Issue Seven 2018

Creating Chemistry

FOR A SUSTAINABLE FUTURE

SUPERCOMPUTERS

Age of the super brains

Supercomputers are already today lightning-fast analyzers. Now the next great breakthrough is just around the corner. And the potential is enormous.

FOCUS

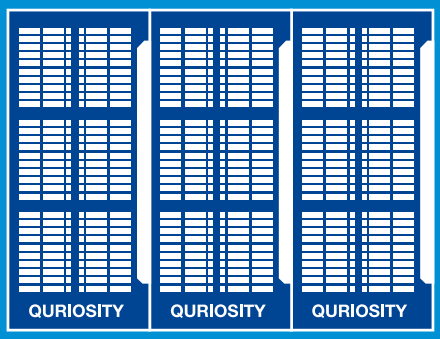
The supercomputer – a solution for our problems?

Pages 06–25

24

1.75 quadrillion calculations

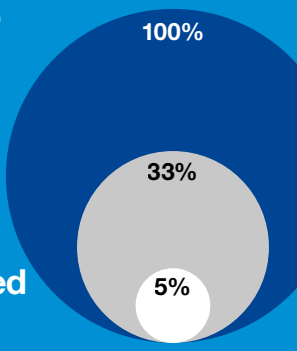
– the number that the QURIOSITY supercomputer from 2017 can perform



each second. That is equivalent to the power of around 50,000 laptops.

Source: BASF

In spring 2017, E.U. industry provided about 5 percent of High Performance Computing resources world-wide, but consumed one-third of them.



Source: European Commission

20

“There is a tremendous opportunity for artificial intelligence to help people.”

Source: Interview with Professor Barbara Grosz

Integration with customers

With online data from customers’ painting lines, BASF sets the correct shade for an automobile, or can make immediate adjustments if necessary.

Source: BASF

EDITORIAL

The global race to reach one quintillion – that's a one with 18 zeros – computing operations per second is in full swing. Ever faster and more powerful supercomputers are bringing together and analyzing the volumes of data that we generate in the modern world. They are helping us to find better solutions more quickly to challenges such as climate protection and disease research.

"Where are the opportunities and the limits of digital technologies?"

At BASF, we are using digital technologies to become more efficient and innovative in research and production, in logistics, and in working closely with our customers. For example, with the help of our supercomputer, our researchers are analyzing many millions of possible molecular compounds in complex simulations and modeling. They take the most promising of these and examine them further in the laboratory. But how clever can machines become? Also, even more importantly, in what areas are they – and will always be – surpassed by humans? Where are the opportunities and the limits of digital technologies? The answers are provided by experts we have consulted for this issue of *Creating Chemistry*.

Where new technologies are involved, society's reaction is often a mix of approval and curiosity on the one hand, and reservations and fear of risks on the other. In *Creating Chemistry*, you can also learn more about what influences the way we assess risk, the things we fear and whether we trust facts. We highlight topics that drive our society. These include the question of the future of diesel, or how palm oil can be cultivated sustainably. Ultimately, human beings are always the focus of new developments and ideas. Everybody has a responsibility to be well informed and to play a part in shaping the future.

I wish you an enjoyable read!
Yours,

Kurt Bock, PhD
Chairman of the Board of Executive Directors
BASF SE

Photo: BASF

Your opinion is important to us

You are reading the latest issue of the BASF magazine. What do you think of it? Which topics would you like to know more about? Write and let us know your opinions and ideas.

creating-chemistry@basf.com

Photo: Alex Trebus Illustration: Jörg Block, ASCS

CONTRIBUTORS

FOCUS

TWO PERSPECTIVES

Photo: IASS/L.Ostermann, Alex Trebus, Tom Saater, Andreas Pohlmann, Jonas Ratermann

REPORTAGE

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million tons of palm oil and palm kernel oil are consumed today

It's in half of all the packaged goods we buy. Global consumption of palm oil is growing fast, but the costs to the environment are high. How to meet rising demand while protecting forests, communities and wildlife?

28

Distorted risk perception

Tornados, terrorism and contaminated food. We are surrounded by risks, but are often afraid of the wrong kind. This has its consequences.

42

Made from waste

To some it is garbage, to others an important resource. We present products that use discarded items as unusual raw materials.

640,000

metric tons of discarded fishing nets and other equipment are in the world's seas.

Photo: Sebastian Olényi, sustentio GmbH, gettyimages, Buero

Content

2018 issue

Creating Chemistry magazine can also be found online with additional content at
basf.com/creating-chemistry-magazine

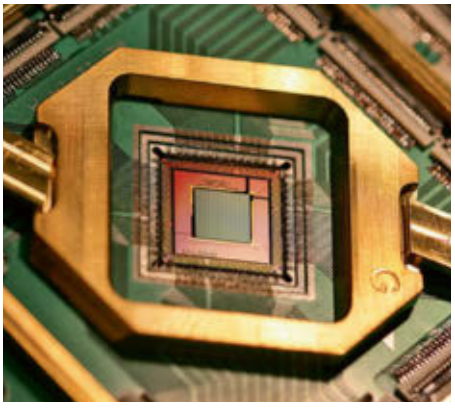
Age of the super brains

Focus Supercomputers are creating a stir as lightning-fast virtual analyzers, but the race for the next great breakthrough in IT has already begun – with quantum computers. Find out how this development is changing society and business.

Photo: gettyimages, ASCS Illustration: ASCS

Supercomputer
The high-performance computer at TU Dresden, Germany, fills a whole hall of its own. Its peak performance is more than 1.5 quadrillion computing operations per second.

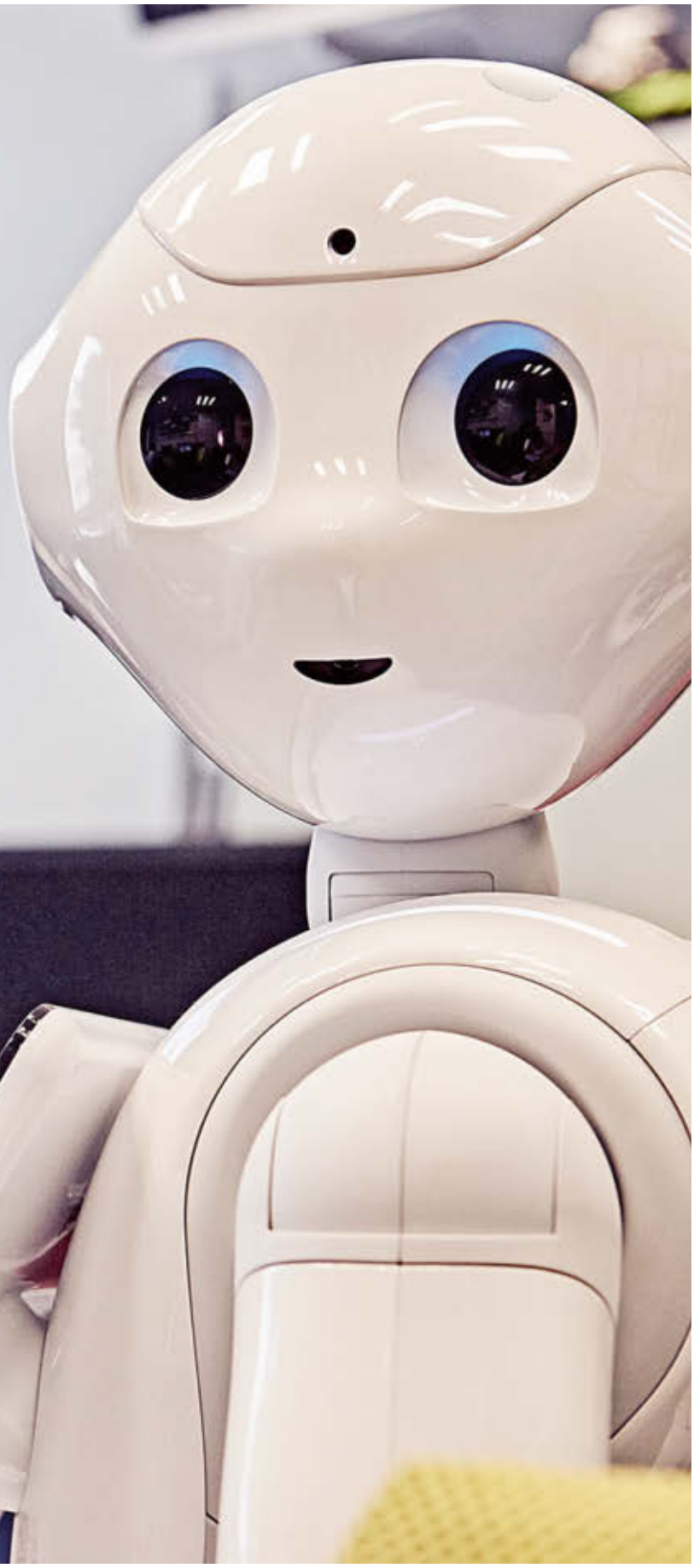
Photo: Jürgen Lösel/dpa, d-wave systems, Connie Zhou/IBM



Quantum computer
Above: IBM experts examine the hardware of a quantum computer in the IBM Q Lab. Left: With their fragile qubits, processors form the heart of the quantum computer. At present, a maximum of 17 qubits can be achieved, but 30 to 50 qubits are required for the quantum computer to be truly superior to existing supercomputers.

Human and machine
Above: A machine-learning computer in Tokyo plays Japanese chess to a professional standard. First chess, then Go, and now even poker: computers are surpassing humans in increasing numbers of intelligent challenges. Left: Programmers stand behind the achievements of artificial intelligence.

Photo: gettyimages, shutterstock, ullsteinbild/BSIP/Marie Bienaimé



Pepper, the little robot from the Japanese mobile communications company Softbank, speaks 20 languages and even recognizes emotions, thanks to the technology of IBM's supercomputer, Watson.

The answer to all the ultimate questions of life is actually very simple. It is 42. This was calculated in 7.5 million years by Deep Thought, the supercomputer in the science fiction novel, *The Hitchhiker's Guide to the Galaxy*. Unlike the machine in a 40-year-old work of fiction, today's powerful computers provide usable results. In chemistry, for example, they help in molecular simulation for finding new active agents. They make water and energy supplies more efficient and are important helpers in predicting epidemics and earthquakes or in diagnosing illnesses. For example, oncologists in Japan were groping in the dark in the case of a 60-year-old woman until they enlisted IBM's Watson. This supercomputer required just 10 minutes to compare the data of the sick woman's diagnosis against millions of cancer studies to find an extremely rare type of leukemia. The doctors adjusted their therapy and the woman was treated successfully with the help of "Dr. Watson."

Record-breaking supercomputers

Supercomputers that achieve top computing power with several thousand processors could play a key part in meeting the challenges of the future. "We are facing changes that will prove to be revolutionary," the U.S. computer science professor and supercomputer expert Thomas Sterling predicts. Thanks to their ▶

01 Super-computers

Server racks lined up in rows: what a super-computer looks like from the outside.

computing power, Sterling places super-computers on a par with innovations that have given a decisive impetus to human development, such as the discovery of fire. Competition in the market is correspondingly fierce. China and the United States, in particular, are engaged in a race among high-performance computers.

The world's first supercomputer came on to the market in 1964 in the United States, in the form of the CDC 6600. The Americans dominated the scene for many years, but recently computers from China have made their way to the top. At 93 petaflops – that's 93,000,000,000,000,000 calculations per second – the Sunway TaihuLight is the fastest supercomputer by far (as of November 2017). "With its help, complex climate models, for example, can be calculated nearly a hundred times faster than by a computer capable of one petaflop, which would need one year for the task. This adds a whole new dimension to the fight against climate change," Sterling says. The Sunway is followed by the Tianhe-2, which still has almost twice as much computing power as the Piz Daint from Switzerland, which comes third. The fastest U.S. computer, Titan, is fifth.

Development of computing power

Calculations per second (FLOPS)

1941 Konrad Zuse's Z3, Germany: the world's first functioning digital computer
2

1946 ENIAC, USA: the first electronic universal computer
500

1964 CDC 6600, USA: the first supercomputer
3,000,000

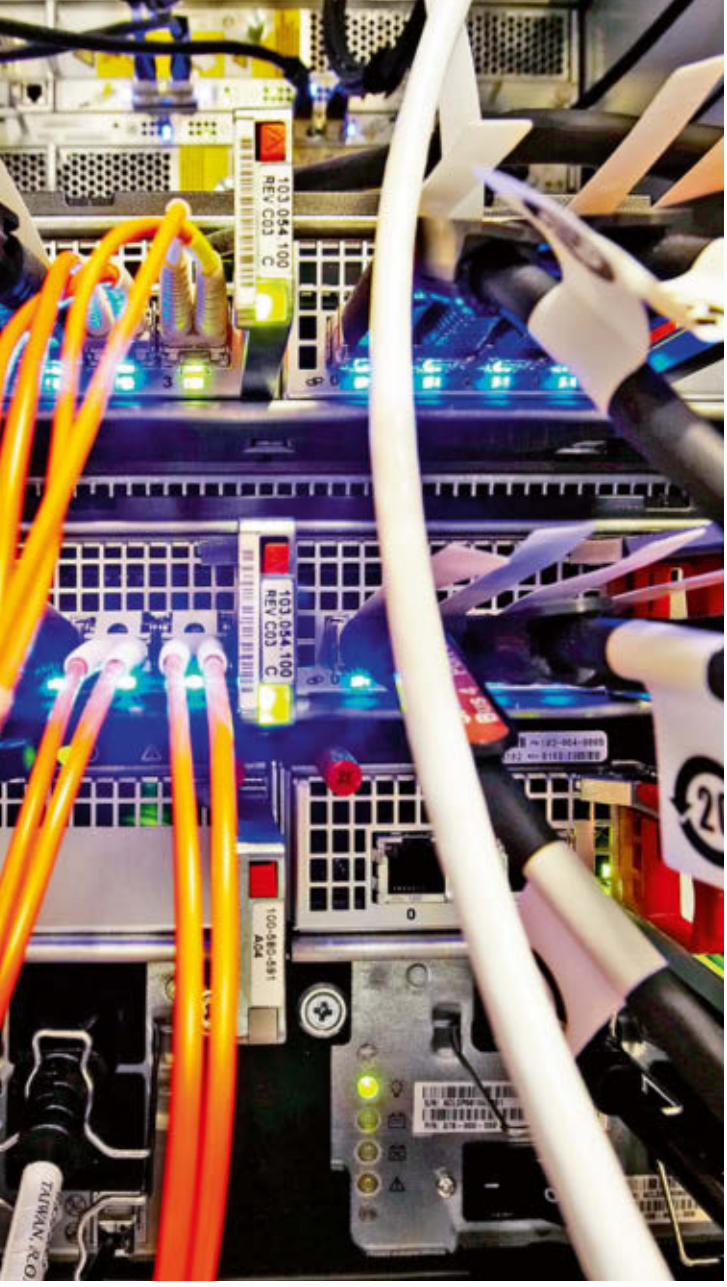
1984 M-13, Soviet Union: the first computer in gigaflop range
24,000,000,000

2017 Sunway TaihuLight, China: fastest computer to date
93,000,000,000,000,000

Supercomputer ranking (as of November 2017)
www.top500.org

But performance rankings often involve great simplifications. A high level of computing power alone does not help with every scientific question. A big part is also played by the size of the memory – and above all by the programming. Nevertheless, computing power is a major requirement for these super brains to exploit their abilities to the full. For this reason, researchers around the world are already working on the next stage of supercomputers: the exascale computer. With a capacity of 1,000 petaflops, this will be able to perform one quintillion – meaning 10 to the power of 18 – computing operations per second. China says it has already begun building a prototype, and it is followed in this by the United States. So they do not fall behind, the U.S. Department of Energy this summer announced $258 million to

Photo: Jürgen Lösel/dpa, gettyimages



Meters of data connections to the server

The road to super-intelligence

- **1951** Marvin Minsky builds the first neurocomputer, SNARC.
- **1956** Scientists present the first AI program, Logic Theorist.
- **1972** Introduction of Mycin expert system for the diagnosis and treatment of infectious diseases.
- **1994** First test of autonomous automobiles on German roads.
- **1997** The Deep Blue computer beats the reigning world champion Garry Kasparov at chess.
- **2011** IBM brings the powerful AI computer Watson onto the market.
- **2017** The Libratus software beats four world-class players at poker.

"We are facing changes that will be revolutionary."

Thomas Sterling
Professor of Computer Science,
Indiana University, USA

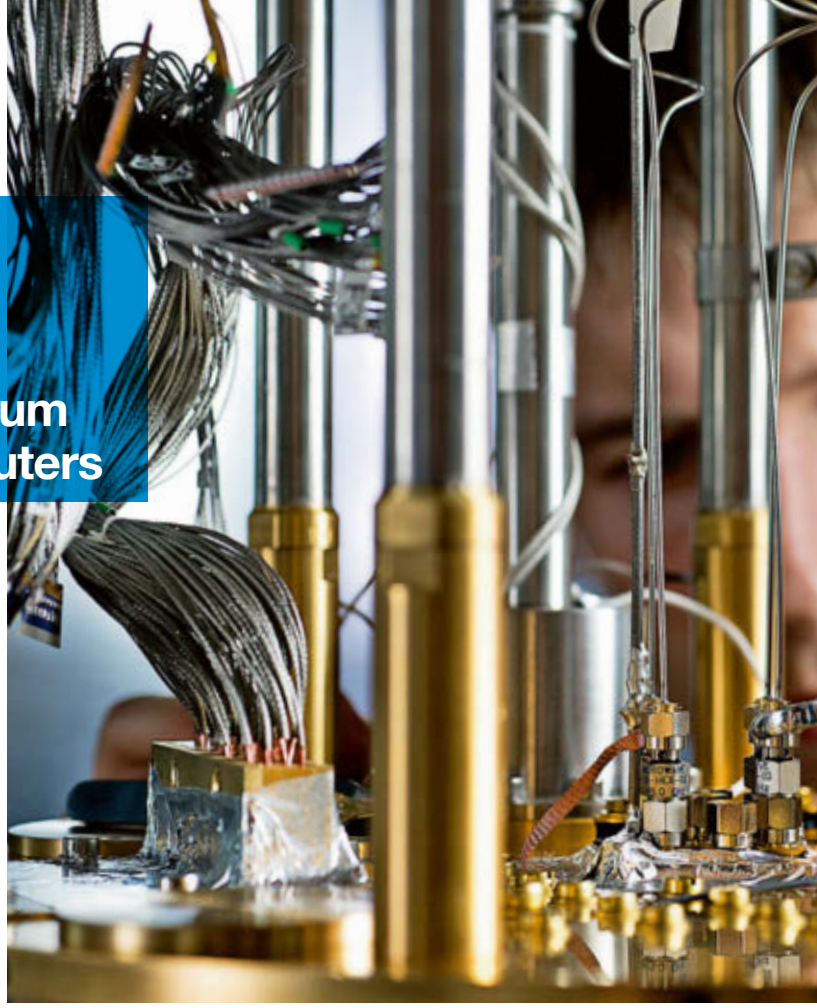
support companies to make progress on the exascale computer in the next three years. Meanwhile, the European Union, which has so far been lagging some way behind, is likewise planning to invest heavily in breaking the exascale barrier by 2022, according to Andrus Ansip, the Commissioner for the Digital Single Market. The E.U. estimates that €5 billion will be needed for this. At present, E.U. states are much too reliant on the computing power of supercomputers based in, for example, China and the United States. For instance, as recently as spring 2017, E.U. industry provided only around 5 percent of the power of high-performance computers but used one-third of global resources. Japan, too, is getting involved in this catch-up race and is aiming to top the supercomputer league as early as 2018 with its AI Bridging Cloud Infrastructure.

Helpers for scientists

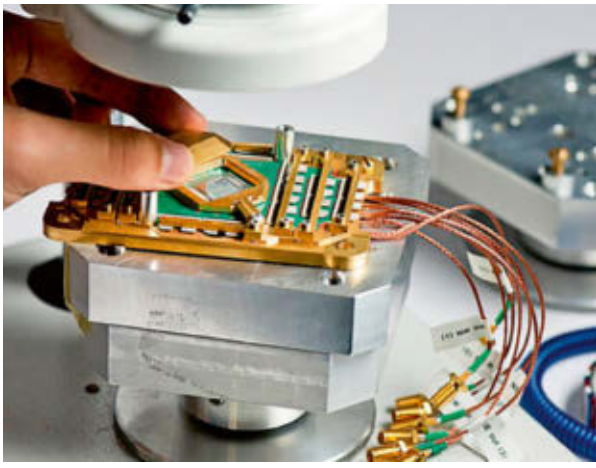
"Especially in the natural sciences, powerful supercomputers are already indispensable for simulating molecular processes one to one," says the German philosopher of science and expert in artificial intelligence (AI), Professor Klaus Mainzer. Out of the many possible combinations of these building blocks, they help to single out those that offer the prospect of surprising discoveries and new products. The supercomputer is capable of learning, and it performs an initial selection, so that only the most promising substances find their way into the laboratory. Accordingly, BASF has, since fall 2017, relied on just such a powerful digital helper for developing virtual experiments and answering complex questions. It shortens the time taken to obtain usable results from several months to a few days (see pages 24–25).

"The challenging problems in the field of chemistry could become drivers for supercomputing," Sterling believes. In his view, they could contribute to investigating the critical boundaries of technology – and how to overcome them. The bottlenecks between processors and memory pose increasing problems to the industry. These become more serious as the masses of data which have to be shifted around, in simulations for example, grow larger. "This bottleneck in traditional von Neumann computer architecture needs to be eliminated," Sterling says. A new way of thinking is required to bring together computing and memory operations in a smart way. Another technology has already assimilated the elementary logic by which chemical processes work: the quantum computer, which could open up new horizons of knowledge. The next dimension of super brains – thinking in several states at once – is in the starting blocks. ▶

02 Quantum computers



Precision work by hand on the D-Wave quantum computer, which developers at NASA and Google, for example, are using.



Such processors are intended to make quantum computers the most powerful type available.

A shiny, silver cylinder holds the treasure: qubits, frozen by a helium pump to minus 273 degrees Celsius. These are the building blocks that enable quantum computers to work, because, unlike the bits in a classical computer, qubits can store and process two states simultaneously. This new computer logic is intended to make them much faster than any supercomputer, and their search for new products, applications or patterns more efficient. The disadvantage is that qubits are extremely volatile. They function in a stable, fault-free manner only if there are no external influences. To ensure this, they have to be not merely frozen but also shielded from the outside world in a vacuum.

Fragile super brains

Efforts to crack this problem are still in the initial stages. To date, researchers have developed fully programmable five-qubit computers and more fragile 10 to 20-qubit test systems. For example, in May 2017, IBM presented a processor with 17 qubits, which is intended to form the foundation of the first commercially available quantum computer. "We're progressing faster and faster," says IBM researcher Anthony Annunziata, PhD, from the United States. Now, he notes, the IBM system is stable enough to perform computing operations over a fairly long period. But Annunziata warns that the technology is still at a very early stage. "Quantum computers are more or less at the same stage as classical computers were in the 1940s, but they are developing even more rapidly than classical computers did back then," he says.

> **"Quantum computers are more or less at the same stage as classical computers were in the 1940s."**
>
> **Anthony Annunziata, PhD**
> IBM researcher, USA

It is only when we reach around 30 to 50 qubits that a quantum computer would be superior to any conventional supercomputer in solving a specific problem, in the view of experts such as Professor Raymond Laflamme, Director of the Institute for Quantum Computing at the University of Waterloo in Canada. "But if we extrapolate the trend of the last 15 years, 100 qubits are conceivable within the next 10 years," says the pioneer in quantum computing. The Massachusetts Institute of Technology predicts that a fundamental breakthrough for quantum computers could well be made within four to five years.

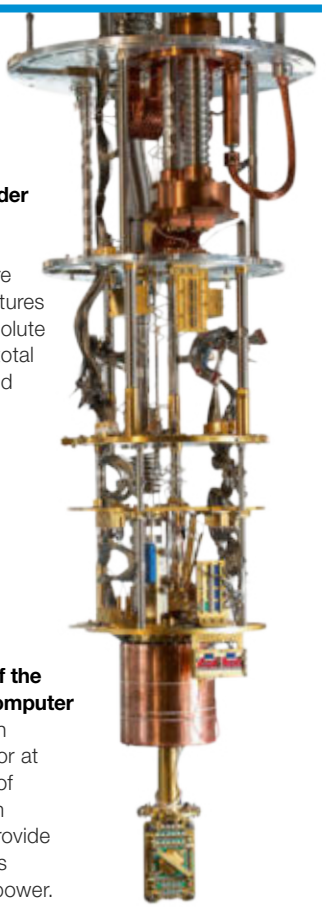
Whether it is IBM, Google, Microsoft or Intel, none of the big tech companies is afraid of the high cost involved in developing a powerful quantum computer – to say nothing of secret services like the U.S. NSA, which are probably working "under the radar" on powerful quantum systems to crack encrypted communications.

Quantum computers bring impetus

This is because Moore's Law, according to which the power of computer chips will double every one to two years, is now getting close to its technological limits. Experts believe that a breakthrough in quantum computers could provide a fresh impetus. According to Laflamme, six to seven teams worldwide are currently engaged in research to achieve this goal, and billions are being spent in the process. For example, the European Commission is planning to invest €1 billion in driving progress in quantum technology over the next nine years. Also, China made headlines in August 2017 with the news that a satellite had shared a quantum key with a ground station for the first

Photo: d-wave systems

Looking under the cover
Inside the cylinder there are temperatures close to absolute zero – plus total darkness and silence.

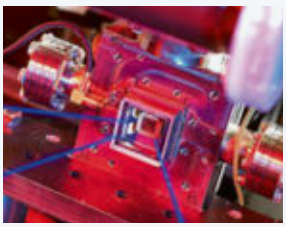


The heart of the quantum computer
The qubits in the processor at the bottom of the quantum computer provide its enormous computing power.

Photo: d-wave systems, gettyimages

How quantum computers are unique

How they work Special building blocks (qubits) enable quantum computers to process data very quickly and simultaneously.



What a qubit is
A qubit is an information unit in quantum mechanics. Whereas the bits of classical computers work in a state of 1 or 0, a qubit can simultaneously assume both values – or an infinite number of intermediate states. If it were possible to bundle hundreds of these building blocks together in a quantum computer, that computer would be able in a moment to store and process more values than there are elementary particles in the universe.

What is special about them
A quantum computer would be able to calculate highly complex models that have so far been beyond traditional systems.

Now and then:
Learn more about the history of computers
on.basf.com/now-and-then

time – a milestone on the road to virtually unhackable encryption through quantum technology.

However, "for the foreseeable future, quantum computers won't surpass or even substitute supercomputers across the board," Annunziata says. "They will act as a supplement, for the solution of very special problems." They are ideally suited to represent dynamics in molecules and thus to show, for example, how one electron interacts with another and with the nucleus. "If the number of electronic states increases, the number of possible interactions increases exponentially. As conventional computers can't represent that properly, they try with approximations," he says. A quantum computer, meanwhile, is already using quantum mechanics, the kind of mechanisms that are also at work in molecular interactions.

Benefits for research

Several sectors can benefit from the greater precision of modeling, such as materials sciences and the chemical or pharmaceutical industries, Laflamme says. Researchers can use the disadvantage of quantum particles – their sensitivity – to their advantage here, for example in prospecting for natural resources or diagnosing illnesses. For instance, qubits are already being deployed as super-sensitive sensors that can precisely detect individual atoms of defective proteins that might turn cancerous. To do this, they focus very closely on the vibrations of one specific atom.

Currently, though, the main priority is to increase the number of people who want to understand and use quantum computers, Annunziata says. This is why IBM made its quantum computer accessible to the public about a year ago. Since then, 50,000 users have accessed the Quantum Experience platform. Through the open source approach, it is possible to learn from and with the community, Annunziata says. According to media reports, Google's parent company Alphabet has recently followed suit with its quantum computer and is planning to open it to academics and developers. This may result in the emergence of a kind of ecosystem, in which the discipline of "quantum computing" is able to flourish. ▶

A human gives the orders, and the artificial intelligence systems learn.

03

Human and machine

The human factor – Four theses on the new relationship between humans and algorithms.

$15.7

trillion
is the expected value of additional growth in the global economy from AI up to 2030.

1 Algorithms are only human, too: The deceptive semblance of objectivity

Data are being analyzed by software in more and more areas of life. Such algorithms are gaining in power as a result. However, they are as subjective and selective as their programming by their human "creators." Algorithms incorporate the conscious or unconscious prejudices and life experiences of their programmers. Loans are refused or made hard to obtain because the software places the borrower in a problematic neighborhood, even though the person is perfectly solvent. Seemingly objective software to predict crime ("predictive policing") can serve to reinforce existing discrimination. If it leads police to perform a particularly high number of checks in socially deprived areas, they will possibly record more crime there. This will then be more strongly weighted in digitized forecasts.

2 The world is a story to be told – not a thing to be counted: True value creation results from a combination of data analysis and human expertise

As early as 2008, Chris Anderson announced the "end of theory." "The data deluge makes the scientific method obsolete," wrote the editor of *Wired* magazine. He believed that, thanks to big data, algorithms could find patterns that research and science would never discover with their own methods. "With enough data, the numbers speak for themselves," Anderson said. However, some ten years after Anderson's article, that euphoria has been replaced by a more sober assessment. This is attributable to failures by data collectors like Google, whose Flu Trends program in 2012/2013 saw a flu epidemic on the march that never actually materialized. In complex situations, correlations cannot take the place of causality, or assumptions the place of evidence. Human expertise is required here.

3 Computers propose, humans dispose: We have to maintain control over technology

Artificial intelligence (AI) systems are already developing independently. Using mathematical logic, they are learning from their mistakes and making their own decisions. It is barely possible for humans to grasp exactly how the neural networks of AI reach their conclusions in every case. This is an area with an urgent need for improvement, says informatics professor Alan Bundy from the University of Edinburgh in Scotland. Meanwhile, politicians and consumer-rights activists are demanding recognized standards for AI algorithms as they grow smarter. They also want their workings to be subject to independent examination – especially when

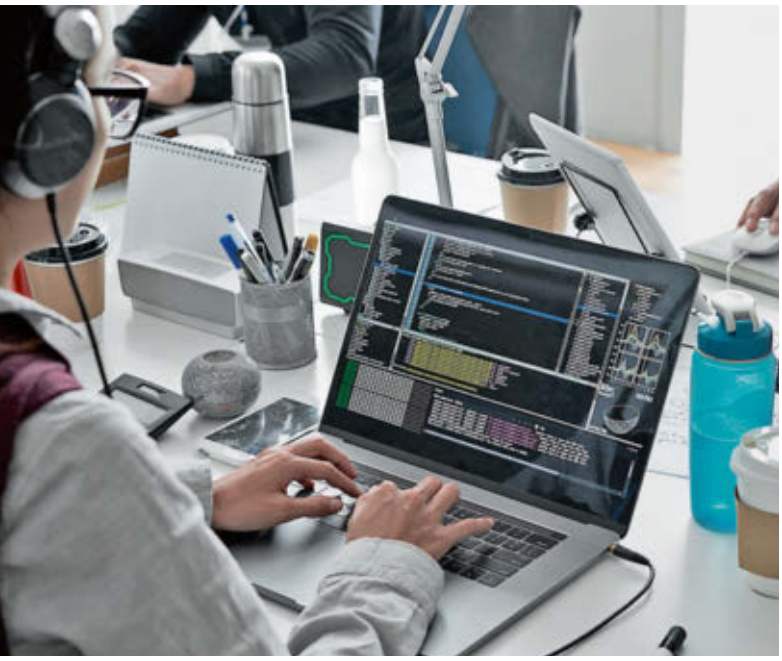
Photo: shutterstock, Magdalena Jooss, private

AI is operating in socially sensitive areas. And they are calling for AI machines to give a warning before they act outside their area of competence, so that humans can assist them – or take back complete control.

4 Supercomputers are not automatically better than humans: Human experience and values cannot be replicated

Machines are making rapid progress in learning, thanks to AI and machine-learning algorithms. Researchers regard super-intelligence – machines superior to humans in many or all areas – as possible within a few decades. This requires a rational look at the limits and scope of new technologies. In specific areas, artificial intelligence can use solid data as the basis to make objectively better decisions than humans, who often act intuitively. However, in complex decisions that go to the heart of the way that humans live together, such as the fight against poverty, there is no right or a wrong answer. Behind such decisions there are humans, making choices according to their respective experience, values and goals. This essence of a humane, democratic society cannot be delegated to smart machines. ■

It is the programming that unleashes the power of super-computers.

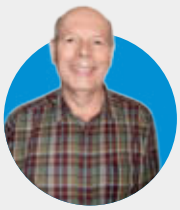


Will artificial super-intelligence outpace us?

Pro and contra The momentum of artificial intelligence allows both skepticism and hope to flourish.

Klaus Mainzer
Professor of Philosophy and the Theory of Science and expert in artificial intelligence, TU Munich, Germany

Pro Artificial intelligence (AI) systems are already capable of doing things that we achieve through learning experiences and intuition. They do this just with great computing power and sophisticated mathematics. It is, without doubt, a significant innovation, and we should make use of it. Artificial intelligence can beat any poker expert, without emotion or consciousness, even though the game is regarded as a byword for intuition. Moreover, poker is merely a prototype for situations in which humans have to make decisions with incomplete information. Sooner or later, these algorithms will also be used in decision-making situations in business and politics. For example, they could support us, but not take our place, in complex contracts. Thanks to big data, it is now possible to identify the opinions of specific groups very precisely. Technologically, through AI, something like a government by "perfect populism" is imaginable. Some authors even believe democracy is endangered by highly intelligent algorithms. This debate could be dismissed as science fiction. I take it seriously. Therefore, we must take care to ensure that AI systems remain our servants.



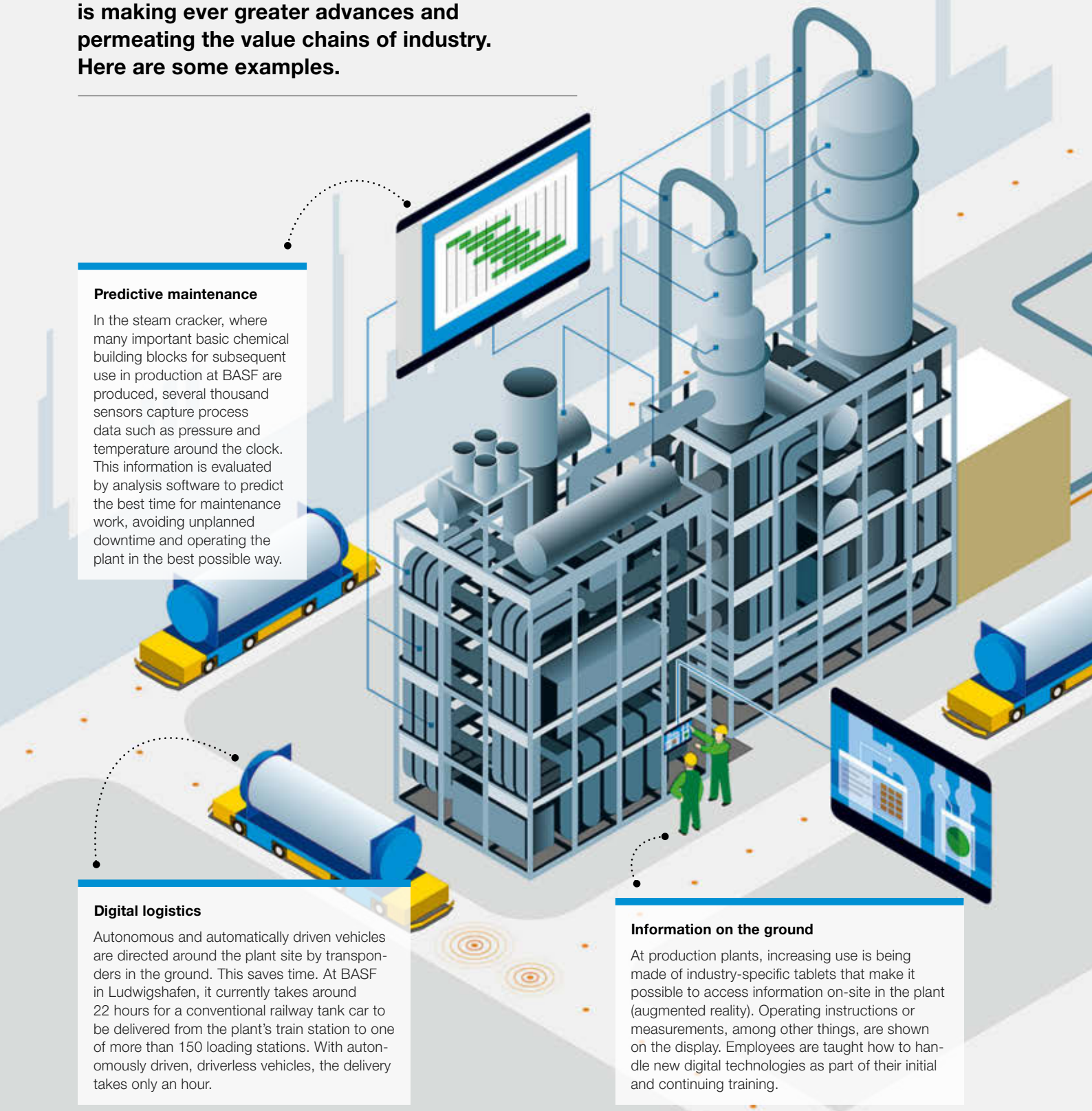
Alan Bundy
Professor of Automated Reasoning, School of Informatics, University of Edinburgh, Scotland

Contra We are still extremely far from seeing intelligent machines take over the world. If a Google computer is better than a human at mastering a very complex game, there will be awestruck comments. "Oh, these machines are smarter than us." But a program of that sort can actually only do that one thing. Even AI systems used in autonomous driving still have a very limited focus. The artificial intelligence won't be saying to itself, "Um, the way I'm acting right now might not be particularly safe." Humans, however, can take a step back and look at things from a broader perspective. The real danger isn't technology becoming too smart, but comes from overrating stupid machines, from entrusting them with tasks that overstrain them. For instance, when doctors rely too heavily on AI in their diagnoses. But these are threats to individual people, not to humanity as a whole.

Digital industry

04
Focus
Infographic

Infographic **The digital transformation is making ever greater advances and permeating the value chains of industry. Here are some examples.**



Predictive maintenance

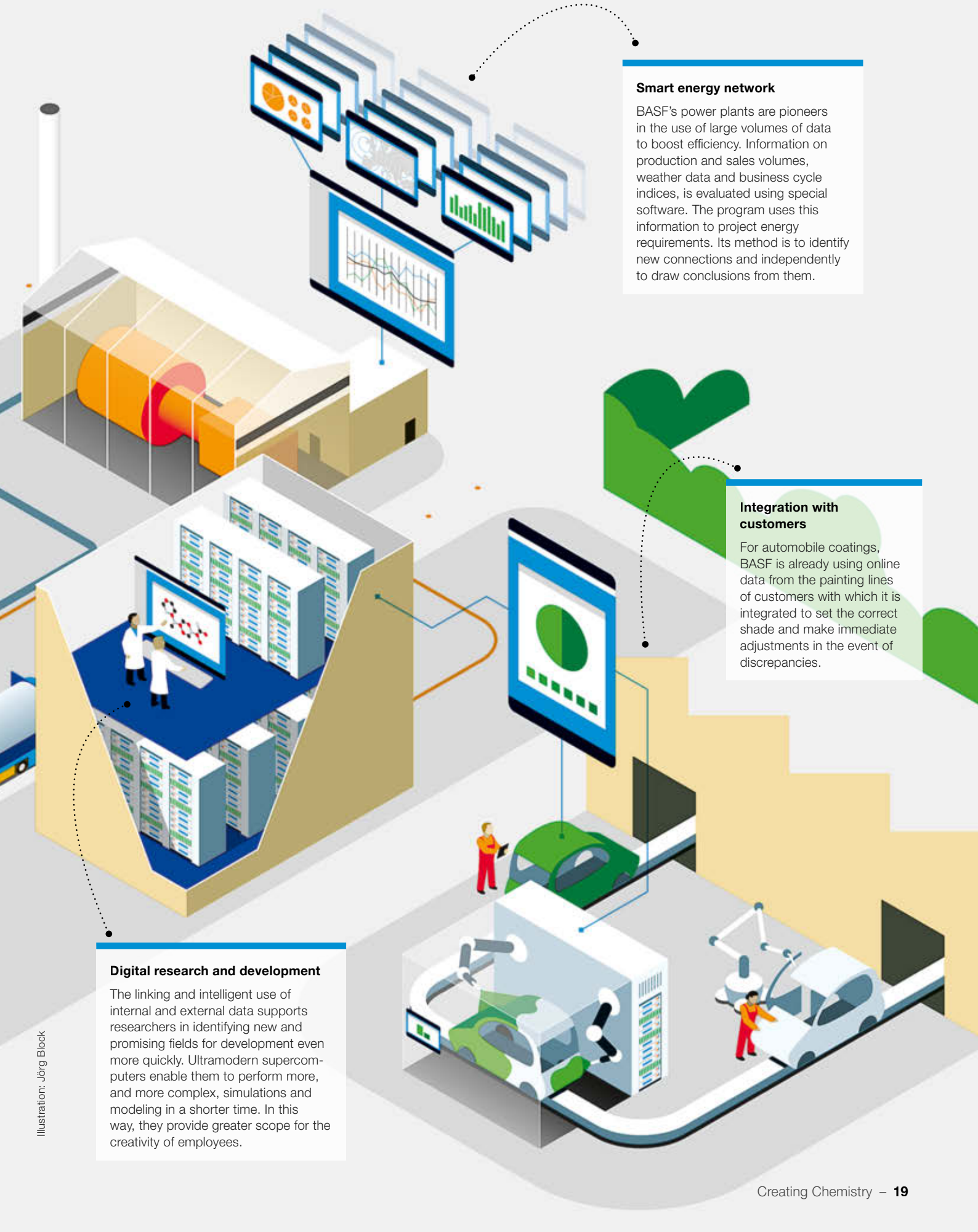
In the steam cracker, where many important basic chemical building blocks for subsequent use in production at BASF are produced, several thousand sensors capture process data such as pressure and temperature around the clock. This information is evaluated by analysis software to predict the best time for maintenance work, avoiding unplanned downtime and operating the plant in the best possible way.

Digital logistics

Autonomous and automatically driven vehicles are directed around the plant site by transponders in the ground. This saves time. At BASF in Ludwigshafen, it currently takes around 22 hours for a conventional railway tank car to be delivered from the plant's train station to one of more than 150 loading stations. With autonomously driven, driverless vehicles, the delivery takes only an hour.

Information on the ground

At production plants, increasing use is being made of industry-specific tablets that make it possible to access information on-site in the plant (augmented reality). Operating instructions or measurements, among other things, are shown on the display. Employees are taught how to handle new digital technologies as part of their initial and continuing training.



Smart energy network

BASF's power plants are pioneers in the use of large volumes of data to boost efficiency. Information on production and sales volumes, weather data and business cycle indices, is evaluated using special software. The program uses this information to project energy requirements. Its method is to identify new connections and independently to draw conclusions from them.

Integration with customers

For automobile coatings, BASF is already using online data from the painting lines of customers with which it is integrated to set the correct shade and make immediate adjustments in the event of discrepancies.

Digital research and development

The linking and intelligent use of internal and external data supports researchers in identifying new and promising fields for development even more quickly. Ultramodern supercomputers enable them to perform more, and more complex, simulations and modeling in a shorter time. In this way, they provide greater scope for the creativity of employees.

Illustration: Jörg Block

05 Focus Interview

Professor Barbara Grosz is Chair of the Standing Committee of the "One Hundred Year Study on Artificial Intelligence."

Artificial intelligence will support people, not replace them

Interview Barbara Grosz, Higgins Professor of Natural Sciences at Harvard University, has worked since the 1970s at the highest level of artificial intelligence (AI) research. Here she talks to Creating Chemistry about her passion for the field, and why it would be a terrible mistake to replace people.

Creating Chemistry: Artificial intelligence seems to be everywhere today, but what exactly is it?
Professor Barbara Grosz: They say that if you ask six researchers to define AI, you will get seven different definitions, so I'll give you mine. Artificial intelligence is both a field of study and a set of computational methods. As a field of study, the focus is on what I would call a computational understanding of intelligent behavior. By a computational understanding, I mean determining the kinds of cognitive processes and representations that are needed to produce intelligent behavior, then determining how to realize those in a computer system. The set of computational methods are then the algorithms, even the mathematics, but also the computational structures, that you need to actually operationalize that understanding.

Creating computer systems that can communicate freely with people is a key challenge in artificial intelligence. How has your work on natural-language processing aided in the pursuit of this goal?
When I started, there were a lot of people working on syntactic processing, meaning the structure of sentences, and semantic processing, which is how meaning is built. Everybody knew, in some sense, that context, dialogue and pragmatics mattered, but they had no idea how to handle these factors computationally. So, one of the first things I did were what were later known as "Wizard of Oz" experiments. I put two people in two different rooms, communicating with teletype machines. I told one of them that they were talking with a computer, and I asked them to complete a task. The transcripts generated in those experiments revealed that these kinds of "task-oriented dialogues" have a structure, that the structure parallels the task, and that the way in which we talk is affected by that structure. Once I'd developed a computational model of these task-oriented dialogues, the next question was how you generalize from those to other types of conversation. That led me, with colleagues, to the development of intentional models and to speech-act theory, which other people in AI have picked up on.

> **"I believe there is a real opportunity for artificial intelligence to make a difference."**
>
> **Barbara Grosz**
> Professor of Natural Sciences at Harvard University, USA.

What happens when there are multiple agents communicating with each other?
In a dialogue, you can't assume that every participant understands everything about the other participants' knowledge or intentions. When you have multiple participants working together, you have to model not only their individual plans but also the way participants interact and the way their plans are interwoven. One thread of my work has been the development of those models. Another has been to use the theoretical models as inspiration for design, or as constraints on what parts of systems you have to build. An example is a project I'm working ▶

Photo: Alex Trebus

on with a pediatrician at Stanford Medical school involving children with complex conditions. Those children may see upwards of 12 or 15 care providers, who may have little detailed knowledge about each other's work. Today's electronic health record systems do nothing to help these providers coordinate care delivery. We are using our multi-agent systems theory of collaboration as an analytic lens to see what is going on when care providers and patients, or in this case parents, try to work together, to see where the missing pieces are, and understand what systems we can design that would help them work more effectively as a team. One of those pieces is something that ensures all participants can see what the goals are, so they know what they are trying to achieve. Another relates to improvements in the way team members exchange information.

There seem to have been huge leaps in the development and application of AI technologies in recent years. What is driving that progress?

Many of the most important ideas in AI, like neural networks or text mining, have been around since the 1960s, but the computers of the time weren't powerful enough, so they just didn't work. Now, thanks to video games and the development of powerful graphical processing units, there is a lot more computing power out there. That's enabled the machine-learning community to develop what's known as deep learning, which involves neural networks with many more layers. That's made an enormous difference in a range of areas of AI. Deep learning is not by itself sufficient, though. It's unlikely even to handle all the vision and natural language problems, but it has made a huge difference to what AI systems can currently do.

What challenges still need to be overcome before we see truly "natural" conversations between computers and humans?

One major challenge is getting good data. There's a lot more data around today than a few years ago, but it's not always the right sort of data. If you want to learn about natural language, you need to study real dialogue. Twitter is not good data for that, because it isn't like real

Photo: Alex Trebus

Barbara Grosz is an expert on multi-agent collaborative systems.

dialogue, nor are the sort of rudimentary interactions we currently have with Siri and similar personal assistant systems. It will be difficult to get the right sort of data and to do it ethically, because you need permission from the participants if you are going to study their conversations. It will also be difficult to ensure you collect data from a full range of people. You can't just collect data from college sophomore students, as they have traditionally done in psychology research, nor just from today's heavy users of social media, nor just of English speakers. Even within a single country there will be different dialects and different cultural influences on conversational structures.

Will developments in other areas of computer science, like quantum computers, have a significant impact in the field of AI?
There's no question that when they get quantum computing to work, it will allow us to solve problems we can't solve now. But I can't tell you what those problems will be. The extent to which these technologies will help to increase reasoning capabilities is dependent on us understanding better how to get systems to reason at the higher cognitive level involved in human intelligent behavior.

Where do you think AI technologies will have the biggest impact in future and what are the implications for people's jobs and roles?
I don't want to do any crystal ball gazing, but there is a lot of interest in using AI to improve education and health-care delivery. I also think the autonomous vehicle arena is going to see a lot of change. With regard to health care and education, I think there's a huge ethical question for society at large. We could build those systems to complement and work with physicians and teachers, or we could try to save money by having them replace people. It would be a terrible mistake to replace people. There are great things that AI systems will be able to do in terms of processing large amounts of data, but that doesn't give you the same view into a patient. What patients need is a physician who knows them in depth. The same is true in education. Rather than trying to replace teachers, you can design systems to support them. If you have 30 or 40 students working on computer systems, the teacher can't track them all, but a computer can. It can detect when students are not paying attention or are running into difficulty, and it can alert the teacher to who needs help and why. That's exactly the kind of system we've been building.

"It would be a terrible mistake to replace people."

Barbara J. Grosz
Professor of Natural Sciences at Harvard University, USA

Barbara J. Grosz is Higgins Professor of Natural Sciences at Harvard University, USA. The "One Hundred Year Study on Artificial Intelligence," whose Standing Committee she chairs, periodically looks at the effects AI will have on every aspect of how people work, live and play.

Grosz has a bachelor's degree in Mathematics from Cornell University in Ithaca, New York, and an MA and PhD in Computer Science from the University of California at Berkeley. Grosz spent the early part of her research career the SRI International Artificial Intelligence Center, Menlo Park, where she directed the institute's Natural Language and Representation program.

Explain-it video: Learn more about how AI works
on.basf.com/AI

The widespread use of AI will raise important risks and ethical issues. How can they be addressed?
All human activities carry risks, and managing those risks requires a combination of design, policies and regulations. I believe we have to deal with ethics at the moment of design. That means we need to teach our students to consider ethical issues in design and how to address those issues. And industry needs to make ethical issues and ethical design as important as the design of efficient algorithms. We need industry to form partnerships – as it is now doing – to share best practices, and we need to have technology people, social scientists and cognitive scientists as well as lawyers in the room when regulations are written.

What potential areas of application for AI technologies do you personally find most exciting?
I believe there is a tremendous opportunity for AI to help people in low-resource communities around the world to have better lives, and also for the environment, if we make that a priority. There are some people working on AI for such settings today in a variety of applications, including education systems and health-care delivery systems. I think that's very exciting. It may not make a lot of money for anybody right away, but the long-term economic benefits from raising the level of health and education in low-resource communities and improving the environment will be much more important.

Photo: Alex Trebus

Supercomputer under the microscope

BASF QURIOSITY is the most powerful computer in the chemical industry worldwide. The new BASF supercomputer is intended to find new chemical compounds and products that would otherwise remain undiscovered. But it can do even more than that.

BASF's brand-new supercomputer, QURIOSITY, can perform 1.75 quadrillion calculations per second – an achievement that really heats up the hardware. "The waste heat from one rack alone could heat two houses," says Stephan Schenk, PhD, Team Leader High Performance Computing & Databases at BASF, half with a smile and half with respect. In all, the 18 giant racks have the capacity of around 50,000 laptops – which would make QURIOSITY's cables overheat and its components melt if it were not for its sophisticated air-water cooling system. It is connected to the BASF Verbund, an intelligent production system connecting all BASF plants at a site, which already plays a important role in cooling production facilities. "Electricity and cooling are the big challenges that still impose limits on supercomputers," Schenk says. The new super brain can provide about 10 times the computing power that was possible at BASF until now. It is by far the biggest computer in the chemical industry.

Its planning, too, went quickly. "In September 2016, our requirements for our supercomputer were clear, and we launched the tender soon after that," Schenk says. At that time, the experts at Hewlett Packard Enterprise (HPE) were already in the process of developing a new generation of supercomputers. In December 2016, BASF and HPE signed a contract under which BASF would receive the first new-generation supercomputer. In the subsequent months, HPE in Texas got down to the practical work of creating BASF's supercomputer. The right hardware and software architecture was sketched out on flip charts standing meters high and the first models were made out of foam and cardboard until, finally, the components of QURIOSITY were assembled in the computer racks of a Houston factory hall as big as a soccer field. After successful performance measurements, the supercomputer was then delivered to Ludwigshafen, Germany, in July 2017.

Chemistry out of a supercomputer

Researchers and developers in particular were waiting eagerly for QURIOSITY – with its concentrated computing power and fed with the right information, the supercomputer can help to evaluate complicated models. In the future, QURIOSITY is intended to help with tasks like calculating new molecular compounds in a very short time. BASF researchers will be able to use it to find out

1.75

quadrillion
the number of calculations that the QURIOSITY supercomputer can perform each second, equivalent to the power of around 50,000 laptops.

BASF supercomputer:
Learn more about QURIOSITY
on.basf.com/supercomputer

Stephan Schenk, PhD, (left) and Marcel Michael at the commissioning of QURIOSITY.

The supercomputer's first calculations include simulations of industrial catalysts, crop protection products and materials.

06
Focus BASF

what happens when variables in a chemical compound change, and then to test the new compounds in laboratory experiments. Expectations are high. It is intended that, by simulating chemical processes, the supercomputer will reveal completely new possibilities that were previously considered impossible theoretically or on a laboratory scale. Already today, there are indications of the potential of such huge computing power when computer simulations support laboratory experiments. For example, BASF was looking for an existing active agent in a soluble form for a crop protection product. Instead of performing thousands of experiments, they fed a large number of possible structures into a computer, which derived suggestions for experiments from that information. The best hundred found their way to the laboratory. This was not merely faster but also more successful. "In that way, we found products we would not have discovered otherwise," Schenk says. The supercomputer is also intended to help a scaleup – the step from making something in the laboratory to getting it to production scale – to happen more quickly in the future. The problem here is that chemicals behave completely differently in the laboratory and in a production reactor. BASF researchers were able to represent these changes by means of complex computer simulations. "This saved us needing to build a pilot plant," Schenk says.

At the same time, QURIOSITY can also be used as an optimizer in production. Thanks to this digital computing genius, data from everyday operations and those relating to price and business cycle trends can be pulled together, enabling facilities to be more efficiently run. Maintenance dates can be predicted before damage occurs, and raw materials and energy can be made available with even greater precision. "The supercomputer is a tool that can provide valuable support in many parts of BASF, from research and development to production and logistics and new digital business models," says Martin Brudermüller, PhD, Vice Chairman of the Board of Executive Directors and Chief Technology Officer at BASF. Schenk adds that "if it enables me to improve a product by 1 percent, this can, in the best case, result in earnings of tens of millions per year." This means that the energy costs when the brain of the computer heats up again are a good investment. ■

"We have found products we would not have discovered otherwise."

Stephan Schenk, PhD
Team Leader High Performance Computing & Databases, BASF

Photo: Andreas Pohlmann

Seen this yet?

New discoveries In this section we present inspiring innovations that make everyday life both easier and more sustainable.

0.3

micrometers
The air filter can capture particles as small as 0.3 micrometers.

Clean air to go

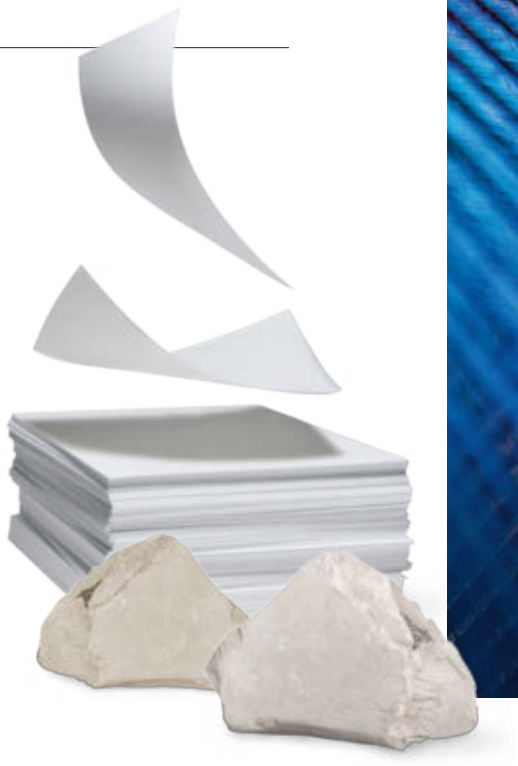
Product In the car or at the office, or even out on the street, the small can called Wynd wraps its owner in a bubble of fresh air. Battery-powered and connected to an app, this portable air purifier combats unpleasant odors, as well as harmful nitrogen oxides, allergens or smoke, with the help of an exchangeable filter. A sensor constantly measures the air quality.

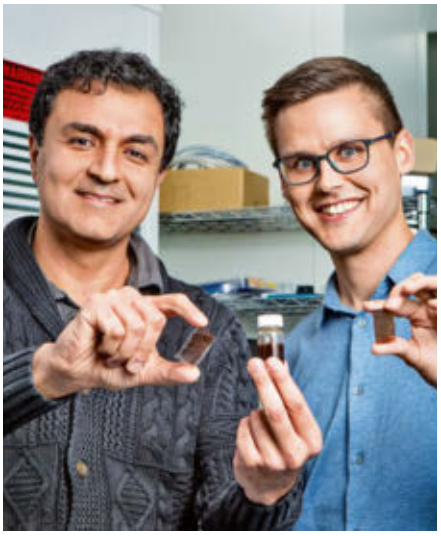
shop.hellowynd.com

Making paper from stone

Product LIMEX is a paper alternative made without trees or water. Developed by Japanese company TBM, it is made instead from limestone – an abundant resource. To make a metric ton of regular paper uses some 20 trees and 100 metric tons of water. LIMEX, by contrast, can help reduce deforestation and water shortages. It is also durable, lightweight and recyclable – you can even write on it under water.

www.tb-m.com/en/about/paper/



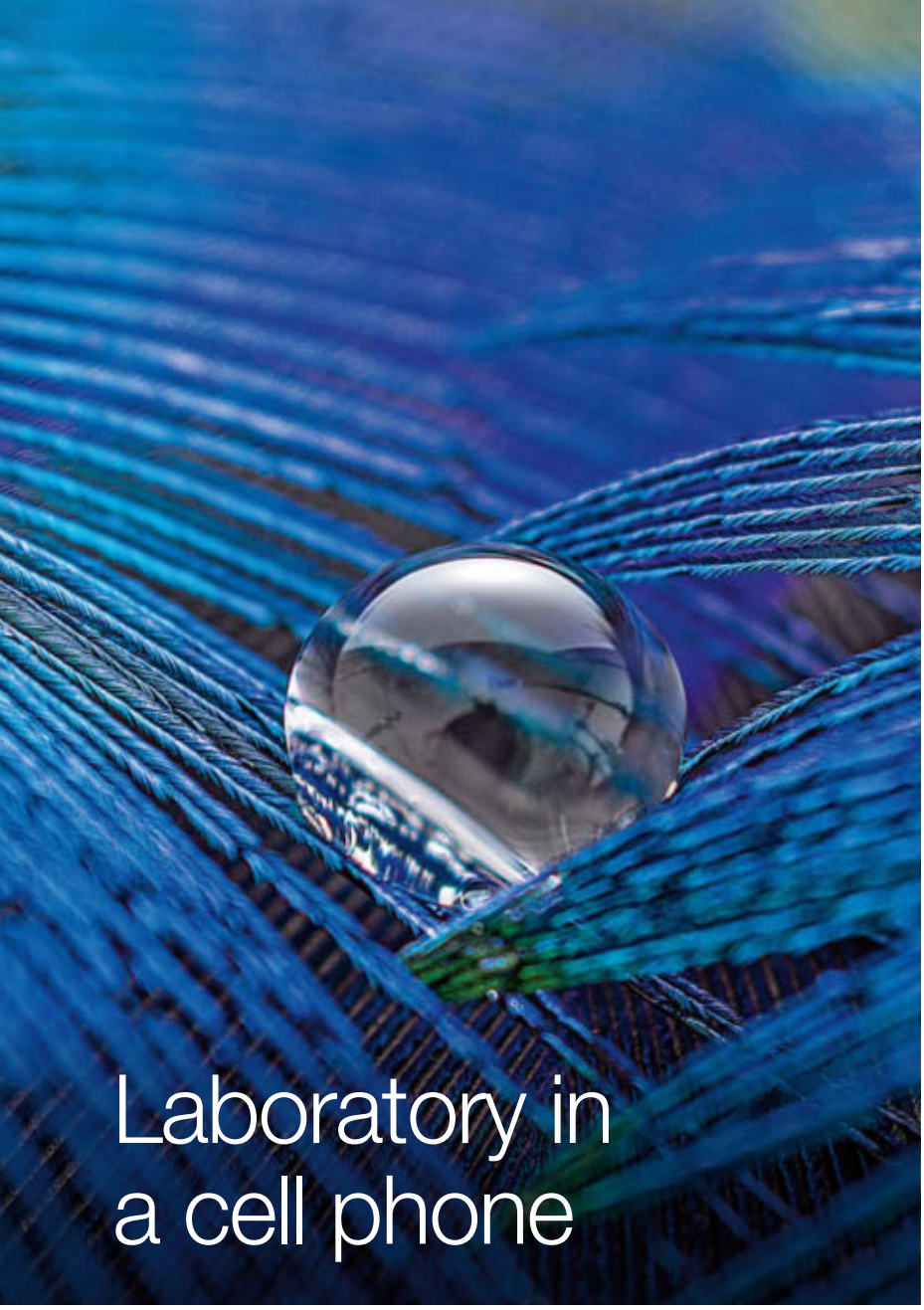


Solar paint

Prototype Researchers from the Royal Melbourne Institute of Technology in Australia have developed a paint that generates clean energy. The key ingredient is a new compound, synthetic molybdenum sulfide, that acts as a semi-conductor and catalyzes the splitting of water into hydrogen and oxygen. Mixed with titanium oxide particles, it creates a sunlight-absorbing paint that produces hydrogen fuel from solar energy and moist air.

www.rmit.edu.au

Photo: hellowynd, gettyimages, shutterstock, Solarpaint



Laboratory in a cell phone

Prototype Is this strawberry really ripe? What is the level of the environmental pollution around me? Is this tablet genuine? Consumers may be able to obtain answers to these and other questions on their cell phones in the next two to four years, thanks to wafer-thin infrared sensors. To do this, trinamiX, a wholly owned BASF subsidiary, is encapsulating the specially developed Hertzstück™ sensors not in a case but within a new patent-pending film, which is less than one-hundredth the thickness of a hair. The sensors are smaller than a pinhead, tiny enough to fit into the relevant measuring devices in smartphones. They operate sensitively and precisely in a wavelength range of 1,000 to 5,000 nanometers, thus making the invisible visible.

www.hertzstueck.de

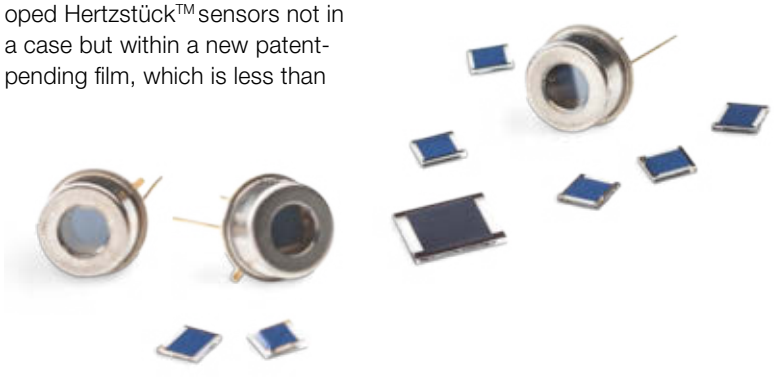


Photo: gettyimages, TrinamiX, VTT, ASCS

Turbo growth for fruit and veggies

Prototype It looks like a miniature table lamp, but this small Finnish incubator for home use does not provide light but produces fruit and vegetables in just a week. The 3-D printed device consists of a reactor and a cartridge containing plant seeds enriched with nutrients. These seeds are cultivated entirely automatically, with light, water and air. To enable the process to happen so quickly, the experts from the Technical Research Centre of Finland do not cultivate the whole plant but only the nutrient-rich cells. The device is already producing, among other things, various berries containing all the nutrients and vitamins of their traditionally planted counterparts. However, one challenge remains: The appearance of the berries grown in the reactor takes some getting used to, and their flavor is still rather bland.

www.vttresearch.com

Exercise caution

Three rules of thumb to help you quickly recognize whether a danger is real – or not.

1 **Always be skeptical.** Pay attention to the source. A well-known institution is better than an obscure source on the internet.

2 **Analyze the data.** Check whether relative or absolute figures are being cited. Percentages make many things seem more dramatic than they really are. And do not forget that statistics can be used to prove anything – and often the opposite, too. Pay close attention when interpreting figures.

3 **Do not get automatically carried away by anxiety.** Do not be misled into making hurried decisions by sensational headlines in conventional or social media – get the full picture.

Landing approach to Los Angeles over the highway. Statistically, airline passengers are at much less risk than motorists.

Photo: gettyimages

The wrong kind of fear

Risk We are surrounded by dangers. Terrorism, air crashes, contaminated food – these all cause us fear. But maybe we should actually be afraid of completely different things.

On September 11, 2001, 256 passengers lost their lives in the airplanes used in the terrorist attacks in the United States. During the following year, an alarming after-effect was observed. In 2002, statistics showed a drastic increase of 1,600 in the number of road traffic fatalities – about 4 percent more. "Out of fear, many people avoided airplanes and used their cars instead. The increase in traffic resulted in more road accidents. And consequently more deaths," explains Professor Gerd Gigerenzer, Director of the Harding Center for Risk Literacy, Berlin, Germany. Shocked by the attacks, people now perceived air travel as very dangerous. "Paradoxically, we have hardly any fear of dying in an accident, but we are more afraid of perishing along with many others – as in an aircraft or a terrorist attack," Gigerenzer says. We disregard the fact that we have already put the – statistically – most dangerous part of the journey behind us when we leave our car in the parking lot at the airport. Their feeling tells people they are more in control behind the steering wheel of their own car than in a plane flown by a pilot. "And a controllable risk seems less dangerous than an uncontrollable one," says Paul Slovic, a professor of psychology at the University of Oregon, USA, and one of the leading experts in risk perception. However, in the first years following the attacks, not a single deadly accident happened during commercial flights in the United States.

> **"Subjective fear strongly differs from factual reality, which can be substantiated with figures and statistics."**
>
> **Professor Gerd Gigerenzer**
> Director of the Harding Center for Risk Literacy, Berlin, Germany

A sense of reality looks different

Epidemics, terrorist attacks, plane crashes – people nowadays often rate risks higher than they should. They suffer from an emotional imbalance. "It's difficult for people to ▶

assess risks correctly. Their subjective fear strongly differs from factual reality, which can be substantiated with figures and statistics," Gigerenzer says. People today are afraid of dangers that either do not exist at all for them or are very unlikely – for dangers are one thing, but the probability that they will actually happen is something else. A lion is certainly dangerous, but if it is captive in a zoo the danger to humans is relatively low. "Our lives are more low-risk than ever, and dangers often seem more threatening to us than they actually are," says Professor Ortwin Renn, Scientific Director at the Institute for Advanced Sustainability Studies (IASS) in Potsdam, Germany, who has worked extensively on the topic of risk perception. Paradoxically, this fear is intensified by the fact that we are so well off and everything is actually fine. "That is because this naturally also means we have a lot to lose," Renn says.

> **"A controllable risk seems less dangerous than an uncontrollable one."**
>
> **Professor Paul Slovic**
> University of Oregon, USA

In saturated societies such as those of the Western industrialized nations, he explains, people have correspondingly more fear than in less developed societies, where individuals expect to make personal progress by taking risks.

Irrationality is international

There are many reasons for our incorrect assessments. Our perception of risk is influenced by feelings, not by our intellect. Thus our assessment of probabilities is different from the statistical reality. "Most risk analysis in daily life is handled quickly and automatically by feelings arising from what is known as the 'experiential' mode of thinking," Slovic says. The fact that we repeatedly also experience improbable things and that the media report on them confirms us in our belief that improbable things may not be so improbable after all. That is an error in reasoning. The thing that we fear most is probably the thing that we are most unlikely to experience.

Social and cultural factors also play a big part in what frightens us. Nevertheless, irrationality is international. It is universally true that the risk of rare and spectacular things such as tornados, air crashes or terrorist attacks is overrated, while more probable causes of death are overlooked. Risk expert Slovic has identified two more factors. If someone takes a risk by choice, he'll perceive it as less dangerous than a risk forced upon him. The greatest dangers, however, are met with indifference – high blood pressure, obesity, alcohol, smoking. Also, a high-fat diet is wrongly considered more low-risk than genetically modified food.

Top 5 most poisonous substances

Poisons Four of the five most poisonous substances are found in nature and one is a by-product of industry.

Figures given are LD_{50}-Value

This means that if laboratory animals such as rats or mice are given the amount of the substance shown below per kilogram of body weight, 50 percent of them will die.

1. Botulinum toxin A (natural)
Source: *Clostridium botulinum* bacterium
0.00000003 mg

2. Tetanus toxin A (natural)
Source: *Clostridium tetani* bacterium
0.000005 mg

3. Diphtheria toxin (natural)
Source: *Corynebacterium diphtheriae* bacterium
0.0003 mg

4. Dioxin (synthetic)
Source: By-products of incineration in industry
0.03 mg

5. Muscarin (natural)
Source: various types of mushroom
0.2 mg

Source: *The Extraordinary Chemistry of Ordinary Things*, Carl H. Snyder, 2003

Photo: gettyimages

The risk of tornados in the United States is especially high from March through July. This tornado raged through Campo, Colorado, in May 2010.

Photos: gettyimages, Litera Japan Co, shutterstock

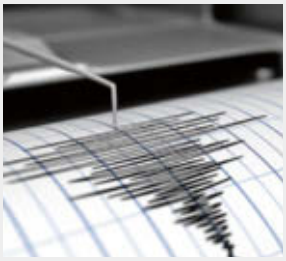
Culture of fear

Mariko Nishizawa, PhD
Risk researcher and founding director, Tokyo, Japan

Risk assessment The risks that people fear also depend on their culture and society, says the Japanese risk researcher and founding director of Litera Japan Co, Mariko Nishizawa.

"What people know, or think they know, often does not frighten them," Renn says. Similarly, many people are more anxious about the risks of new technologies than the risks of familiar ones. However, fear of the unknown, or technophobia, is not a good adviser, for responsibly managed risk means innovation, progress and, consequently, improved living conditions. Giving up these effects entails a high risk for society. Harboring reservations about the unknown therefore means high indirect costs.

The fact that we assess dangers wrongly is also related to modern technology. Modern methods of analysis can identify the smallest impurities. Scientists are now literally able to find needles in haystacks – one molecule among a septillion of others. To express this in a tangible way, a ▶



Risk perception always depends on the context. If people are constantly hearing news items about the spread of viruses, they are more likely to believe that they, too, could get infected. By contrast, if they are used to certain risks, they will regard those as not so dangerous. For example, the Japanese have lived with earthquakes for generations, and so are much more relaxed about the risk of earthquakes than, say, Germans, who have scarcely any knowledge of earthquakes from their own experience.

Food quality
By contrast, the Japanese are very sensitive about the quality of their food. They do not like it to contain any artificial additives or added colors. Americans, however, tolerate artificial additives that enable food to be kept longer. Hormone treatments for animals are also taboo in Japan, as they are in many European countries. In the United States, though, they are regularly given to animals. Therefore, it is evident that what people reject as risky varies by culture.

New technologies
This is also made clear in attitudes to technological innovations. In Germany, risks are investigated at an early stage. People are aware that there is no such thing as a 100 percent risk-free technology – and they are, therefore, often hesitant and cautious about taking new, unfamiliar paths. This may be a small reflection of the old German angst. Americans, by contrast, are open to technological progress. In Japan, too, high-end technology is overwhelmingly valued and is already being used on a huge scale – from high-speed trains that run on time to robots at hotel reception desks.

single grain of rye can now be identified in a 20,000-kilometer-long freight train full of grains of wheat. The same applies, of course, to any trace of poison, however small, even though it often would have no consequences for the organism. After all, it is the dosage that makes it a poison – or, indeed, a medicine. For example, botulinum toxin, better known as botox, is the most poisonous substance that nature produces. One tablespoon would be enough to poison the whole of Europe, the German Neurological Society has calculated as a mental exercise. Nevertheless, many people voluntarily have this neurotoxin injected under their skin or use it medicinally for cramps, spasms or excessive perspiration. This is because in greatly diluted form – a tiny bottle contains only one-billionth of a gram of the poison – and correctly used, the benefit is greater than the possible risks or side effects.

Flood of information alters perception of risk

Alongside the greater precision of analysis, there is also a glut of media-generated information about dangers that is changing perceptions. News constantly rains down on us from all corners of the globe. This news actually affects individuals only rarely, but it has a huge impact on our perception of risk. Especially in relation to the discovery of chemicals in food, one shock wave seems to follow another. Although critical reporting is fundamentally important, it often turns out, when viewed calmly, to have been about something far from the level at which a danger would exist. By contrast, one of the biggest risk factors in relation to food lies in an area that attracts little public attention: consumers' hygiene habits, as the German Federal Institute for Risk Assessment is repeatedly pointing out. Across Germany, the *Campylobacter* bacterium is now the most common cause of intestinal infection, with more than 70,000 documented cases a year, and the true figure could be much higher. However, hardly anybody knows about it, and this pathogenic bacterium has so far rarely featured in the media. However, *Campylobacter* is found on nearly every chicken and is therefore also present on other pieces of meat that are roasted or grilled. Often, all that it takes to cause an infection is for a raw piece of chicken to be placed on the grill and for the same hand then to touch a cooked sausage.

Danger of death in perspective

One micromort equals a one-in-a-million probability of dying. This unit of risk measurement is credited to Professor Ronald A. Howard, Stanford University, USA.

540 kilometers automobile driving

1 micromort

11 kilometers motorbike riding

1 micromort

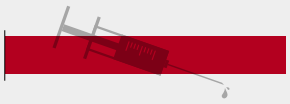
1 mountain-climbing trip

3 micromorts

1 marathon

7 micromorts

1 anesthetic in a non-emergency operation



10 micromorts

Selected risks in the United Kingdom – or, for marathons, in the USA
Source: *The Norm Chronicles*, Michael Blastland and David Spiegelhalter, 2013

Risk as a political issue

The more unsettled the public are, the harder it becomes for policymakers to maintain a rational course. This is demonstrated repeatedly in relation to controversial topics such as food safety, nuclear power or green genetic engineering. Risk awareness is a good weapon against such a nervous atmosphere. "Only if we learn how we ourselves process risk and draw appropriate, realistic conclusions from information about risk will we have the means to assess risk better in the future and to handle it more appropriately," Renn says. There is no way of avoiding this, the risk researcher stresses. "Risk is part of our lives." ■

"We have to learn how we process risk in order to handle it more appropriately in the future."

Professor Ortwin Renn
Scientific Director at the Institute for Advanced Sustainability Studies, Potsdam, Germany

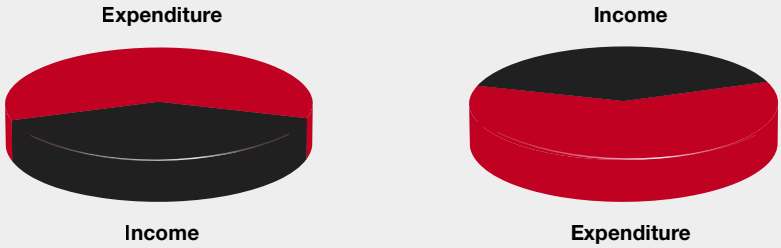
Photo: IASS/L.Ostermann Graphic: ASCS

Fiddling with figures

Manipulated There are many opportunities for distortion when dealing with figures.Their graphic presentation, in particular, has a big influence on the conclusions we draw from them. Here are three examples showing how designers of infographics manipulate information.

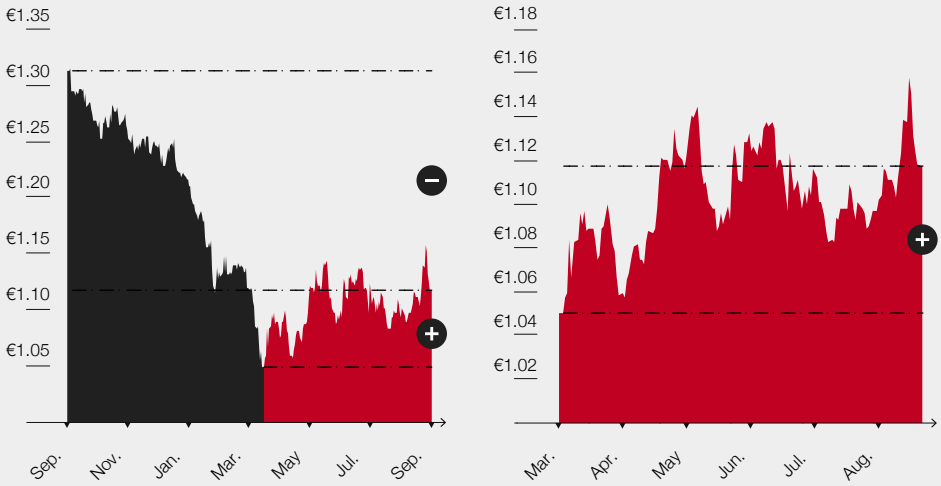
Optical illusions

Keep an eye on the pie 3-D charts look more modern – but the perspective leads to the proportions being distorted. The share of expenditure (red) is the same in both charts: 60 percent.



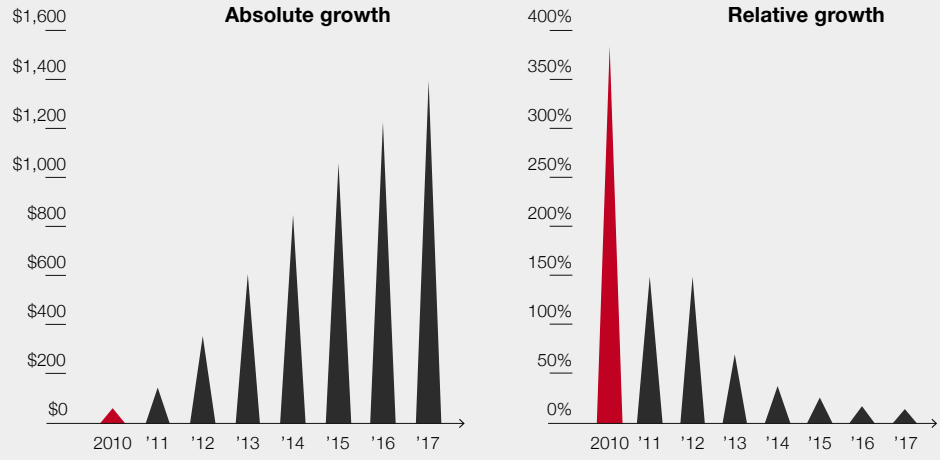
Up and down

Charts On charts, the y-axis is often truncated, and this makes it hard to appreciate the scale of the fluctuation. Also, the trend can be twisted downward or upward depending on how you select the starting time.



Growing absolutely, shrinking relatively

Absolute versus relative The absolute figures are rising, but the gain in percentage terms is falling from year to year. Absolute or relative growth – a company's success can be presented in very different ways.



Graphic: ASCS

Silence in the city

Reportage New York City is one of the most vibrant cities in the world, but also one of the noisiest. Right at its heart, in the Guggenheim Museum, artist Doug Wheeler created a space of deepest silence. We went to visit.

What is it like to step off the streets of New York City into a place so quiet you can hear your heartbeat? Artist Doug Wheeler's installation *PSAD Synthetic Desert III*, conceived in 1971 but first realized only recently at New York's Solomon R. Guggenheim Museum, transported visitors from the roar of city life into a space of profound silence.

Designed to manipulate sound, light and space in a "semi-anechoic chamber," the work suppressed all but the lowest levels of ambient sound. Wheeler compared the visual and acoustic impression of *Synthetic Desert* to his own experience in the deserts of northern Arizona, where near silent conditions profoundly influence the visual sensation of distance. Silence as we know it measures at 30 decibels; *PSAD Synthetic Desert III* measured in the range of 5–10 decibels – so quiet it was possible for visitors to hear their own heartbeat. What was it like to experience this?

To reach the installation, it was necessary to ascend to the topmost gallery of the spiraling Guggenheim Museum. Once there, we waited our turn at the unassuming entrance. The mood was subdued and rather reverent in the little alcove. A museum attendant

Basotect®

Sound-absorbing material Pyramids that swallow sound.

Properties:
Basotect is a flexible foam made of melamine resin, a flame-resistant, dimensionally stable plastic. Its open-cell structure is formed from slender, easily flexed filaments. These make it possible to almost completely absorb sound. In addition, the foam is a good thermal insulator.

Applications:
Buildings, indoor swimming pools, skyscraper elevator cabs, automobiles, rail vehicles, aerospace technology – there are are versatile application areas for this sound absorber. The foam is in demand as a thermal insulator in, for example, hot water tanks or solar collectors.

Photo: gettyimages, Solomon R. Guggenheim Foundation, New York

The famous Guggenheim Museum on New York's Fifth Avenue

made the rules clear: no electronic devices, keep movement to a minimum and no talking or whispering. In groups of just five at a time, we were conducted through the series of sound-proofing antechambers that separated the rest of the museum from the installation space.

From city buzz to desert silence

The room itself was large and subtly lit by concealed neon tubes. A viewing platform extended from a carpeted walkway along the back wall. The effect was like being on a high ledge or at the mouth of a cave, looking off into the distance. The pale ceiling was domed, without edges or corners, reminiscent of an expansive sky. The floor, back wall and parts of the sides and ceiling were covered with hundreds of melamine foam pyramids and wedges made of Basotect® melamine foam, a sound absorbing material from BASF. The installation made use not only of Basotect's sound-absorbing qualities but also of its versatility. "Basotect can be cut into any shape, coated in any color or wrapped in certain textiles for different textures, providing practically unlimited design options," says Doyle Robertson, Basotect Sales Manager for BASF in North America. In *PSAD Synthetic Desert III*, the lighting combined with the geometry of the pyramids to create striking negative spaces and shadows that called to mind trees and mountains, or even people in a crowd. The angles were uniform and perfect. It felt like a vast open space, rather than a medium-sized room in a building in New York City.

Once inside, there were the initial muted sounds of shoes on carpeting. The small group spread out and quickly sat down. Then it was quiet. The only sounds were the small noises of our own breathing and swallowing. We became acutely aware of ourselves in space and in relation to others in the room.

Places of silence

Even in today's noisy world, there are still places that offer true peace and quiet.

1 Eisriesenwelt Ice Caves, Austria
At a length of more than 40 kilometers, this frosty labyrinth may be the world's largest ice cave. In the eerie silence, dramatic ice formations appear like giant beings.
www.eisriesenwelt.at/en

2 Makgadikgadi Pans National Park, Botswana
The dry savanna land of the Kalahari Desert surrounds this game reserve. One of the largest salt flats, the only the sound heard during the dry season is the wind.
www.makgadikgadipansnationalpark.com

3 Dhamma Giri – Vipassana International Academy, Igatpuri, India
All the students at this meditation center observe "noble silence" – silence of body, speech and mind. The Vipassana style of mediation is more than 2,500 years old.
www.giri.dhamma.org

To find out more about Basotect, go to **basf.com/basotect**

The initial impulse to understand the construction slowly waned as we allowed the rational part of the mind to quieten. With distractions from the outside world minimized, the installation was an invitation to focus purely on the sensory. Some visitors lay down. It was very peaceful.

"As the world becomes noisier and busier, creating quieter places is important."

Joerg Hutmacher
CEO, pinta acoustic, Minneapolis, USA

A benefit for body and mind

Being still and quiet allows the chance to reconnect with oneself, with others and one's place in the world – an increasingly rare phenomenon in today's world, yet vital for our well-being. "As the world becomes noisier and busier, creating quieter places is important," says Joerg Hutmacher, CEO of pinta acoustic, the company that cut the Basotect pyramids for the installation. "People perform better in an environment that is visually and acoustically comfortable."

After what seemed like a very short time, the guard said 30 minutes had passed. We got up and, a little unsteady on our feet, went back through the sound locks and into the museum. It took a while before anyone said anything. Perhaps we didn't want to break the spell. By the time we reached the lowest level of the Guggenheim's spiraling galleries, equilibrium was returned.

New York City in July is an amazing feast for all the senses. It was gloriously hot and humid, crowded, noisy, smelly and ever so colorful. Holding a little bit of quiet in our minds, we rejoined the world. ■

Photo: Eisriesenwelt/stonephotography

What's ahead for diesel?

"We are being very shortsighted in Europe by focusing on diesel. Electric cars have zero tailpipe emissions. I believe it should be the power behind our future mobility."

Julia Poliscanova

is Manager, Clean Vehicles and Air Quality, Brussels, Belgium, at Transport & Environment, a lobby group that promotes transportation policy based on the principles of sustainable development at E.U. and global level. She has served as an aide on energy and transportation issues for the Mayor of London and the European Parliament.

Photo: Jonas Ratermann

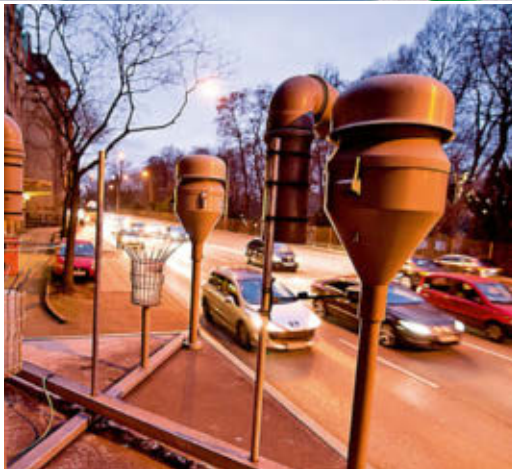
Two perspectives Diesel was once considered a wonder fuel – efficient, powerful and, with lower CO_2 emissions than gasoline, good for the environment. But recently the arguments against it have begun to mount. Is it clean? Is it safe? Does it have a future?

"The latest diesel engines are clean and efficient. But I believe we cannot rely on one form of power – we will need diesel, gasoline, and electric for years to come."

Professor Thomas Koch
is director of the Institute of Piston Engines at the Karlsruhe Institute of Technology in Germany. Prior to 2013, he worked in the commercial engine division of Daimler AG where he was in charge of combustion, turbo charging and fuels. He has contributed to numerous innovations in diesel motors.

Photo: Jonas Ratermann

In 2015, it was revealed that some car manufacturers had cheated on diesel emissions tests, sparking a major debate about the fuel's environmental impact. With studies linking diesel emissions to respiratory illness and cancer, calls have been made to ban diesel vehicles in several major European cities and public confidence has been shaken. Can diesel be turned around or is it the end of the road for this fuel? We ask diesel scientist Professor Thomas Koch of the Karlsruhe Institute of Technology and Julia Poliscanova, clean vehicles expert at the European lobby group Transport & Environment, for their views.



Above: An electric car powers up at a charging station.

Right: Particulate matter is measured at Neckator in Stuttgart, Germany.

Far right: Low emission zones are being introduced in many cities.

Creating Chemistry: Paris, Stuttgart and Madrid are among the cities that face the challenge of banning diesel vehicles by 2025. Are they doing the right thing?

Professor Thomas Koch: No, it's not right to ban them. Modern diesel cars have a negligible impact on urban emissions. Regarding investment cost they may not be the right solution for every driving profile. However, in the latest generation the nitrogen oxide (NO_x) emissions issue has been solved. Under typical driving conditions, they emit far less than the new, stricter European limits permit and even less than many gasoline engines. It's true there are older cars that are less clean. The question is now how to optimize these, which is a different issue from banning diesel technology.

Julia Poliscanova: I agree that in future clean diesel can exist, but the reality is that the current generation of diesel cars still on the market today is not clean. Their real-time driving emissions exceed the new limits. These cars will probably be on the road for another 15 years, while the vehicles with the newest technology will not be certified for sale until 2019 at the earliest. So it's solved in the lab, but it's certainly not solved in real life. Cities simply don't have other options to clean up their air.

The two alternatives to diesel most often mentioned are gasoline and battery-powered electric vehicles. Are these better choices?

Koch: All solutions must contribute to a world of mobility, of course without any impact on people's health. If you make many short journeys within cities, a gasoline, gasoline hybrid, or battery-powered electric vehicle is a very good solution. As soon as you drive more than 12,000 kilometers a year, diesel becomes more attractive. Provided the technology is completely neutral in terms of health, I'm open to every technology. I do not see a real difference anymore, except where the electricity is generated from a fuel source with high greenhouse gas emissions, such as coal.

Poliscanova: The new generation gasoline vehicles will have particle filters but they still have some emissions. By comparison, electric vehicles have zero tailpipe emissions, so it's zero versus low emissions. In terms of the environmental impact of the electricity, a study by a Belgian university, VUB, looked into the life-cycle analysis of different electric vehicles on different electricity mixes, and compared

Photo: gettyimages, Daniel Naupold/dpa

Photo: shutterstock, ASCS

them with the life cycle of diesel vehicles. It found that only when electric vehicles are run on electricity generated entirely from coal-fired plants are they slightly worse than diesel. As we are adding more renewable energy all the time to the energy mix, the electric advantage will continue to increase.

So do you believe an electric-only future is on the way?

Poliscanova: If policy makers want it, it would absolutely be possible to have an electric-only auto world by mid-century. In the medium term, gasoline engines are a perfect combination to first of all go to hybrid gasoline, then to plug-in hybrid, and finally to fully electric. The range issue has largely been solved – the fully electric vehicles coming on to the market this year or next all have a range of over 200 kilometers. In three years it will be over 300. The cost is decreasing and we will have electric vehicles that are pretty much fully competitive with conventional ones by the early 2020s. I think there is still one issue – that of charging infrastructure. However, we have time to solve this. I also think there's a whole change in the way we see mobility. It's a three-way revolution: electric, autonomous and shared. All three will be the future of mobility. In that respect, the electric engine is a perfect contribution.

Koch: There is no doubt that autonomous driving and shared mobility have great potential for the future, but that's a separate issue from whether a vehicle is powered by electricity or by a combustion engine. I also agree that it's one solution to have battery-powered electric cars, but why push this technology alone? There are some real disadvantages: the weight of the cars, the range, fossil-based electricity generation and the cost of infrastructure, which will be passed on to the consumer through taxes and fees. Also, imagine if we were not able to separate the energy for transportation, which today is basically liquid fuels, from the energy for other purposes – think how vulnerable the whole economy would be if there were a breakdown. I believe we will need diesel, gasoline and hybrid engines for quite a long time.

> **"Diesel technology will be lifted to the next level in combination with hybridization and will be further improved."**
>
> **Professor Thomas Koch**

For which uses will diesel continue to be an important part of the fuel mix?

Koch: For long-haul trucks, in particular, diesel engines will continue to give the best environmental balance, but also for medium and longer distance cars. For a standard sedan, the diesel is simply the better drive train, with 10 to 20 percent fewer CO_2 emissions in comparison with gasoline and less than a gasoline hybrid. Taking into consideration the complete production of diesel, from the well to the tank as well as from the tank to the wheel, the diesel engine has a lower CO_2 impact than gasoline. So we need it, that's the message in brief.

Poliscanova: It is true, per kilometer a diesel engine is more efficient than gasoline. But in the last few years, we have seen gasoline engines ▶

catch up, and the difference in CO_2 emissions today is very small, especially for smaller cars. Diesel, by contrast, is driving the wrong kind of consumer behavior by encouraging people, especially in Europe, to buy bigger cars, thus nullifying the advantage. With trucks, diesel will continue to play a role, but long term there are other solutions. We might not have all trucks electric because of battery weight, but other options include e-highways, where trucks are powered by overhead electric cables.

How would you compare maintenance and running costs between these drive trains?

Poliscanova: According to the European Consumer Association, electric vehicles are becoming the better solution in terms of total cost of ownership. One recently updated study by Element Energy found that they will catch up with conventional cars in the next few years. If you look at lease contracts, which is already a big part of the market, electric vehicles have reached parity with diesel vehicles. By the early 2020s they will also reach parity with private vehicle owners. From the perspective of consumers, I think the one issue they still have with electric vehicles is that there are not enough models offered on the market. If there were, consumers would buy more electric cars today.

> **"In the last few years, gasoline engines have caught up with diesel. The difference in CO_2 emissions today is very small."**
>
> **Julia Poliscanova**

Koch: The total cost of ownership of electric vehicles is still higher than diesel. For many operating conditions, they are not competitive. Also, without gasoline and diesel's contribution to tax income, which in Germany is about €36 billion, the battery electric vehicle would come under pressure. However, as I said, I see electric as another interesting approach which makes sense for certain uses. I would be happy having competitive battery-powered vehicles. But diesel will remain an attractive, consumer-friendly option for a very long time.

Government incentives and taxes make a difference to consumer choices. What would happen if the playing field were level?

Koch: If the subsidies for electric cars were reduced, this technology would definitely come under pressure. I agree that electric cars are an interesting approach, and for urban mobility pure electric vehicles do make sense to a certain extent. What governments should do is set environmental standards and let the market offer vehicles that meet those standards, rather than defining which technology we use. Diesel technology will be lifted to the next level in combination with hybridization and will be further improved. It will continue to be an attractive alternative for consumers for years, independent of the level of taxes, as well as being the most environmentally friendly way to move.

Poliscanova: In Europe, the lower taxes on diesel mean that around 50 percent of new sales are diesel cars. But if you look at markets where there is no diesel subsidy, sales are below 5 percent. In the U.S., they are less than 1 percent and in China less than 2 percent. The biggest change we would see in Europe if we were not subsidizing any fuel is that demand for diesel would drop and we would produce more smaller compact city vehicles. We don't need more than that in European cities.

What are your final thoughts?

Poliscanova: The main minus of diesel is the complexity required to clean it up. Yes, we can add another technological solution, another exhaust after-treatment, another pipe, another catalyst, another sensor, but as such diesel is just very complicated and that makes it expensive. In comparison, electric vehicles are simple, clean and low maintenance. Also, we should consider the competitiveness issue: 70 percent of global light duty diesel vehicles are sold in Europe. The share in the U.S. and China is less than 1 percent. You cannot ignore the fact that other regions in the world aren't going down the diesel path. My personal belief is that the future is electric.

Koch: I wonder why opponents of diesel technology argue by ignoring so many facts. But we do not disagree on one point: What we are doing today is not environmentally friendly – we import fossil fuel and burn it here in Europe. What we need to do instead is develop completely synthetic fuels, hydrocarbons, that are 100 percent environmentally friendly. We've started working on this and it is the right way forward to build on this important technology. For now, affordable diesel provides the freedom to drive quickly anywhere at any time in every weather – at minus 15 degrees Celsius or plus 40 degrees Celsius. One of mankind's dreams. ■

Viewpoint BASF

Why we still need diesel

The future of mobility may one day be electric, but we believe diesel still has an important role to play. That is why our chemistry supports the development of a range of clean technologies, from the latest diesel engines to battery-powered electric vehicles.

If we take current estimates about global warming seriously, we need diesel. It has a clear advantage over gasoline in terms of CO_2 emissions and fuel efficiency. What is more, the latest diesel engines are the cleanest ever, taking 99 percent of NO_X and particulate matter out of the exhaust. Nor is this just under laboratory conditions. The new Real Driving Emissions test mandated by the European Union in 2017 measures the pollutants emitted from all new certified cars under real driving conditions, proving that new diesel vehicles run cleanly not just in the testing laboratory but also on the road.

Fortunately, these stringent standards are already achievable, thanks in part to the contributions of BASF chemists and engineers. Our catalyst technologies and after-treatments help new vehicles pass the toughest environmental tests.

Clean diesel as part of the mobility mix

I strongly believe that in the future battery electrical vehicles will gain a significant market share and going to play an important role in the future mobility mix. For the foreseeable future, range, battery weight and power output will continue to restrict the value of pure electric vehicles to short commutes and light commercial uses. Expense will also be an inhibiting factor for some time. To match total cost of ownership with an internal combustion engine, the battery cost would have to fall considerably. Here again BASF makes important contributions toward these goals. The company produces and develops advanced cathode materials for lithium-ion batteries and is exploring next-generation battery material concepts, including lithium-sulfur technology.

At BASF's Hanover Engine Lab, future catalyst technologies are tested for their functionality and durability.

99%

of NO_X and particulate matter is taken out of the exhaust by the latest diesel engines

Frank Mönkeberg
Frank Mönkeberg, PhD, is Head of Application Engineering for Europe at BASF. He is based in Hanover, Germany.

As electric vehicles are still a technology in the early stages, we need clean diesel as part of the mobility mix, particularly if we are to meet the Paris Climate Accord goal of restricting global warming to 2 degrees Celsius. It's fine to think about an electric future, but if we want a livable one, we need a range of clean technologies. And instead of hoping for an electrical mobility revolution it makes more sense to use all options in place. Synthetic fuels (CO_2 neutral), for example, could also play an important role in achieving global CO_2 targets.

The future of mobility has to be sustainable. How we meet that goal must be the subject of continuing fact-based discussion. Meanwhile, our technologies will continue to make a variety of clean options possible so the consumer can choose the one that best suits their needs. ■

Photo: BASF, Jonas Ratermann

Waste finds a second life

A glimpse around the globe To some it is just waste, but to others it is an important resource. Here we show some products that use discarded items as unusual raw materials.

BRUSSELS, BELGIUM

1. Recycling without end

In development Sport Infinity aims to create a new generation of sports shoes that will not simply be discarded, and where every gram is recycled an infinite number of times. The idea is that the shredded source material will be molded into new products, enhancing them with recycled materials from other industries, such as carbon fiber from aircraft construction – without the addition of adhesives. The goal is to develop waste-based materials that also make it possible to produce individually customizable sporting goods from synthetic materials in a single process step. Ten partners from industry and commerce, including BASF, are involved in the project, which is funded by the European Commission.

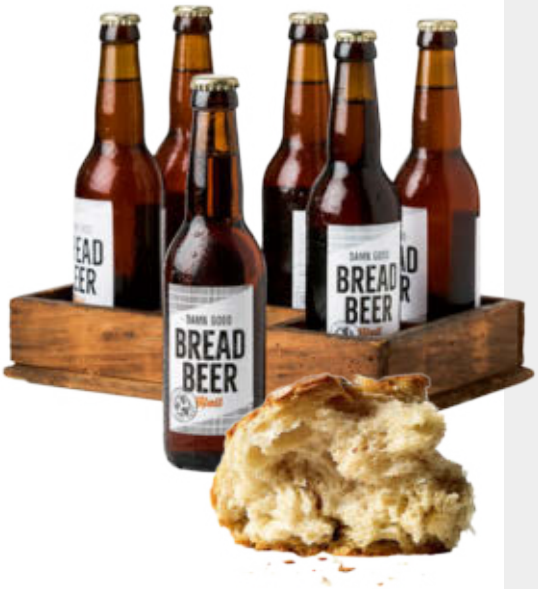
on.basf.com/sportinfinity

WEINFELDEN, SWITZERLAND

2. Making old bread into beer

Commercially available
Dominic Meyerhans and his beer make sure that less leftover food is thrown away. He collects unsold bread from bakeries, dries and grinds it, and then brews beer out of it with water, yeast, hops and barley malt. Meyerhans says that the bread replaces up to one-third of the brewing malt. Eight metric tons produce about 1,000 hectoliters of “Damn Good Bread Beer,” as this specialty beverage has been named.

www.breadbeer.ch



SANTIAGO DE CHILE, CHILE

3. Skateboards from old ghost nets

Commercially available
Fishing nets drifting around without owners are a deadly threat to fish, dolphins and seabirds. Three U.S. surfers have found a use for this dangerous flotsam: skateboards. To turn their idea into reality, they established “Start-up Bureo” in Chile in 2014 and set up collecting points in Chilean coastal towns, where fishermen can hand in their old nets instead of throwing them overboard. At a recycling plant in Santiago de Chile, the nets are then shredded into plastic granulate and processed.

www.bureo.co

Photo: Adidas, Bread Beer, gettyimages, Buero

Discarded fishing nets

The Food and Agriculture Organization believes that the world's seas currently contain a total of 640,000 metric tons of fishing nets and other fishing equipment, and that this accounts for some 10 percent of all waste in the sea.

Photo: repurposeschoolbags, Olympic Movement

SANDTON, SOUTH AFRICA

4. Schoolbags light the way

Commercially available The journey to school can mean a long trek on busy roads for children in rural South Africa. Repurpose Schoolbags, made of 100 percent recycled plastic, lighten the load for disadvantaged students who would otherwise carry their books in old plastic bags. The cleverly designed schoolbags are not only environmentally friendly, but also have reflective strips to increase visibility and safety on the road. And, after school, they even double as a lamp. A solar panel turns into a desk lamp to provide up to 12 hours of light for reading and homework – vital help for students from homes without electricity.

www.repurposeschoolbags.com

TOKYO, JAPAN

5. Electronic waste made ready for medals

In planning Gold, silver and bronze made from waste: for the first time, it is planned to have all the 5,000 Olympic medals in Tokyo made entirely from recycled metal – or, more precisely, from cell phone and electronic waste. According to the organizing committee, this will require eight metric tons of precious metals. For comparison, one metric ton of cell phones contains around 300 grams of gold, 3 kilograms of silver and more than 140 kilograms of copper. Since April 2017, around 2,000 collection boxes have been set up in selected mobile phone shops all over the country for the Japanese to deposit their unwanted electronic devices.

www.tokyo2020.jp/en/

The palm oil challenge

Palm oil It's in everything from pizza and margarine to cosmetics and detergents. Demand for palm oil has grown fast – but the costs for rain forests, animals and local people are high. As the industry works to improve sustainability, we ask what progress has been made and what needs to happen next to protect the environment and people.

"I have witnessed the struggle of the elder generations to stand up against companies who wanted to take over the forest and convert it into oil palm estates. Now I preserve the forest for the sake of future generations." Arifin is a forest keeper in West Kalimantan, Indonesia. Deforestation, displaced communities, destruction of the natural habitats of rare species – the impact of palm oil production has caused widespread public concern in recent years and even sparked calls to boycott palm oil products.

Yet palm oil remains the most widely consumed vegetable oil in the world, found in half of all packaged products. In the decade from 2003 to 2013, global demand for palm oil more than doubled and since then has continued to rise. No wonder. It's versatile, easy to process, and yields per hectare of land are much higher than sunflower, rapeseed and other vegetable oils. It helps feed a growing world population and gives work to millions of small farmers. In addition, palm kernel oil also has unique chemical properties which make it an important renewable raw material.

An urgent dilemma

How do we meet rising demand in a way that protects the environment and respects the rights of local peoples? Through the Roundtable on Sustainable Palm Oil (RSPO) certification process, some progress has been made, yet still a good 80 percent of palm oil in the global supply chain comes from non-certified production. What needs to happen next? We asked key players along the value chain how we can turn this challenge around.

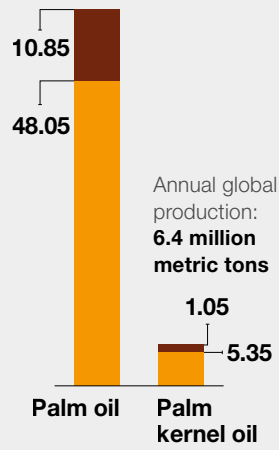
Photo: shutterstock, 123RF

Progress to sustainability

The quantity of certified sustainable palm oil is steadily increasing. The availability of certified palm kernel oil, however, is still a long way from meeting global demand. Palm oil is used widely in food and as a feedstock for biofuel. Palm kernel oil is primarily used in soaps, cosmetics, candles and detergents.

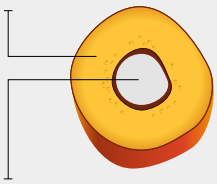
Production of oil 2016

- certified sustainable
- non-certified



Palm fruit

Pulp: needs to be processed within 24 hours



One sixth of the fruit are the palm kernels. They are extremely hard and can be transported and processed separately from the pulp.

Sources: BASF estimates, Oil World, RSPO impact report 2017

The retailer

It starts in the supermarket, like ALDI SOUTH, where many of the products people buy every day contain palm oil or ingredients produced from it.

"Most of the palm oil we use is in food products. Switching to other oils is often no more sustainable, it just shifts the problem. Since 2015, all our own-brand food products in Germany, Austria, Switzerland, the United Kingdom, Ireland and Australia are certified under one of the three RSPO supply chain models. In other countries, where the availability of certified palm oil is still limited, we are working to reach this goal by the end of 2018. We don't label many products in store with the RSPO certificate. Some contain only tiny amounts and consumers already face multiple labels that we do not wish to add to unnecessarily. Also, palm oil is only one of the topics we are addressing; we have a team of over 40 people working on corporate responsibility issues. In the end, we want our customers to rely on us to provide products that are sustainable. That should be the baseline. Our aim is for 100 percent sustainable palm oil in all products. The reality is that the last 20 percent is always hard. It's a question of how far you can push the market. Collaboration with suppliers and engagement in multi-stakeholder initiatives is essential, but pre-competitive collaboration with other retailers is also very important as we are all facing the same issues."

"We want our customers to rely on us to provide products that are sustainable."

Mareike Felix
ALDI SOUTH

Mareike Felix
Mareike Felix, Manager Corporate Responsibility International, ALDI SOUTH Mühlheim/Ruhr, Germany

Photo: shutterstock , ASCS, Aldi

The manufacturer

Beauty products manufacturer L'Oréal uses palm oil and its derivatives to make products such as lipsticks and shampoos. To ensure its products will not contribute to deforestation, it is tracing palm derivatives back to their origin.

"We want to reassure our consumers that the issues they are concerned about also concern us. Palm oil is high up that list. We see it as our responsibility to work with our suppliers and be a force for change. The first step is knowing where our palm oil comes from, so we have invested heavily in traceability. This means working on the ground with independent organizations to trace it back and evaluate the source for environmental and social factors.

"It is our responsibility to work with our suppliers and be a force of change."

Alexandra Palt
L'Oréal

Nothing is as valuable as going into the field. The biggest challenge is the huge number of players involved from the moment the fruit is picked to when it reaches us. We haven't achieved 100 percent traceability yet – it's an ongoing process – but the more we know, the more influence we can have. Today, consumers expect this level of transparency. It is what retailers ask of us and what we ask of our suppliers. What is required next is a collective will to drive through change in the sector for deforestation-free and responsible palm production."

Alexandra Palt
Chief Corporate Responsibility Officer, L'Oréal, Clichy, France

The chemical company

BASF offers ingredients used to produce cosmetics and home and personal care products. A key raw material for these ingredients is palm kernel oil.

"Demand for natural cosmetics and personal care products has boomed over the last ten years. Few people realize that this success story is largely built on palm kernel oil. To understand why, you need to take a deep dive into its chemistry. Compared to many other vegetable oils, it has almost unique lines of connected carbon atoms – the c-chains. The mid-cut chains produce foaming effects; the short chains are perfect for moisturizing and smoothing effects. We fractionate the oil into its different c-chain lengths and add functional groups to obtain the desired performance. The oil goes through up to 10 different processes to get the final ingredient, be it a surfactant or an emollient for moisturizers. This is how we are able to offer ingredients for natural cosmetics based on renewable resources. But one more step is needed to make these renewable resources sustainable: certification. This gives users certainty that oil comes from plantations and mills that protect forests, biodiversity and the rights of people living there. We need all the stakeholders to support the RSPO standard and strictly implement its rules. Our ultimate goal is to have only certified and sustainable palm kernel oil in the value chain."

"Our ultimate goal is to have only certified and sustainable palm kernel oil in the value chain."

Xavier Susterac
BASF Personal Care Europe

Xavier Susterac
Senior Vice President BASF Personal Care Europe, Düsseldorf and Monheim, Germany

Photo: shutterstock, gettyimages, ASCS, L'Oreal, BASF

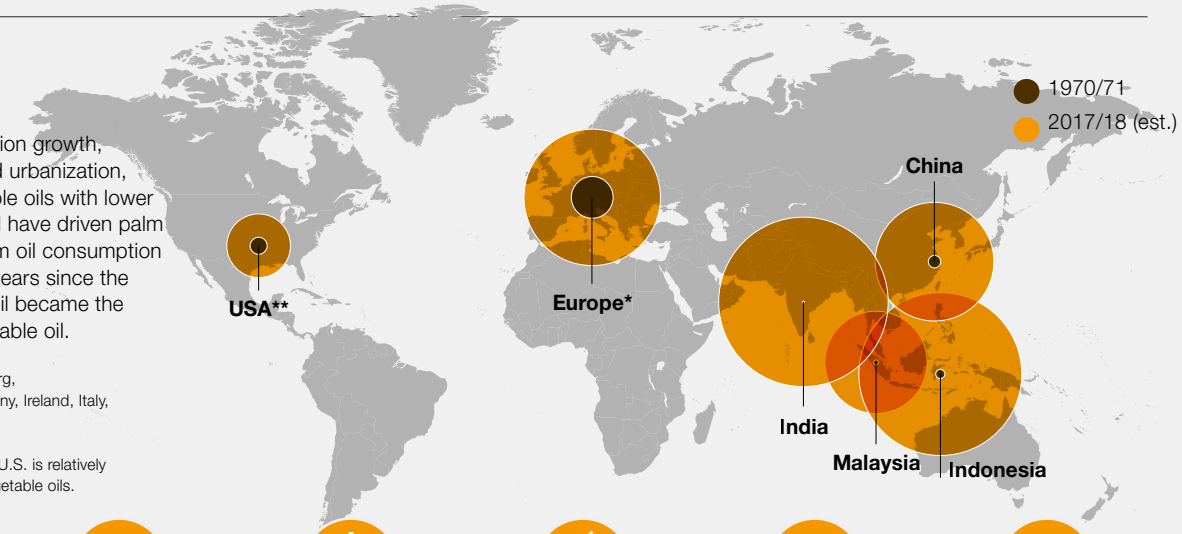
The growth dilemma

In demand Global consumption of palm oil and palm kernel oil has grown rapidly from about 4 million metric tons in the late 1970s to some 70 million tons today. Major changes in consumer behavior, population growth and energy politics have been the key drivers.

Major users

Consumption Population growth, increasing incomes and urbanization, substitution for vegetable oils with lower yield, and use in biofuel have driven palm oil demand. Global palm oil consumption has doubled every 10 years since the 1960s. In 2007, palm oil became the world's dominant vegetable oil.

*1970/71: Belgium, Luxembourg, Denmark, France, West Germany, Ireland, Italy, Netherlands, Sweden, UK
2017/18: EU27
** Palm oil consumption in the U.S. is relatively low due to the use of other vegetable oils.



1950s
The food processing industry starts to grow and with it comes a trend toward ready meals and snacks.

1960s
Demand for animal feedstuff rises as higher living standards lead to increased meat consumption.

1970s
Growing health consciousness means consumers seek alternatives to trans fats in foods like cookies and crackers.

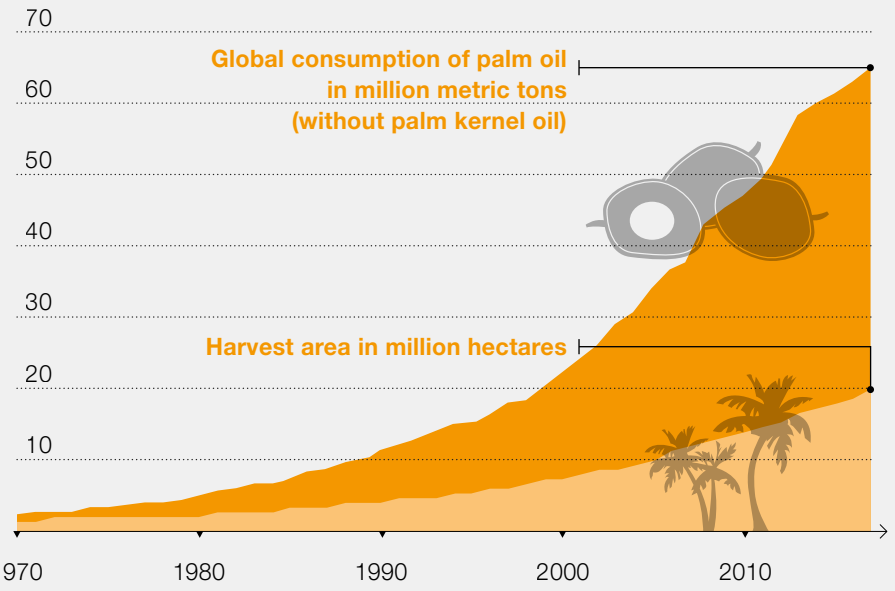
1980s
Consumers of shampoos, soaps and cosmetics begin looking for products based on natural ingredients.

1990s
In search of also renewable energy sources, biodiesel plants are opened in European countries and palm oil is used for biodiesel.

Today
In emerging countries, palm oil is used mainly for cooking, so population growth continues to drive demand.

Land use

Growth limit Some 95 percent of existing palm oil plantations are located in a latitude range of 10° north and south of the Equator. Although productivity is growing, growth rates may fall: Scientists see climate becoming unsuitable for growing oil palm in many tropical regions, especially after 2050.



2050

Growth estimates
Global population: over 9 billion
Required increase in food production: 70 percent more than in 2005
Demand for palm oil: By 2050, 264 to 447 million metric tons may be needed worldwide. Indonesia could cover roughly half of the demand.

Graphic: gettyimages, ASCS

Sources: United States Department of Agriculture; BASF estimates; RSPO impact report 2016; USDA 2011; Afriyanti et al., 2016; Paterson et al., 2017; FAO, 2009; Corley, 2009; Oil World Global Research and Analysis

The plantation owner

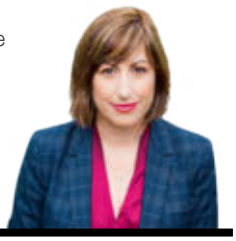
Golden Agri-Resources is the leading palm oil plantation group in Indonesia and one of the largest palm oil companies in the world.

"A lot of pressure to protect the environment comes from E.U. customers and NGOs, but for us it is a working reality. You can't be in agribusiness for the long term if you don't take care of the environment you rely on to grow your produce, and if you feed distrust and resentment in rural communities, you won't be successful. The palm plant is there for 20 to 28 years. We have to take a long-term perspective. In 2016, we said we would trace our palm oil back to the point of origin. Meeting our commitment will not be easy. We employ 170,000 people across Indonesia and deal with thousands of independent farmers, many without email or 3G phones. Yet somehow we want them to understand what these requirements are about and to inspire them. We are also involved in complex negotiations with people from local communities who are very poor and see setting aside a conservation area as a barrier to their own development. Getting informed consent is essential. We are glad to see that others in the industry are investing in these changes, too. There is a real momentum and a desire to work together to achieve sustainability."

"If you feed distrust and resentment in rural communities, you won't succeed."

Anita Neville
Golden Agri-Resources

Anita Neville
Vice President, Corporate Communications and Sustainability Relations, Golden Agri-Resources, Singapore



The campaigner

In Indonesia, the non-governmental organization Greenpeace campaigns to prevent further destruction of the rainforest to protect biodiversity, local communities and the environment.

"Big companies have woken up to the environmental costs of the palm industry. These are nowhere more evident than in Indonesia. In 2015, we had the worst forest fires for almost 20 years as a result of decades of forest destruction. The question remains, is the industry doing enough? We're not against palm oil or the palm oil industry per se. Yet while most big companies have adopted sustainability policies, unsustainable palm oil is still making its way into their supply chains through small and medium-sized firms involved in forest destruction and human rights abuses. These firms need to either compensate for their damages in a timely manner or be entirely cut off from the market. To achieve this, companies have to ask the right questions of their suppliers. For that, they need to fully understand their supply chain and must take action. Suppliers who continue to breach commitments must realize there is a big price to pay.

"Companies have to ask the right questions of their suppliers."

Bagus Kusuma
Greenpeace

The industry can and must enforce these commitments along the supply chain, even with growing demand. It is critical to break the link between palm production and environmental damage."

Bagus Kusuma
Forest Campaigner, Greenpeace Indonesia
Jakarta, Indonesia

Photo: shutterstock, gettyimages, Ivonne Goffin, Greenpeace

The view from West Kalimantan

Explain-it video: Find a video on the topic through this link **on.basf.com/all-about-palmoil**

Quiz: Find more information on the topic through this link **on.basf.com/palmoil-quiz**

Smallholders Forty percent of the palm and palm kernel oil produced globally comes from smallholder farmers, many of whom are in Indonesia. Helping them grow oil palm without any adverse effects on the environment will have a major impact.

Suwarni is an oil palm farmer living in West Kalimantan, Indonesia.

Photo: Sebastian Olényi, sustentio GmbH

West Kalimantan is an area of swampy lowlands, rivers and forest on the Indonesian part of the island of Borneo. Lying on the equator, it is hot and humid much of the year – an ideal environment for growing oil palm, the plant from which palm oil and palm kernel oil are derived.

This is where Petrus Purba and Suwarni live and work with their families. Suwarni is a farmer. Alongside oil palm she also taps rubber and works part-time in a local preschool. Purba is a trainer from the Farmers' Field School. A graduate of the Agricultural Vocational School in Sintang, he grows oil palm on his 3.5-hectare land – a typical size for many smallholdings here.

Reaping the fruits

Indonesia is now the number one producer of palm oil in the world, having recently overtaken Malaysia. A rapid rise in global demand over the past few decades has made it an attractive crop for growers. Today it is the main export earner for the Indonesian economy, contributing around

> **"I feel proud that I can now provide a good life for my children and family."**
>
> **Suwarni**
> Smallholder, West Kalimantan, Indonesia

$18 billion in 2016 and employing millions of Indonesians. Over 10 million hectares of the country's land is now planted with oil palm. For a smallholder like Suwarni, it can make a major difference to the family's standard of living. "My parents are farmers but they cultivate vegetable crops. I saw the difference between the crops and was more interested in oil palm," she says. "The yields are more profitable and for every fresh fruit bunch harvested, it is guaranteed money. But you need determination to succeed."

Many farmers in Indonesia are new to oil palm, having previously farmed rubber or rice, and lack the expertise to grow it efficiently. Learning how and where to plant, and when and how to fertilize, brings

Win-win

How to help smallholders improve their livelihood while protecting forests and biodiversity.

1 **Good agricultural practice**
With better agronomic skills and sustainability knowledge, farmers are more aware of the value of biodiversity and forests.

2 **Yield increase**
Farmers can raise the quality and quantity of output with access to better seedlings, herbicides and fertilizers, as well as knowledge of how to use them.

3 **Information**
Smallholder communities need easy access to expertise, market information and infrastructure for sustainable practices.

4 **Financial education and access to financial products**
Learning about money management and the responsible use of financial products and services encourages farmers to save for replanting.

5 **RSPO certification**
Forming smallholder groups and supporting them toward certification improves income and reduces the risk of deforestation.

Petrus Purba from Belitang Hulu is a Farmers' Field School trainer as well as an oil palm farmer himself.

immediate tangible benefits like increased yields and additional profits.

Learning best practice

This is the kind of training that Purba provides. The Farmers' Field School is part of a project supported by BASF in collaboration with the consumer goods company Henkel and the development organization Solidaridad. The teachers are employed by a local cooperative, Credit Union Keling Kumang, which has more than 160,000 members. The focus is not only on efficient production but, equally important, on sustainable farming methods and occupational health and safety standards. Farmers are taught how to make better use of the land rather than open up new plantations. They learn about the role that forests and peatlands play for wildlife, indigenous people and the environment, and about the whole palm oil supply chain. The ultimate aim is for smallholders such as Suwarni to adopt the sustainable practices that allow them to gain RSPO certification. Meeting the complex certification requirements is costly and difficult, which is why they need support.

The project currently reaches around 5,500 farmers in Indonesia. Classes take place in the field and farmers are able to talk about issues that concern them. "They ask a lot about fertilization and seed selection," says Petrus. He attended the Farmers' Field School himself before becoming a trainer.

40

kilograms of oil
That's how much a palm tree produces every year. The fruit can be harvested every 10 days and each fruit contains 30 to 35 percent oil.

"The oil palm industry is welcome here, as long as the environment is preserved."

Petrus Purba
Farmers' Field School Trainer, West Kalimantan, Indonesia

"I want to train other farmers how to cultivate oil palm. I want everyone to have good yields because oil palm is the main commodity here," he says.

For Suwarni, the benefits were quickly evident: "We used to fertilize every 6 months. Now we know it should be every 3 to 4 months. We learned that to reduce cost and preserve the environment, we only need to spray crop protection products along the harvest lane instead of the whole area. I can already see the savings," she says.

"Smallholders are mostly family businesses. They are entrepreneurs who want information that will help build their business so that they can improve their livelihood and enable their children to go to school and university. They have a huge desire to make it work," says Xavier Susterac, Senior Vice President BASF Personal Care Europe. "We need to support them in adopting sustainable agricultural practices. With RSPO certification they can be a major part of the future sustainable supply chain."

Suwarni sums up the motivation for her and other smallholders: "Previously, there were times when food was short. Now, we can provide enough for our family. My dream is for my children to live a better life than their parents."

Photo: Sebastian Olényi, sustentio GmbH

Nature's catalysts

The enzymes in laundry detergents remove dirt at lower temperatures.

Close-up Produced by living cells, enzymes work constantly behind the scenes, enabling vital chemical reactions in biological systems and accelerating the speed at which they occur. Learning how these proteins work and harnessing their power can help us develop more sustainable industrial processes and products.

A specialist tool for every task

The sweet taste when we chew bread is the enzyme amylase in our saliva doing its work. It breaks down starch into sugar so that our bodies can convert it into energy. Plants, animals, human beings and micro-organisms – all life forms depend on these highly skilled proteins. They are involved from the very start in the genetic process that creates life, they drive the digestive system that converts food to energy, and they enable the process of decomposition at the end. There are millions of different enzymes – approximately 75,000 in the human body alone – and each of them is perfectly designed to perform a specific task or step in a biological process. Made of long chains of amino acids that fold over each other, giving them a three-dimensional structure, each has a "pocket" on its surface that the reactant, or "substrate," fits into perfectly. Once in the pocket, the enzyme aids the reaction to form the product.

Tireless workhorses

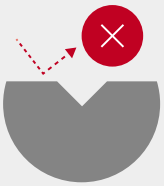
Enzymes have supported mankind's production processes since the earliest times. The microorganisms that transform barley into beer and milk into cheese all have their own enzymes working in the background to assist the necessary reactions. From softening leather to baking bread or making salami, we have long relied on these natural catalysts. Engineers, biologists and chemists have sought ways to harness their power since they were first identified in the 19th century. Today, enzymes are used widely in human and animal nutrition, as well as in detergents and cleaners. The enzyme protease, for example, is commonly used in laundry detergents to aid stain removal. It breaks down proteins and enables clothes to be cleaned at lower temperatures.

Enzymes are not changed or consumed by the reactions they facilitate, so under the right conditions they just continue doing their job, making them a valuable resource in the quest for more sustainable industrial processes. Compared with chemical catalysts, they do not require high temperatures or pressure to function. At BASF, an enzyme-based process is now used

The lock and key principle

Each enzyme has a pocket – the active center – with a very specific shape.

A perfect fit
If the substrate fits the pocket, it binds to the enzyme and a reaction occurs. When it is released, the pocket is ready for the next substrate.



No fit, no reaction
If a substrate does not fit precisely in the pocket, no reaction takes place. There is a specific enzyme for every biochemical reaction.

Photo: gettyimages Graphic: ASCS

In the research lab for white biotechnology at BASF, the microorganisms are grown on agarose plates. Enzymes from BASF enable innovative product solutions for various customer industries.

BASF laboratory technicians isolate individual strains of microorganisms under sterile conditions.

to produce acrylamide, a product used in wastewater treatment, papermaking, mineral processing and enhanced oil recovery. By switching from copper catalysis to a biocatalytic production method, less energy is needed and fewer by-products are generated.

Enzymes offer an efficient way to make things we need with minimum environmental impact. They are also excellent recyclers. Without them our waste would still be lying around. Created by cells as required, when no longer needed they break down into their molecular components, leaving no residue.

The hunt for new enzymes

Enzymes are found in microorganisms all over the planet, from deep sea thermal vents to the top of the Himalayas. Scientists scour the planet for new enzyme diversity that can be applied to a variety of industrial challenges. This means seeking potential enzyme sources in ecosystems that are similar to the conditions created by industrial processes, such as volcanoes, geysers and mudholes. Small samples of soil, water, sediment, leaf litter, termite guts or other materials from the environment provide abundant samples for BASF's collection of microbial gene libraries, estimated to contain over two million microbial genomes. The samples are screened in the search for enzymes with useful properties. If additional enzyme performance is required, further diversity can be generated using BASF's proprietary molecular biology tools and technologies.

A living factory

With the development of modern biotechnology, new possibilities have opened up for producing useful enzymes at an industrial scale using genetically modified microorganisms. The filamentous fungus *Aspergillus niger* has the natural capacity to produce enzymes such as phytase, glucanase and xylanase. It normally produces these biocatalysts in small quantities. When modified, the fungus can speed up production and increase its yield of enzymes. *Aspergillus niger* is now used to manufacture BASF's Natuphos® and Natugrain® TS, optimized versions of phytase, glucanase and xylanase. These feed enzymes help pigs and poultry to better utilize phosphorus and other important nutrients.

Nature's gift

Understanding the principle function of an enzyme, what makes it work and how this relates to its structure, makes it possible to modify it at the molecular level to improve its performance – like tuning a motor to get the optimum performance. In the past, this work was carried out blindly. Today, 3-D images of enzymes help work out what to tweak to get the desired outcome. The more that is understood about enzymes, the better they can be used to make industrial processes more sustainable. ■

Photo: BASF

Fresh produce and a fresh start

Inspiration With 85 million hectares of uncultivated arable land, why is Nigeria a net importer of food? Nigerian entrepreneur Angel Adelaja has set out to tackle this problem, using advanced technology to grow fresh produce.

Angel Adelaja at one of Fresh Direct's micro-farms in Abuja, Nigeria.

Photo: Tom Saater

According to the World Bank, Nigeria imported around $3.4 billion worth of vegetable products in 2014 and exported only $760 million. Yet it has vast areas of uncultivated arable land. With a population of 186 million, growing at 2.6 percent a year, improving food security means developing innovative approaches to agriculture.

This is the mission behind Fresh Direct, a startup founded by Nigerian entrepreneur Angel Adelaja. Her aim is to help Nigeria reduce its reliance on food imports by introducing advanced technologies to improve crop yields. Fresh Direct uses a hydroponic system in adapted shipping containers to grow produce. The production of vegetables from just one six-meter container is equivalent to that from around 6,000 square meters. When the containers are stacked on top of each other, the output per square meter of farm rises dramatically. Plants are grown under lights and without soil. Instead, they are suspended in nutrient-rich water and drip-fed water. This method means growing takes place 24/7.

Growing fast

Fresh Direct says it can achieve 10 times the yield of traditional farming, using one-fifteenth of the land and a fraction of the water requirements. The company now has four containers at two sites in Abuja, the Nigerian capital. Six more containers are planned, as well as a warehouse in Lagos. In any given month, each container produces around 3,000 heads of vegetables, and the

Young employees at Fresh Direct (from left): Salome Salime Umoru, Solomon Tyopev, Mercy Nanret Da'ar

company, founded in 2015, is now earning enough money to reinvest and expand.

"It's not a silver bullet," says Adelaja. "The amount we produce is a drop in the bucket. What's important is the synergy between traditional rural farms providing the bulk of the produce and our container farms focusing on crops that are mostly imported."

> **"I feel I'm impacting people's lives. I'm creating jobs and opportunities."**
>
> **Angel Adelaja**
> Founder, Fresh Direct, Abuja, Nigeria

To avoid competing with local farmers, Fresh Direct focuses on vegetables that are not grown locally and have to be imported, such as butterhead lettuce and blue dwarf kale. There's enough land around the containers to farm fish, chicken and goats, too. "We have two major customers that purchase most of what we produce, and then we have a little extra for our other customers," says Adelaja. "We're scaling to meet demand. Our market is where there are people interested in healthy eating. If you look at Lagos, Port Harcourt, Abuja, Kaduna, Kano – those are the places." Growing the produce close to the city means Fresh Direct avoids the problems of poor transport infrastructure and high fuel costs. But it's not just about output; it's about people, too. Fresh Direct's employees are mainly young, local people who benefit from training and higher-than-average salaries. Adelaja acts as a guarantor to help them obtain bank accounts and access the wider financial system.

Before setting up Fresh Direct, Adelaja worked with the national coordinator of the Nigerian president's poverty eradication program. Youth unemployment in Nigeria stands at 7.8 percent. The government has set up initiatives such as micro credit and conditional cash transfer, but Adelaja felt more could be done to raise people out of poverty, so she looked for ways to directly stimulate the local economy. ▶

Team Fresh Direct: Skills, experience, empowerment

Fresh Direct provides an opportunity to gain skills and experience. Solomon, Mercy and Salome talk about what they have gained through working for the company.

Salome Salime Umoru, 24, started working on the farm in December 2016. "I didn't know anything about agriculture or hydroponic farming before. I was working in a salon as a cleaner. Now I earn more every month and am more optimistic about my future," she says.

Solomon Tyopev, 25, looks after the livestock – chicken, catfish and tilapia – and does deliveries. He's been working at the farm for a year. "I used to work in a bar. Before coming to Fresh Direct I had no idea about farming. Now I feel more secure," he says.

Mercy Nanret Da'ar, 23, has also been working at Fresh Direct for a year. "Before, I was unemployed. The job interested me because you can get a lot of experience in a business like this," she says. "Agriculture as a business is very important. There should be more farms like this."

The produce is grown at sites close to customers so that it is fresh on delivery.

Photo: Tom Saater

Water is carefully drip-fed on to each plant.

Angel Adelaja holds a freshly harvested organic lettuce.

"Agriculture as a business is important. There should be more farms like this."

Salome Salime Umoru
Farmer at Fresh Direct, Abuja, Nigeria

Agriculture makes up 21 percent of Nigeria's economy and is the largest source of employment. It therefore seemed the ideal sector to target. But Adelaja quickly realized that traditional smallholder farming techniques could not be efficiently scaled up, and poor rural infrastructure was also a problem. After initial research, she decided that hydroponics was the way forward. The idea of using shipping containers came to her while visiting a construction company. She and her partner then set about building a prototype in her yard.

Making a difference

"If you can't push well-meaning policies into action and impact people's lives then there's no point. With Fresh Direct, I feel I'm impacting people's lives. I'm creating jobs and opportunities," she says. "Most of the young people who work for Fresh Direct had no previous agricultural experience. They were working as house helpers or janitors. We want to empower everyone that joins us."

Fresh Direct's success has caught the attention of development agencies. In 2017, Adelaja won the World Economic Forum's award for "breakthrough female technology entrepreneur."

"We've had a lot of interest, and that's been helpful. People have contacted us from Senegal, Ethiopia and other places because they want to replicate what we are doing. Now we're thinking about how to create a franchise model," she says. The plan is to expand in Nigeria, then test the market in places such as Dakar, Senegal, and Accra, Ghana. "Longer term I see Fresh Direct across West Africa and even East Africa as well," says Adelaja. "I want to see a system where people are employers and entrepreneurs. I want success stories – I want this to be what government can't do." ■

BASF: Derelict buildings to urban farm in Detroit

USA The Michigan Urban Farming Initiative in Detroit aims to use urban agriculture to promote education, sustainability and community. The 1.2-hectare farm produces more than 300 vegetable varieties provided free to the local community. A vacant building at its heart is being transformed into a community space. With insulation materials and impact-reducing Green Sense® concrete admixture donated by BASF, it will be one of the most sustainable, energy-efficient buildings in Detroit. BASF has also provided its polyurethane binder Elastopave® for the top layer of a rainwater harvesting cistern and irrigation system developed from the foundation of a vacant, blighted home.

Photo: Tom Saater, freshdirect, 2016 Jeffery Sauger/ General Motors

Fact or fiction?

Scientific fallacies **As scientific knowledge advances, many things we take for granted are challenged. Some beliefs, however, become ingrained, Here are three examples of things that we always thought we knew but, in fact, didn't.**

Calmer chameleons

Showing their mood People who change their appearance or character to fit in have long been described as "chameleon-like," after the lizards' supposed ability to change color and blend into their surroundings. But chameleons are already very well camouflaged – and they are fast runners, too. Their color changes actually relate to mood, temperature, light and communication, rather than to avoidance of predators. A darker color, for example, can signify anger or absorb heat, while a lighter shade could help attract a mate. Scientists used to believe the changes were dictated by pigment in the chameleons' chromatophore cells, but a 2015 report revealed that it is more complicated. Relaxing or tensing the skin causes nanocrystals in a further layer of iridescent chromatophores, called iridophores, to act as prisms and reflect different wavelengths of light, so creating the impressive palette of colors.

Photo: gettyimages

A matter of taste

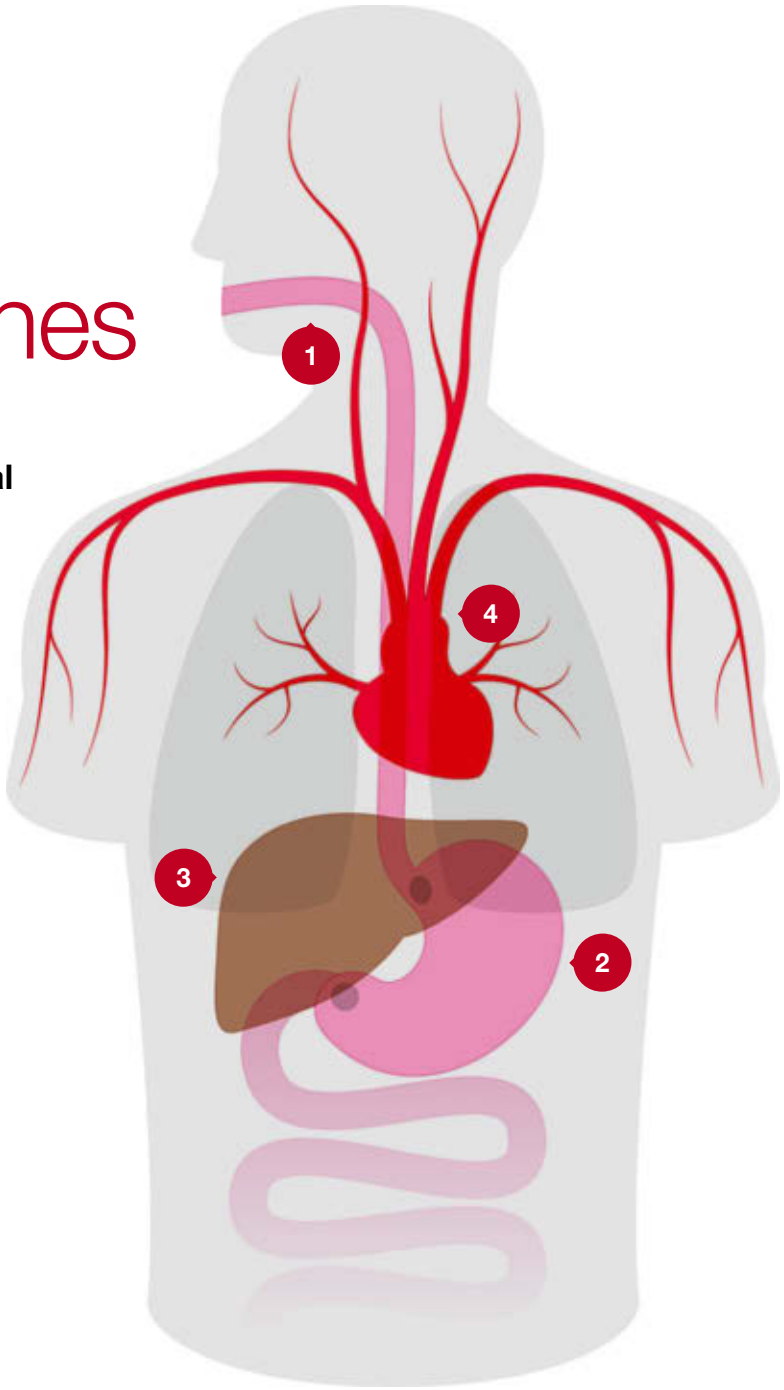
Signals from the tongue It used to be a staple of the school science lesson – the "tongue map" diagram showing which parts of the tongue respond exclusively to salty, sweet and bitter tastes. It was always, however, an oversimplification. The receptors are actually distributed all over. The theory behind it originates from a paper written in 1901 describing slight differences in taste thresholds around the edges of the tongue. It was almost three-quarters of a century before the "map" was challenged. Research at Columbia University, New York, USA, in 2017, has further identified special molecules that help the tongue send signals to the brain to identify different tastes. The taste receptor cells are able to express molecular signals that attract the correct taste neurons and so relay information to our brains.

Not eggs-actly right

Healthy after all For decades, people were warned against eating too many eggs because of dietary cholesterol in the yolks. But in 2015 the U.S. government's Dietary Guidelines Advisory Committee quietly amended its recommendations, stating that the evidence showed "no appreciable relationship" between dietary cholesterol from, for example, eggs, and blood cholesterol levels. Although the revision proved controversial, according to current science it is better to cut down on saturated fat in foods such as butter, meat and full-fat dairy products. For most people, an egg a day is just fine.

How active ingredients become medicines

Chemistry around us **There is no medicine without an active ingredient, but additional helpers are still needed. Read more about how they interact in a tablet.**



The way through the body

1 Mouth and throat
The tablet passes through the esophagus without difficulty.

2 Gastrointestinal tract
The tablet disintegrates in the stomach, the active ingredient is released and absorbed into the bloodstream.

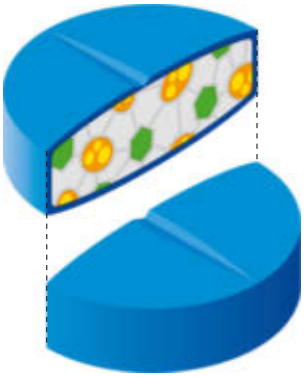
3 Liver
The liver breaks the active ingredient down to a greater or lesser extent.

4 Heart
The heart pumps the blood with the active ingredient to its destination in the body.

They improve the taste with sweet coatings, serve as disintegrants enabling tablets to release their active ingredients quickly, or act to improve their appearance. Pharmaceutical excipients have no healing effect themselves, but active ingredients could not properly unleash their own healing power without them.

For example, they package the active ingredient to make it easier to swallow or able to resist aggressive gastric juices and liver enzymes. The requirements for excipients are becoming more and more demanding: whereas the molecules of active ingredients often used to have simple structures and were highly soluble, they have now changed and are less soluble. This makes it hard for the human body to absorb them and limits the medicine's effectiveness.

This is a problem in more than 70 percent of all newly developed active ingredients. To improve their effectiveness, BASF is developing excipients such as Soluplus®, a solubilizer that enables the body to absorb drugs that do not dissolve easily. In all, BASF offers more than 100 different products that boost the performance of medicines. ■



Coating
Protects against moisture and unpleasant taste and can determine where the active ingredient is needed in the body and when it is to be released.

Filler
Increases the volume and makes tablets easier to handle.

Active ingredient

Solubilizer
Helps dissolve the active ingredient.

Binder
Holds the various parts of the tablet together.

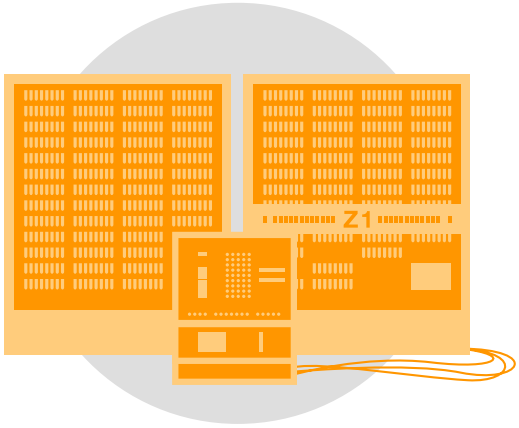
Disintegrant
Makes sure that the tablet disintegrates quickly on contact with liquid.

Photo: Jörg Block

BASF Digital

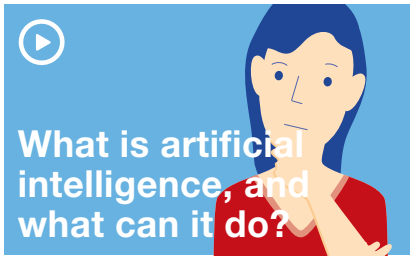
More content, interactive stories and additional information

From Z1 to artificial intelligence



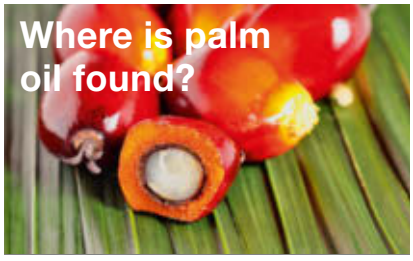
Computer history The first functioning computer, Konrad Zuse's Z1, is hard to compare with those available today. But it is exciting to look back. What mistakes were made from the 1940s to the 1970s, and which forecasts were correct?

on.basf.com/now-and-then



Artificial intelligence What examples and advances have there been, and what developments are emerging for the future?

on.basf.com/AI



Quiz Which products contain palm oil, and which do not? From candles to fuel, you can test your knowledge online and find out more about palm oil in our videos.

on.basf.com/palmoil-quiz

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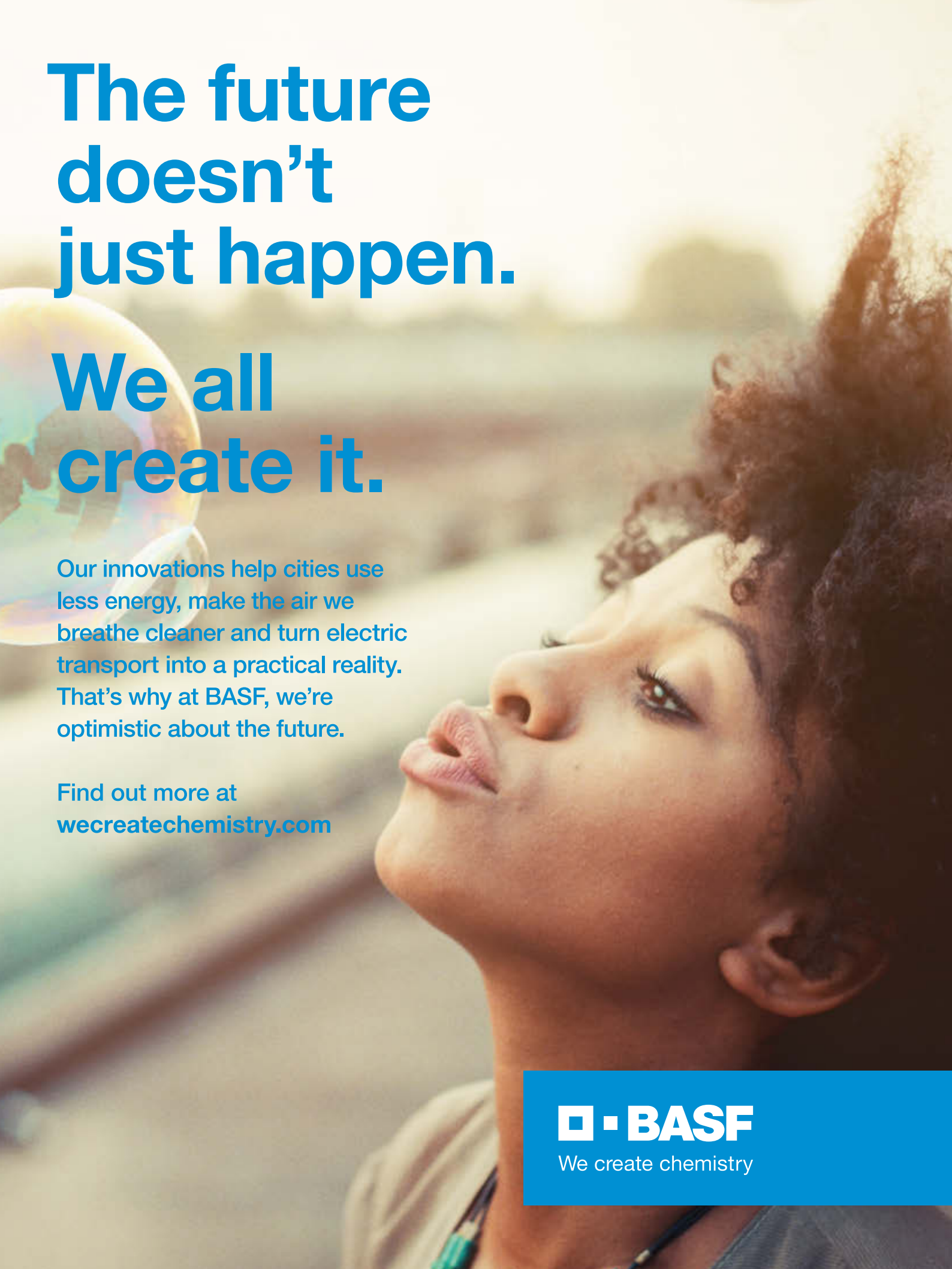
The future doesn't just happen.
We all create it.
Our innovations help cities use less energy, make the air we breathe cleaner and turn electric transport into a practical reality. That's why at BASF, we're optimistic about the future.
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