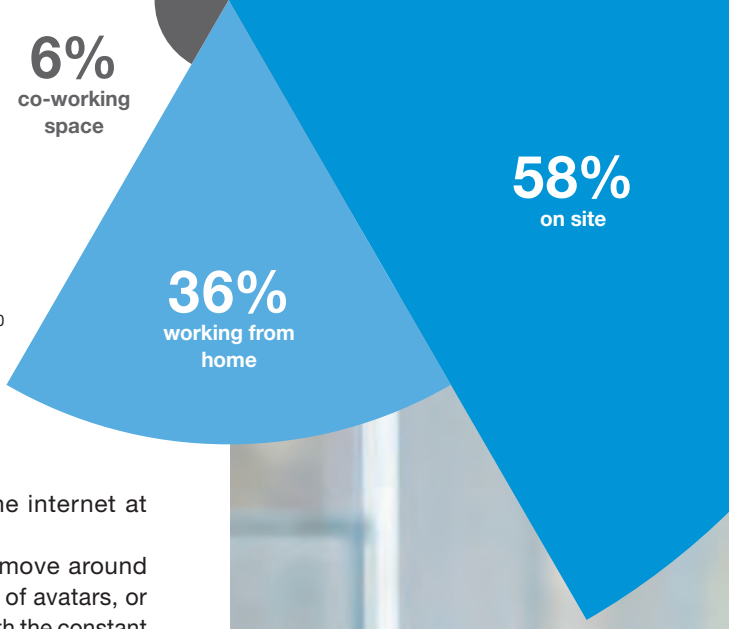
The value of informal contacts

Quite apart from such strange-seeming diversionary tactics, experts also see problematic consequences for completely digitalized business communication in the long term. "Many companies still underestimate the value of informal contacts," warns Professor Martin Korte, a neuroscientist at the Technische Universität Braunschweig, Germany. Chance encounters, such as ▸



Working from home – the new normal?

How U.S. Americans would change their work situation after the coronavirus pandemic
Source: Statista



How BASF employees want to divide their working hours

Source: BASF employee survey, Ludwigshafen, Germany, June 2020

those that happen between colleagues at the coffee machine, he says, "go hand in hand with creative processes and allowing new ideas to form and develop organically." Discussions that can be contentious, such as those surrounding a company's strategy, "are extremely hard to choreograph online," he adds. The solution to this problem, Korte thinks, could lie in hybrid formats, where online work and completely analog meetings complement each other. This is because without personal encounters there is a danger that identification with the company – and, ultimately, its own identity – could be lost. "We are talking here about a sense of cohesion, which constantly needs to be generated afresh," Korte says.

Can the interpersonal closeness that is essential for team spirit also be generated virtually? Professor Blair MacIntyre answers that question with an almost categorical "Yes." In March 2020, MacIntyre, who heads the Augmented Environments Lab at the Georgia Institute of Technology, USA, was obliged to move his renowned IEEE (Institute of Electrical and Electronics Engineers) Virtual Reality (VR) Conference onto the internet at short notice.

Visitors were able to move around in virtual rooms by means of avatars, or digital representatives. "With the constant improvements in VR headsets and sensors, this now feels akin to lifelike immersion," MacIntyre says. However, it was still possible for only a small proportion of conference participants to interact at the same time using their avatars. "It is not yet possible technologically or in terms of computing power to bring several thousand participants together in one virtual room," MacIntyre admits. In the meantime, he sees technological and coronavirus-related restrictions as an opportunity to rethink event formats – for instance, as an online conference moving around the globe from one time zone to another. One positive

A glance around the globe

Graduating with an avatar
To avoid the risk of infection, the Indian Institute of Technology (IIT) in Mumbai moved its graduation ceremony online at short notice. Instead of being squeezed into an auditorium, students were honored in a virtual space. Their digital representatives went up to the stage and received their certificates with a loud round of digital applause.

Workcations
Japan is using the pandemic to tackle rural to urban migration. Traditional houses in depopulated areas are being renovated and fitted with fast internet – meaning that employees can work there for weeks, socially distanced. The concept, complete with open-air conferences, was developed by companies in collaboration with the Japanese authorities.

Robots working from home
What do robotics engineers do during the coronavirus pandemic? They simply take their smart machines home – where they then teach their new housemates to walk and climb. This has resulted not only in new insights for the engineers from Boston Dynamics in the USA, but also in skeptical looks from their neighbors.

PHOTOS: BASF SE; IITB; GETTY IMAGES / PAUL BIRIS; DDP IMAGES / FERRARI PRESS

A BASF Digital Solutions employee uses HoloLens smart glasses to investigate new, virtual ways of collaborating globally in everyday office work.

PHOTO: TU BRAUNSCHWEIG/JOHANNES FELSCH

side effect of the coronavirus crisis is that people from the world's poorer regions, who in the past could not afford to travel to his virtual reality conferences, would be able to take part.

Avatars encourage interactivity

VR, as a technology for the future, is also part of BASF's digital toolbox. "We piloted a platform where employees were at least able to come together virtually and still hold workshops successfully during the coronavirus lockdown," Stork says. Avatars of employees communicated in the digital sphere. "This meant they could also be more active for longer than in a traditional video-conferencing format, and they also felt much more closely involved," he says.

The use of new tools at BASF is not limited to the office. In production, too, workers are now wearing HoloLens smart glasses. These enable users to see information and data streams from machines that would otherwise be hidden from view. "By using virtual reality, big companies could detach themselves from the 'real world' to a certain extent," MacIntyre believes. "It is possible to zoom in as far as the molecular level of chemical processes or to gain a bird's-eye view of a whole factory."

For the aerospace engineer and global companies alike, the coronavirus has again given a fresh thrust to digitalization. ■

Three questions for Martin Korte

Professor Martin Korte from Braunschweig, Germany, researches the biochemical processes involved in learning and memory.

1 Why do we find it so much harder to concentrate during video discussions than during in-person meetings?
The social aspect works its way into our brains through the synapses. Information intake is supported by neurotransmitters, many of which are secreted only if I feel that I am a true member of the group.

2 Why are video conferences so draining?
They are incredibly taxing for the brain. It has to constantly endure the cognitive mismatch in the fact that somebody is present on the screen but not really, physically, there. Part of our computing capacity is always being used up in trying to make sense of this situation.

3 Are there matters that are better managed by using digital media?
Yes, if I have widely differing levels of knowledge of a subject! With digital tools, you can address individual needs. Software can have advantages for knowledge retention – for example, if you are using people's instinct for play to motivate them. Take gamification, for instance.

Venturing into new worlds

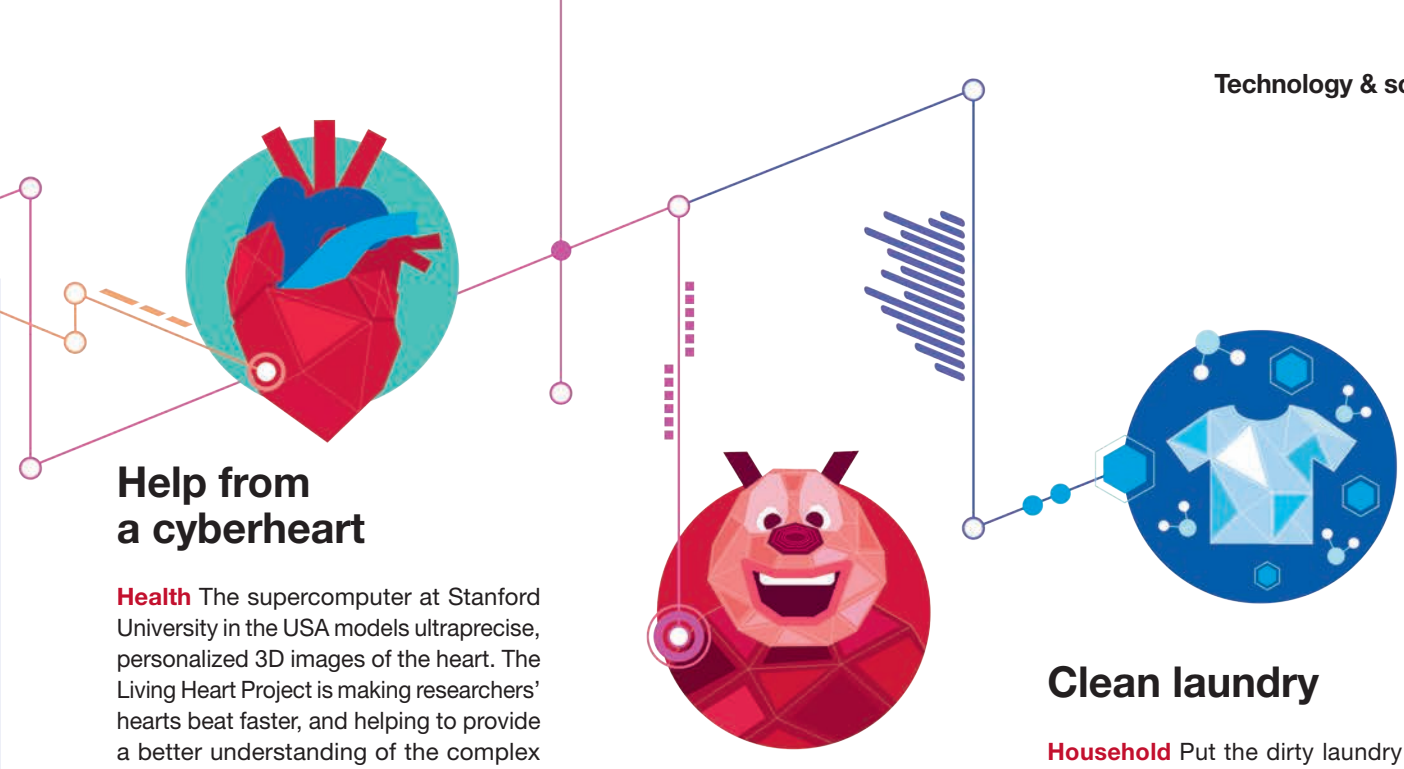
Supercomputers have revolutionized science and research. Their immense computing power helps to find better solutions, faster. But what does that mean in practice?

A total of 442 quadrillion computing operations per second – that is what the fastest supercomputer in the world, housed at the RIKEN Center for Computational Science in Japan, can perform. There are many scientific questions that can only now be systematically investigated thanks to the unimaginable computing capabilities of these digital superbrains. They help to use energy more efficiently, identify illnesses more quickly, or unravel the mysteries of the cosmos. In the fight against the SARS-CoV-2 coronavirus, the supercomputer is also helping to predict the course of the pandemic more precisely and to simulate the pathogen's response to thousands of active agents.

BASF has been using its Quriosity supercomputer since 2017. It is the most powerful computer in the chemical industry worldwide and performs more than 10,000 tasks every day. There are 400 employees, mainly from research and development at BASF, who use it for example to calculate new chemical reactions or formulations. In this way, the computing genius helps in the search for new materials or catalysts.

In terms of computing power, the future belongs to new types of special hardware. These include quantum computers capable of solving in a short space of time problems that would take many years on traditional supercomputers. However, researchers worldwide are still struggling with obstacles, including the fact that the elementary computing units known as quantum bits, or qubits for short, remain stable only for fractions of seconds. This means that calculations have to be completed within that time. In addition, the algorithms that work on quantum computers have yet to be developed. Nevertheless, BASF expert Dr. Stephan Schenk, Product Manager High Performance Computing, Ludwigshafen, Germany, is already certain about one thing: quantum computers will be disruptive. However, when they will be able to start working in a meaningful way is rather less certain. "Routine applications in the chemical industry are not expected within the next few years," Schenk predicts. "Until that time comes, our traditional supercomputers will perform their computing skills and help to improve many areas of our lives."

ILLUSTRATION: MATHIS REKOWSKI



Help from a cyberheart

Health The supercomputer at Stanford University in the USA models ultraprecise, personalized 3D images of the heart. The Living Heart Project is making researchers' hearts beat faster, and helping to provide a better understanding of the complex actions of our most important muscle, taking account of more than 250 million variables. It enables medical practitioners to analyze the health of cardiac patients in the virtual world on an individual basis and to simulate the type of treatment. The digital heart is also helping in the testing of medicines, by supplementing clinical studies with results obtained at high speed. Whereas studies need months to investigate whether a medicine causes cardiac arrhythmia, the computerized heart was able to do this in about 40 hours – some 27 times faster. The cyberheart is being used in the USA by the Food and Drug Administration and has now been taken up by approximately 500 research cooperation partners.

bit.ly/cyber-heart

High-quality animated movies

Entertainment The Chinese supercomputer Xingyun offers a rendering cloud for animated movies to create high-quality, high-resolution scenes. Its huge computing power significantly reduces production times. To render the many special effects in the Chinese animated blockbuster *Boonie Bears: To the Rescue*, post-production would have lasted nearly six months. At the supercomputer center at Shenzhen, China, it took less than two months and saved 30 to 40 percent of production costs.

bit.ly/boonie-bears

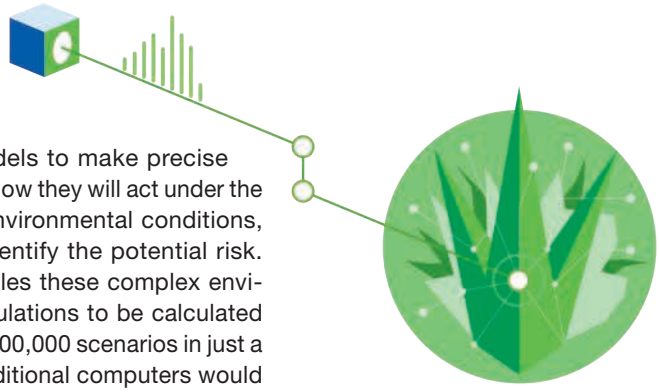
Clean laundry

Household Put the dirty laundry in the machine, add the right detergent, start the wash program, and take out the clean laundry. It sounds so simple, but it is a highly complex process with many interdependent elements, and depends not least on the textiles, how dirty the laundry is, and water hardness. Water temperature and the composition of the detergent also have a part to play. One thing that BASF supercomputer Quriosity has done to develop a better detergent much more quickly is to produce molecular simulations of washing processes, with 26 million atoms as the protagonists. The supercomputer came up with a large number of combinations in the space of a few days, and the most promising will be tested in the laboratory.

basf.com/supercomputer

Safe pesticides

Agriculture It takes more than ten years to develop a new pesticide. Before an active ingredient reaches the market, up to 300 studies are carried out to test its safety and effectiveness. Work is also done to examine how high the potential is that it could possibly get into the groundwater. Major factors for this include not only the properties of the agent itself but also conditions in the field, such as the climate and soil. For this reason, as early as the pesticide development stage, BASF uses computer models to make precise predictions of how they will act under the most varied environmental conditions, and thus to identify the potential risk. Quriosity enables these complex environmental simulations to be calculated for more than 400,000 scenarios in just a few hours. Traditional computers would need several years to do this.



bit.ly/environment-simulation

The central area at the Creation Center in Ludwigshafen, Germany, is a meeting point amid hundreds of samples, prototypes and products. Here Andreas Mägerlein (right), Group Leader, Creation Center Europe, and his colleagues welcome partners and customers.

A space to stretch the imagination

The BASF Creation Centers foster innovation, creativity and collaboration between BASF and the company's customers and partners.

Approaching the gates of the enormous industrial complex in Ludwigshafen, Germany, an unlikely architectural ensemble catches the visitor's eye. Just outside the BASF plant, a gray bunker, relic of the past, serves as the foundation for the Creation Center at the company's headquarters. Built on top, the Creation Center is encapsulated in a white organic lacework structure resembling a foam in close-up. Slightly rotated around its vertical axis, the Creation Center turns in a welcoming gesture towards the visitor, forming a contrast to the rigid symmetry of the square concrete structure beneath. As we come closer, the scars cut by shrapnel during the Second World War become visible and remind us of the structure's original purpose. Today, in stark contrast, an external elevator lifts us upwards along the pocked concrete to the top of the building, where we cross a small bridge into a creative sanctuary.

Pushing the potential of performance materials

The Creation Center in Ludwigshafen is one of four established by BASF at the company's sites around the world to inspire and drive performance material innovation. The others are in Shanghai, China; Mumbai, India; and Yokohama, Japan. "Our passion and purpose are to inspire our customers, utilize our portfolio of performance materials and tap into their huge innovative potential," says Alexandre Dreyer, Head of BASF's Creation Center Asia Pacific.

Performance materials are the plastics that give products their specific qualities. They make surfaces attractive to the eye and touch, chairs comfortable and secure, they lend protective characteristics to work gear, durability and precision to machine parts, absorb vibrations or give back kinetic energy. With a decisive influence on the relationships we form with the objects around us, our purchasing decisions and whether we keep things or discard them prematurely, they have a considerable impact on the success of products in the marketplace – many of which owe them their very existence. "The possibilities for innovation are endless," says Dreyer.

PHOTO: LEMRICH STUDIO

The Concept 1865 e-bike is an experimental prototype designed to illustrate the many applications of modern plastics.

1 The exterior of the Creation Center resembles a close-up of the structure of foam.

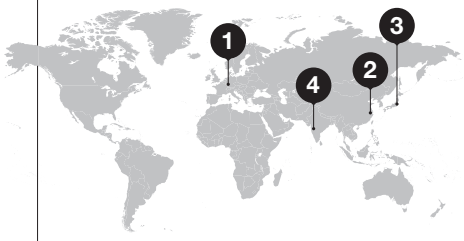
2 Please do touch! Visitors are welcome to explore the versatile characteristics of performance materials.

Inside the Creation Center in Ludwigshafen the creative spirit is tangible. The interior is carefully designed with BASF materials chosen wherever possible. Andreas Mägerlein, Group Leader, Creation Center Europe, guides us enthusiastically through the airy spaces. In the central area, simple steps form an auditorium with room for a small audience. In front of it, a worn wooden workbench is placed center stage. Along the surrounding walls, shelves are filled with objects, prototypes and boxes containing smaller samples and components that do not immediately reveal their purpose or application. There are iconic objects and products, too – bicycle saddles, chairs, car hoods, a firefighter's helmet, and the adidas Boost™ running shoe, which features a sole made of BASF's super elastic Infinergy® polyurethane foam.

A space where objects reign

Out of their everyday context, we look at the objects differently – more carefully and sometimes in awe at their beauty. Materials are the heroes here, but the objects into which they are molded are not put on pedestals or behind glass. The overflowing boxes encourage visitors to browse and touch; to bend, scratch and enjoy colors; to fully experience, explore and appreciate their versatile properties. In adjacent rooms, workspaces can be ▸

Creation Centers in key markets



The Creation Centers are located in strategically important markets. **Ludwigshafen** (**1**) in Germany and **Shanghai** (**2**) in China are key locations for BASF performance materials. Japan's affinity for design and its consumer and car industries make **Yokohama** (**3**) an important location. **Mumbai** (**4**) in India represents one of the most relevant emerging markets, with high customer demand for creative services.

PHOTOS: BASF SE; LEMRICH STUDIO (2)

> “Our purpose and passion are to inspire.”
>
> **Alexandre Dreyer**
> Head of the Creation Center Asia Pacific

seen through doors and windows, as can 3D printers and an open kitchen area. This is a high-tech treasure trove, a laboratory, a meeting-point and a workshop all in one.

“People love to come here,” observes Mägerlein. “For us, it is a wonderful experience to provide our customers and partners with the space and freedom to develop great ideas. The environment we work in has a profound influence on how we feel and think.”

This is a place for inspiration and free thinking, unrestricted by hierarchies, job descriptions and work routines. Customers from all industry sectors and BASF employees meet here, bringing ideas and experiences from their different backgrounds. There are scientists, engineers, computer specialists, managers and marketers. “As designers we facilitate innovation. We have technical expertise but more importantly, we experiment – we are open to new ways of thinking,” says Mägerlein, who describes himself as a hybrid of engineer and designer. “We think about possibilities and opportunities. We use different creative techniques, sometimes highly structured, sometimes very free, depending on the nature of the project. We don’t want to be too prescriptive.”

Connecting the physical and the digital

From the adjoining meeting rooms, visitors can look down on the vast Ludwigshafen site. The view forms a strong connection between the Creation Center and BASF’s chemical complex. Mägerlein, handling a joystick controller, puts on a headset with antenna on both sides. Equipped with receiver headsets, it takes a few seconds before our vision adapts and an impressively realistic three-dimensional representation of the Hymer VisonVenture campervan appears before our eyes. He turns his hand and the van rotates. We zoom in close and explore.

Digital tools play an increasingly important role in the development process. Visualization techniques have enhanced prototyping and ensure the viability of the product development. In addition, a continuously updated database provides information on performance materials and products in the portfolio. All materials found in the Creation Centers can be scanned to gain access to the database and explore graphs, videos, 3D models,

3

4

3 Alexandre Dreyer talks to customers at the Creation Center in Shanghai, China.

4 Performance materials are the plastics that give products their specific qualities – the possibilities for innovation are endless.

Trend books

The trend books published by BASF present a global perspective on trends in society and design that impact on the conceptual development of products. In *Material Selection N° 1*, the teams from the Creation Centers discuss how the circular economy and exclusivity, improvisational art and innovation fit together. They also present innovative polyurethane coatings that make stone flexible and explain how polyamide provides a high gloss in automotive interiors.

PHOTOS: BASF SE (3)

animations, applications, markets and final products. In conjunction with the immediate physical experience, this provides a comprehensive picture in a very accessible format. For customers who are unable to visit the Centers in person, remote workshops can be aided by these digital tools.

From initial ideation or brainstorming to conceptual design, the investigation of practical and formal solutions, the definition of technical specifications, the creation of computer simulations, research and development, preproduction – before a product enters the manufacturing process there are layers of complexity that must be explored and understood. "We try to engage in the process as early as possible," says Dreyer. "Often customers have a very vague idea of what they want to achieve. This is where we come in. We have the knowledge and experience to accompany our customers from the initial stages through the entire development cycle until the product is market-ready."

Societal trends drive design

Both Mägerlein and Dreyer stress the importance of working pragmatically but with purpose in mind. Yet, looking beyond current projects is equally important. Trend scouting is an additional area where the Creation Center teams add value. But that does not mean simply looking at which materials are currently trending. "We turn the question around," says Mägerlein. "We think about how societal trends may trigger new developments in the creation and application of materials."

Consider sustainability. Consumers are increasingly aware of the environmental impact of products, and this influences purchasing decisions. Naturally, this is reflected in the development of materials and products. How the materials used in consumer goods can be redirected into the circular economy is an important focus – and in line with BASF's commitment to sustainability.

"We help our customers understand which trends are driving consumer behavior, and we feed this knowledge into our organization," says Mägerlein. Exploring BASF's Creation Centers provides a deep insight into the potential that can be delivered by design expertise and creativity paired with BASF's material portfolio and manufacturing expertise. But even then, we have only scratched the surface of what is possible.

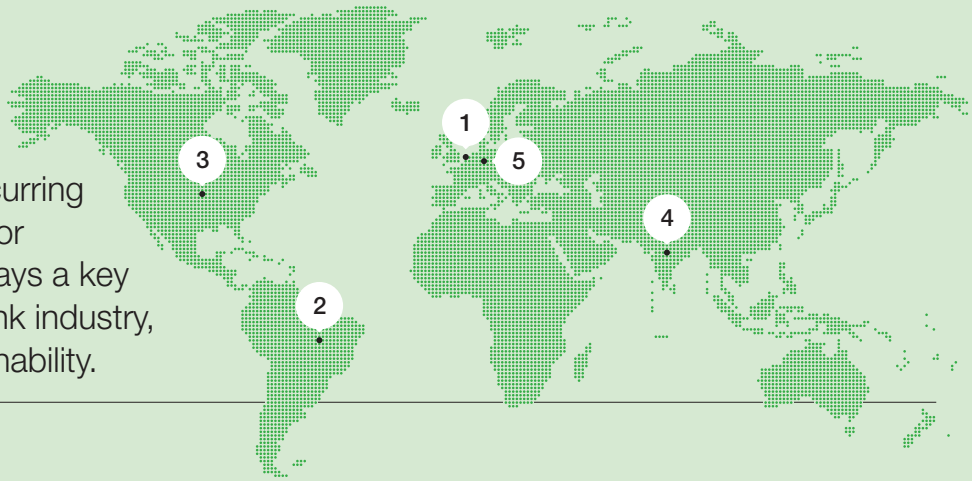
"Designers used to be the styling guys. This is a long-gone notion. Today, the value we deliver in working creatively with customers and our experts from different disciplines is evident," says Mägerlein. "The Creation Centers are living proof." ■

Design is part of the process from the beginning.

Mägerlein and colleagues zoom in on a detail of the 3D representation of the Hymer VisonVenture campervan.

PHOTO: LEMRICH STUDIO

Innovation from an ancient process



Fermentation, a naturally occurring process utilized by humans for thousands of years, today plays a key role in the feed, food and drink industry, driving innovation and sustainability.

Our Neolithic ancestors discovered the benefits of fermentation as a means of preserving valuable foodstuffs. When the food supply was unreliable, it was a matter of survival. Over the millennia, cultures around the world have adopted and adapted the technique to meet their needs. From yoghurts and pickles to alcoholic beverages and leavened bread, the benefits of fermentation go beyond preservation. The process enhances flavors in many foods, such as soy sauce, chocolate and coffee. Fermentation also breaks down starches, making foods such as rice more easily digestible. At the most basic level, fermentation describes the breakdown of complex organic substances into simpler compounds. The process, which occurs naturally in many living organisms, is catalyzed by enzymes produced by microorganisms such as yeasts, molds and bacteria. This is a technique that the food industry continues to explore, experimenting with it to develop recipes, create entirely new products and improve sustainability.

1

Algae into high-quality feed

The Netherlands Algae could provide a sustainable food and energy source for the world's growing population. Fermentation plays an important role in harnessing its potential. Corbion, a Dutch company specializing in lactic acid and its derivatives, uses aerobic fermentation to produce valuable long-chain omega-3 oils from micoalgae for animal feed production. This helps to reduce the industry's dependency on fish oil. Corbion has also partnered with Nestlé to develop microalgae-based ingredients for foods that are rich in protein and micronutrients.

bit.ly/algae-portfolio

PHOTOS: GETTY IMAGES; SHUTTERSTOCK

2 Enhancing coffee aroma

Brazil Ground or pounded, drip-brewed or percolated, espresso or crema – coffee is one of the world's favorite beverages. Coffee producers in Brazil are experimenting with fermentation to change the aroma by breaking down the sugars contained in the coffee cherries. The naturally occurring reaction changes smell, color and acidity. Performed in a controlled environment, the process adds sensorial notes like fruits, caramel and chocolate.

bit.ly/coffee-cherries

5 Fermenting citrus

Germany Customers today increasingly look for foods and fragrances with natural ingredients. Isobionics®, acquired by BASF in 2019, produces nootkatone, the natural flavor ingredient responsible for the typical aroma of grapefruit. Isobionics Natural Nootkatone is manufactured by proprietary fermentation technology deploying the bacterium Rhodobacter sphaeroides. The aroma ingredient, enjoyed in soft drinks and fragrances, is produced from vegetable carbohydrates such as corn starch. A carefully controlled fermentation process ensures consistent product quality and availability, as well as stable prices independent of climate, harvest and storage conditions. Being based only on natural ingredients, the product is recognized as natural under both U.S. and E.U. legislation.

bit.ly/isobionics

3 The flavor of meat

USA If you want to convince meat lovers to switch to plant-based alternatives, getting the flavor right is essential. In hamburgers from Impossible Foods, the ingredient responsible for the typical meat taste is heme. It contains iron, which is found in the blood of animals and in lower concentrations in plants. Heme is made using a yeast that is genetically engineered with the gene for soy leghemoglobin. The yeast is grown via fermentation, then the soy leghemoglobin containing the heme is isolated from the yeast and added to the burger.

bit.ly/plant-burger

4 Space food

India Idli is a traditional Indian dish consisting of fermented rice and lentil paste. According to food historians, it was introduced to the subcontinent between 800 and 1200 AD from Indonesia. It is made by leaving the batter to ferment overnight. Idli is today as popular as ever, with hundreds of variations. The Defence Food Research Laboratory in India has even developed a special recipe for space idlis so that Indian astronauts can enjoy their favorite food while away from Earth. The space idlis are dried using infrared radiation. The desiccation process kills bacteria and other microorganisms and increases shelf life to more than a year.

bit.ly/defence-food

PHOTOS: GETTY IMAGES; SHUTTERSTOCK (2); BASF; PR; ALAMY

Support on the ground

Big commercial farmers use many technologies to improve yields, sustainability and profits. In Egypt, BASF is bringing these solutions to small and mid-scale farmers, improving their livelihoods and self-reliance.

I have been a farmer for 21 years. I grow tomatoes and other vegetables on 12 feddans* of land," says Shaaban Talha, a farmer in the Kafr el Sheikh region north of Cairo, Egypt. "I face many challenges. My crops can be affected by root rot, powdery mildew, blights and leafminers. But in this last year the biggest problem has been low prices. This has meant large losses for me and other farms in the area."

Many farmers in Egypt, like Talha, lack access to technologies such as satellite communication, the internet, big data and artificial intelligence – and the information larger farming businesses use to predict weather conditions so they can take preventive action

* 5 hectares

Farmer Shaaban Talha (right) examines his tomato plants with local retailer Mohamed Shams for any sign of crop disease.

PHOTO: ROGER ANIS

1

2

1 Mohamed Shams in his shop shows Shaaban Talha and other local farmers some of the products that can be used to prevent crop disease.

2 Produce is transported via truck from the Nubareya region, where Shaaban Talha's farm is located, to markets in Cairo, Alexandria and Amreya. The choice of market depends on current prices.

to protect their crops. This not only puts these farmers at a disadvantage, but can be a disaster when your family's livelihood depends on having the right information. BASF is working to change that.

Launched in 2020 by the BASF team in Egypt, Ardena is a disease alert service delivered by text message to the cell phones of registered farmers. It connects the farmer with a sophisticated early disease warning system using satellite technology and artificial intelligence to provide real-time, tailor-made recommendations that help to increase their productivity.

Some 80 percent of Egypt's arable land is farmed by smallholder farmers. Helping them tackle disease not only improves livelihoods, it also contributes to food security. Ardena, which means "our land," gives farmers information about how to apply crop protection products safely and how to use them more precisely to achieve better yield. It works whether the farmer has a basic mobile phone or a smartphone. ▸

"Smallholder farmers are scattered across remote regions, making it difficult to reach them. There is also a high level of illiteracy. They need someone to talk to about their problems, to warn them of changing conditions and offer sound advice. Our agronomers provide that support, including advice on the safe use of crop protection products. At the clinics, it's a one-to-one service. We take time to understand their problems."

Inji Zaki, Regional Sustainability & Digitalization Manager, BASF, Cairo, Egypt

PHOTOS: ROGER ANIS (2); BASF SE

“The Ardena project was launched in Egypt after three years of development. We are currently focusing on scale-up in Algeria and Morocco. As part of BASF’s Starting Ventures, it aims to develop sustainable business solutions and empower people with low incomes to achieve better quality of life at the same time as expanding the market for BASF’s products and building strong business partnerships.”

Thavy Staal
Formerly, Sustainability Manager, Agricultural Solutions Africa & Middle East. Currently, Global Communications, BASF, Limburgerhof, Germany.

3 Farmers need a trustworthy source of information to diagnose their problems and help them find solutions. Mobile Agricultural Clinics meet that need.

4 Tomato plants in the region are particularly susceptible to late blight. Without the right crop protection product, this can destroy the crop.

The alert service is also available to local retailers – a vital link in communication. Talha’s retailer is Mohamed Shams. From his shop in Bangar el Sokar village he serves 150 farmers across the region. “One of the biggest problems farmers face in this area is fruit drop – when fruit is shed from the plant before it is fully ripe,” says Shams. With Ardena, he is forewarned of fungal diseases like early and late blight so that he can stock the appropriate crop protection products and be ready to answer farmers’ questions.

The information flow to the farmers is also supported by Mobile Agricultural Clinics. At the clinics, agronomists from

PHOTOS: BASF SE; ROGER ANIS (3)

“Smallholder farmers are open to innovation. Their livelihood depends on it because every year is make or break. Our services use satellite technology and combine imaging of the fields with weather data to predict disease susceptibility. This is delivered to the farmer via text message with advice on steps they can take, including products, the importance of personal protective equipment, and nearest retailers.”

Abhijeet Sharma
Digital Development and Roll Outs Europe, Africa & Middle East, BASF, Limburgerhof, Germany

BASF meet farmers face to face near their farms to discuss their problems in person. There are up to 25 clinics a year, covering 14 areas of the country and reaching 5,000 farmers to date. Though the pandemic made such events impossible in 2020, they will resume when it is safe for them to do so.

Together, Ardena and the Mobile Agricultural Clinics help to reduce uncertainty for farmers like Talha. “The clinic initiative has a very positive impact because it reaches us close to our lands,” he says. “I got first-hand guidance about the blight problem I was facing. It saved me time and effort.” ■

5 On a farm neighboring Shaaban Talha’s, the tomato crop is harvested.

6 Egypt is the fifth-largest producer of tomatoes in the world, producing some 8 million tons a year thanks to its climate and soil.

7 Shaaban Talha checks messages from Ardena while working in his fields. The service gives him precise information about the disease risk for tomatoes over the next seven days.

PHOTOS: ROGER ANIS (2); BASF SE

How plastic wrap is turned into compost

Plastic wrap that lands in the compost – from 2020, this is no longer tomorrow's world. But what does it have to do with bacteria, and how does it actually work?

We have all seen it: when we buy vegetables in the supermarket, many are packaged in plastic wrap made from polyvinyl chloride (PVC). This keeps the vegetables fresh, but the wrap lands in the trash can after use. The solution is the transparent, breathable wrap Nature Fresh, which keeps food fresh for longer and is industrially compostable. It was developed in early 2020 by BASF and Italy's Fabbri Group. The wrap is based on the BASF bioplastic ecovio®, which is certified compostable. That in turn contains the certified compostable BASF polymer ecoflex®, with a specific molecular structure that enables it to be turned into compost by bacteria and fungi – either industrially or in private gardens, depending on product type.

Here's how it works: the microorganisms living in the compost excrete enzymes to absorb nutrients. The enzymes break the long polymer chains in the wrap down into shorter molecules. These molecules are then consumed and digested by the bacteria and fungi, and turned into biomass and carbon dioxide – in other words, compost.

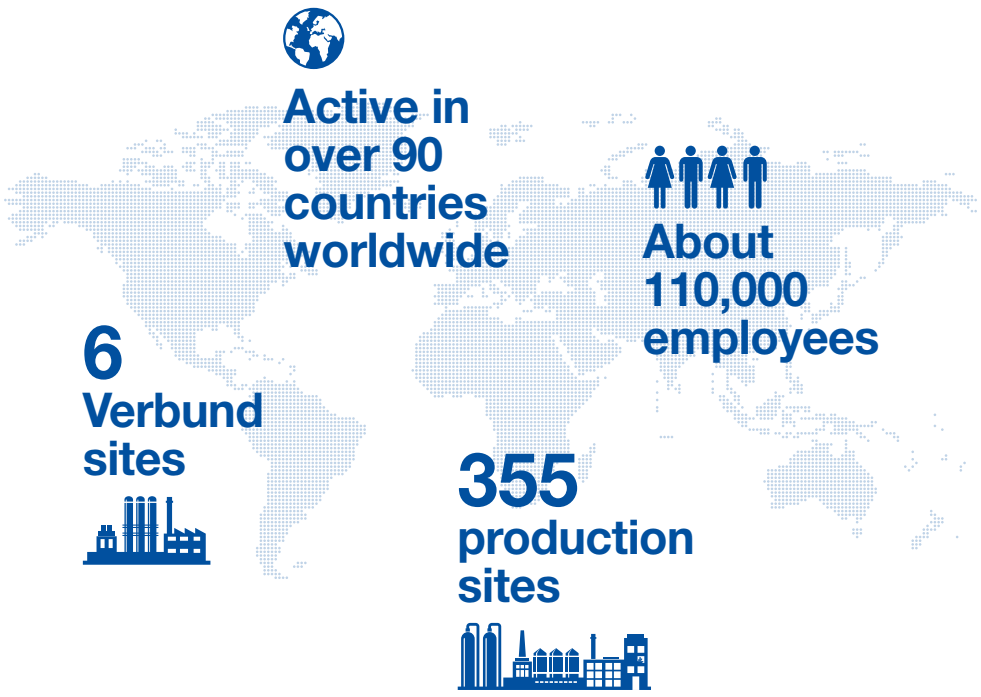
This means that wraps made from compostable ecovio not only keep vegetables fresh for longer, but also make composting easier. With more separated biowaste, more compost can be produced to fertilize fields.

ecovio.basf.com

PHOTOS: FABBRI GROUP; GETTY IMAGES / ALUXUM

Discover the world of BASF

Chemistry for a sustainable future – this is what BASF stands for.



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