Issue Eight 2019

Creating Chemistry

FOR A SUSTAINABLE FUTURE

URBANIZATION

World of cities

Our future will be made in cities. How megacities can continue to grow while still keeping the human factor in focus.

World of cities

1 million people move to Asian cities every week.

+41 megacities

+5% productivity

880 million people living in low-lying coastal zones by 2030.

$24.4 billion in sales

68% living in cities

▸ Pages 6–25

By 2030, there are expected to be 43 megacities with more than 10 million inhabitants. In 1950, there were only two.

▸ Page 20

04 Interview

Collectively, nearly 1 million people move to Asian cities every week – two-thirds of the global total. Asia already has the seven most populous cities in the world, and by 2050 will be home to over half the world's urban population.

▸ Page 11

01 Above and beyond

Larger cities are generally more productive. Studies have found that a city's productivity rises by 2 to 5 percent with every doubling of its population.

▸ Page 15

02 Cities in motion

Global sales of e-bikes are growing rapidly. They are expected to reach $24.4 billion in 2025 – an increase of more than 50 percent on 2016.

▸ Page 24

05 Resilience

Most urban growth takes place along coastlines. By 2030, city populations in these areas will have grown by 40 percent (on a baseline of 625 million in 2000). BASF is helping to protect these populations from floods caused by rising sea levels and extreme weather.

▸ Page 18

03 Infographic

Today, 55 percent of people worldwide live in cities. By 2050, that figure is likely to have reached 68 percent. How vacant spaces in cities can be used.

Sources:
Navigant Research;
Neumann et al., 2015;
United Nations; OECD

Illustration: Jörg Block

Dear readers,

All over the world, more and more people are moving to cities. In 2030, there will be 43 megacities with more than 10 million inhabitants. In 1950, there were only two. Urbanization is presenting policymakers, industry and society – and thus, every one of us – with major social and environmental challenges.

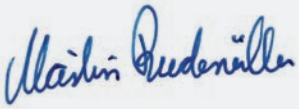
What does all of this have to do with chemistry? Chemistry is an important contributor to overcoming these challenges. Urbanization is one of BASF's core topics, along with climate change, feeding a growing world population, and the sustainable use of resources. Our ambition is to be a partner for society whenever it encounters challenges we can solve with chemistry – mainly with products and innovations that are sustainable. In this way, we can make our contribution to the cities of the future, and especially to their inhabitants.

In this issue of Creating Chemistry, we wanted to find out how cities might look in the future, how ever-increasing numbers of people will find affordable housing, how urbanization can be managed sustainably and how quality of life can be improved at the same time. Discover why megacities need to be planned on a long-term basis, where city-dwellers are reclaiming disused or neglected spaces and how electromobility is being adapted for everyday use.

How can we ensure that all this will work out, that everyone can find their own place and that cities can remain fit for people to live in? It will take creativity and the courage to embrace the new, as well as ideas and technologies – and solutions created by chemistry.

I wish you an enjoyable read!

Martin Brudermüller, PhD



Chairman of the Board of Executive Directors and Chief Technology Officer, BASF SE

Photo: BASF

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Content

PEOPLE

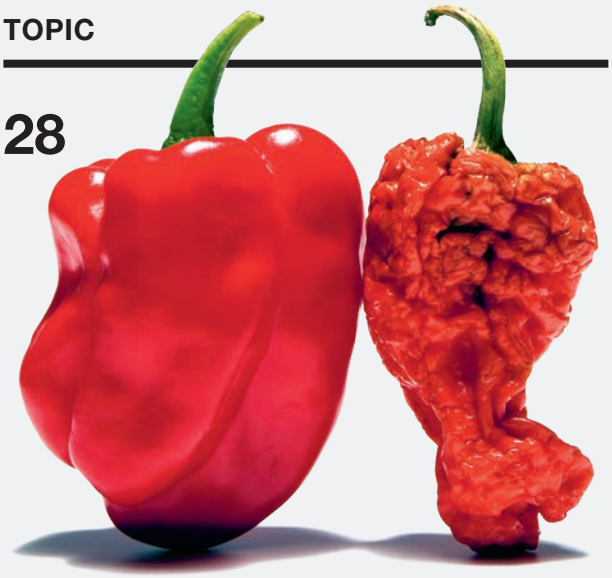
FOCUS

TWO PERSPECTIVES

Photos: Stefen Chow, Rensselaer Polytechnic Institute, Getty Images, ASCS, Guy Martin, Duncan Moore/U.N. Environment

TOPIC

28



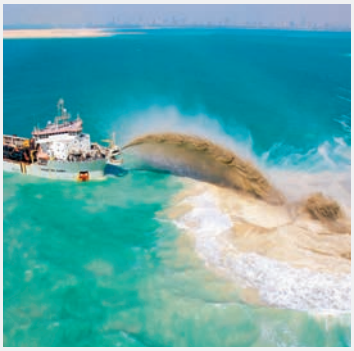
Waste not, want not – Keeping food good for longer

Every year, millions of tons of food are thrown away by households. We look at the benefits of preservatives and packaging technologies and explore the challenge of reducing food waste.

50

150 years of the periodic table

In 2019, we mark the Year of the Periodic Table – reason to pay closer attention to the elements. Our foldout section reveals some surprising finds and interesting facts about the elements.



42

Sand – the scarce resource

The quantity of cheap sand is in rapid decline. How research could change this.

Photos: Getty Images, ASK Images / Alamy Stock Photo, ASCS

Creating Chemistry 8

Content

Issue 2019

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World of cities

Urbanization Space in cities is in short supply and traffic is getting more congested. How cities can continue to grow while providing a liveable environment.

Illustration: Renato Guazzelli Martello (ASCS)

01 Above and beyond
Space in cities is in short supply. How we can still make room for people.
▶ **Page 11**

02 Cities in motion
Concepts to keep traffic moving and improve quality of life
▶ **Page 15**

03 Infographic
How city-dwellers can find new uses for forgotten urban spaces.
▶ **Page 18**

04 Interview
Singapore's former chief planner explains how to make liveable megacities.
▶ **Page 20**

05 Resilience
How BASF helps cities to cope with flooding such as from heavy rain.
▶ **Page 24**

Above: **The residential complex The Interlace in Singapore is like a vertical village. Living and social spaces are connected side by side and on top of each other.**

Left: **Small but spacious: Japan is a pioneer when it comes to living in compact mini-houses.**

Right: **Bangkok, Thailand, has one of the best city transport infrastructures in Southeast Asia. But high traffic volume still poses a challenge.**

Photos: Iwan Baan/OMA/Büro Ole Scheeren, Getty Images, Iwan Baan/Sou Fujimoto

Left, top: **The high-rise skyline isn't the only spectacular thing about Shanghai, China. The elevated pedestrian roundabout is an unparalleled architectural feat.**

Left, bottom: **In Copenhagen, Denmark, there are five times more bikes than cars.**

Right: **The high-rise gardeners of the two Bosco Verticale towers in Milan, Italy, have planted around 800 trees and over 19,000 other plants.**

Photos: Gallery Stock, Studio Boeri Architetti, Iaif

Imagine a sunny morning in the year 2050. You are in a skyscraper. You look down from the panoramic windows on the top floor. Robots are cleaning the façade and making repairs. Further down, a new building module is being inserted into a façade opening. It's an urban farming unit, where vegetables can be grown, and fish and chickens bred directly inside the building. Rainwater is collected on the roof and treated for domestic use. A building membrane converts carbon dioxide into oxygen, and solar panels and wind turbines produce energy. Sounds crazy, right? Not according to the plans of architecture firm WOHA, which has devised a concept for skyscrapers of the future. "We think that the ultimate, sustainable building is a self-sufficient building. We should be striving to create self-sustaining cities on a large scale," says Richard Hassell, co-founder of WOHA. The Singapore-based architecture firm has won many awards for its tropically open and sustainable architecture. One striking example is the Parkroyal on Pickering in Singapore, a hotel that combines architecture and nature.

The club of megacities

Growing megacities, sustainability, quality of life: these topics are increasingly important for city planners and architects. With around 38 million people, Tokyo is number one in the rankings for the world's most populated cities, followed by Delhi, Shanghai and Mexico City. The Japanese metropolitan area has been a member of the exclusive club of megacities (defined by the United Nations as a city with more than 10 million inhabitants) since 1950. The only other member at that time was New York, which has now moved down to ninth place. Today, there are over 37 megacities worldwide, and it is expected that more and more people ▶

01

Above and beyond

The architects at WOHA want to form a close bond between architecture and nature – as we see here with the Parkroyal on Pickering hotel in Singapore.

will continue to move to cities in the future. According to U.N. forecasts, there will be more than 43 megacities by 2030, most of which will be in emerging markets.

The world will need up to 2 billion more apartments in the next 80 years because of rapid urbanization. As cities do not have unlimited ground space to build on, and existing space is increasingly expensive, densification is the new buzzword. "The future of humanity depends on the benefits proposed by vertical densification in cities. This concept reduces land use and the energy required to build and maintain a horizontally expanding city," says Professor Antony Wood from the Council on Tall Buildings and Urban Habitat (CTBUH) in Chicago. This non-profit organization studies tall buildings and their architecture. The CTBUH office is based in an historically significant location: Chicago is considered the birthplace of the skyscraper.

After the Great Chicago Fire of 1871 and a rapid increase in land prices, new buildings steadily started creeping upward. This was made possible by high-strength steel. Crash-proof elevators invented by the Otis company in 1853 also made top floors a more attractive prospect. This was followed by height records being set, primarily in New York, thanks to steel skeleton structures. Today, New York City boasts more than 260 buildings with a height of over 150 meters. This is only exceeded by Hong Kong, which has about 350 skyscrapers.

But the current record-holder for highest building is in Dubai, United Arab Emirates: the Burj Khalifa with a height of 828 meters and 162 stories. Special equipment was required to construct such an extremely tall building, such as tower cranes and super high-pressure pumps, as well as appropriate material technology for the concrete. In the case of the Burj Khalifa, there were extremely stringent stability requirements.

"High-strength concrete was needed. The mixture had to have a pressure resistance of 80 Newtons per square millimeter, which is three times more pressure-resistant than the standard concrete used for house construction," says David Bowerman, Regional Business Segment Manager at BASF in Dubai, who supervised the Burj Khalifa project. MasterGlenium products were used to make the 175,000 cubic meters of concrete that were needed. "These are the only concrete admixtures on the market that met the client's requirements. They ensure rapid solidification and can be processed at temperatures of over 45 degrees Celsius –

Worldwide urbanization

Focus on Africa: This is where we find the fastest growing cities of the future (below). By contrast, the most densely populated metropolises are in Asia (right).

1. Zinder, Niger +67.6%*

2. Bujumbura, Burundi +67.4%*

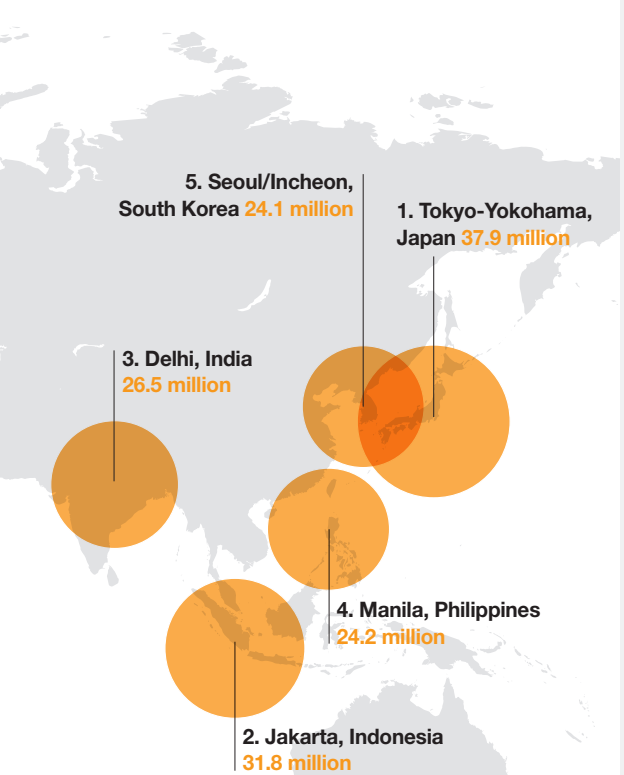
3. Lokoja, Nigeria +65.4%*

4. Ouagadougou, Burkina Faso +61.9%*

5. Mwanza, Tanzania +60.9%*

*Predicted growth from 2016 to 2025

In Hong Kong, China, concrete water pipes are being turned into new mini-homes.



Source: United Nations, demographia, 2016 or previously available years; World Urbanization Prospects 2014

which is not an uncommon occurrence in Dubai in the summer," explains the concrete expert. "Another challenge was that a pump had to transport the concrete mixture from the ground to a height of over 600 meters. That was a new record," says Bowerman.

New gigantism

Innovative solutions clear the path to dizzying heights. Along with ultra-strong concrete, special large bored piles are also used to anchor super skyscrapers meters deep into the ground. And innovative cable-free elevators based on magnetic levitation technology transport residents up to the highest levels of mega towers at lightning speed.

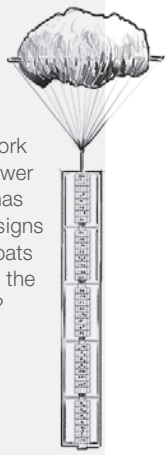
Photos: Patrick Bingham-Hall, James Law Cybertecture International; Illustration: ASCS; Graphic: ASCS

New ideas for skyscrapers

1 The wooden skyscraper
Until now, steel and concrete have been the building materials of choice when it comes to high-rise construction. In the heart of Tokyo, Japan, a record-breaking building constructed using renewable raw materials is being planned for 2041. The world's highest wooden skyscraper will stretch 350 meters into the sky, comprise 70 stories, and cost €4.5 billion.

2 The green apartment block
A spectacular example of the green future of high-rise construction has been set in 2018 in Taipei, Taiwan. The Tao Zhu Yin Yuan Tower designed by the Paris-based Vincent Callebaut Architectures resembles a DNA double helix. With 23,000 trees and shrubs, the façade, the roof, and the balconies of the apartment block provide a beautiful green landscape. The plants should absorb 130 metric tons of carbon dioxide a year – equivalent to the emissions from 27 automobiles.

3 The floating skyscraper
The sky is no limit for Clouds Architecture Office in New York and their Analemma Tower project. The U.S. firm has presented visionary designs for a skyscraper that floats high above the roofs of the city. How does it work? The building will be suspended from an asteroid placed in orbit over the earth.



"The future of humanity depends on the benefits proposed by vertical densification in cities."

Professor Antony Wood
CTBUH Executive Director, Chicago, USA

It is neither the statics nor the foundation that truly limit height. "Most people think that the height of a building is limited by technical factors, but that's not the case," says CTBUH Executive Director Wood. A much more decisive factor is whether you are able to raise the necessary funds and obtain the necessary permits. The new hot contender in the race for the title of world's tallest building is the Creek Tower in Dubai. Once it has been completed in 2020, the tower will loom about 1,000 meters above the ground thanks to BASF concrete admixtures. The construction costs for the mega tower are estimated to be around $1 billion.

Skyscraper expert Wood expects a real surge in the number of skyscrapers over the course of global urbanization. The record set in 2016 of 127 buildings higher than 200 meters completed worldwide was quickly surpassed just one year later with 140 new gigantic towers. Most of these were built in China. Wood is sure that skyscrapers are the ideal way to confront urban densification – not only because of their height, but also because they link together several levels of a city. "Things that are usually at ground level – for example, urban infrastructures or green spaces – will ideally continue onto and into the skyscraper, making the building an extension of the city." The result of this will be vertical cities that grow upward into the sky, where living, working, and leisure go hand in hand. These new buildings are often designed as flexible modular structures that can be easily and cost-effectively adapted to the needs of their users. ▶

Small but mighty

Unusual, mini modular solutions are being developed for cities with an extreme shortage of living space: The OPod Tube Housing project of Hong Kong architecture firm James Law Cybertecture converts concrete water pipes into micro-apartments with a living space of 9.29 square meters. The residential tubes can be stacked vertically and horizontally as needed. Hong Kong is notorious for its lack of space and dense living conditions. This is where the term "mosquito apartment" came from: tiny living spaces only big enough for a mosquito. In Japan and Taiwan, the construction of micro-apartments to fill the smallest gaps is also booming. It's a trend spreading all over the world. Micro-living should provide some relief for large European and North American cities in the coming years.

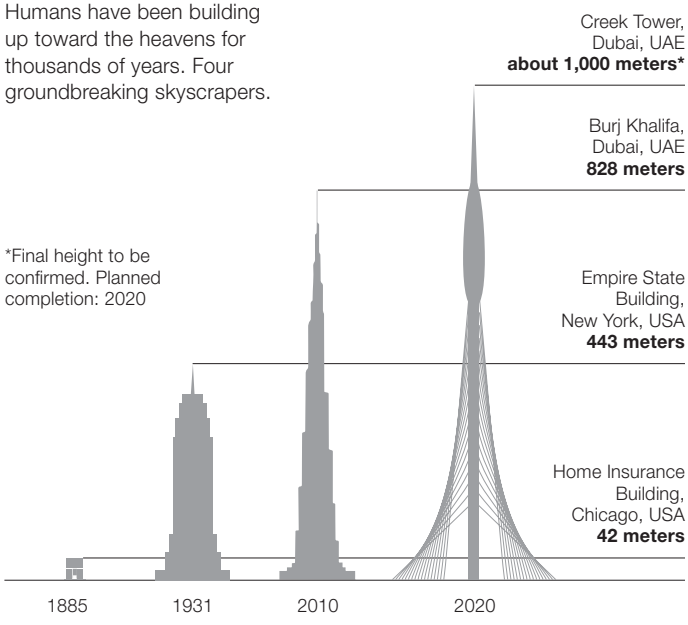
This way of living encourages a new form of cohabitation, which focuses less on private space and more on communal space. The space that we are lacking is shifted beyond the confines of our personal area. Communal areas on different levels and on the roof are just as much a part of all this as launderettes and swimming pools. The future of urban living is about sharing – not just cars, but also private and public space.

At the same time, nature is being brought back into our living spaces. For example, leaves are already sprouting on the spectacular Tao Zhu Yin Yuan Tower in Taipei (see page 13) and on the Oasia Hotel Downtown in Singapore, which was named the world's best skyscraper in 2018. This building designed by WOHA has a red aluminum grid façade, where tropical plants are gradually covering the hotel in a shroud of green. The building is a real eye-catcher that is also benefiting the microclimate. The trend for sustainable urban living is also infiltrating the world of road transport. ▶

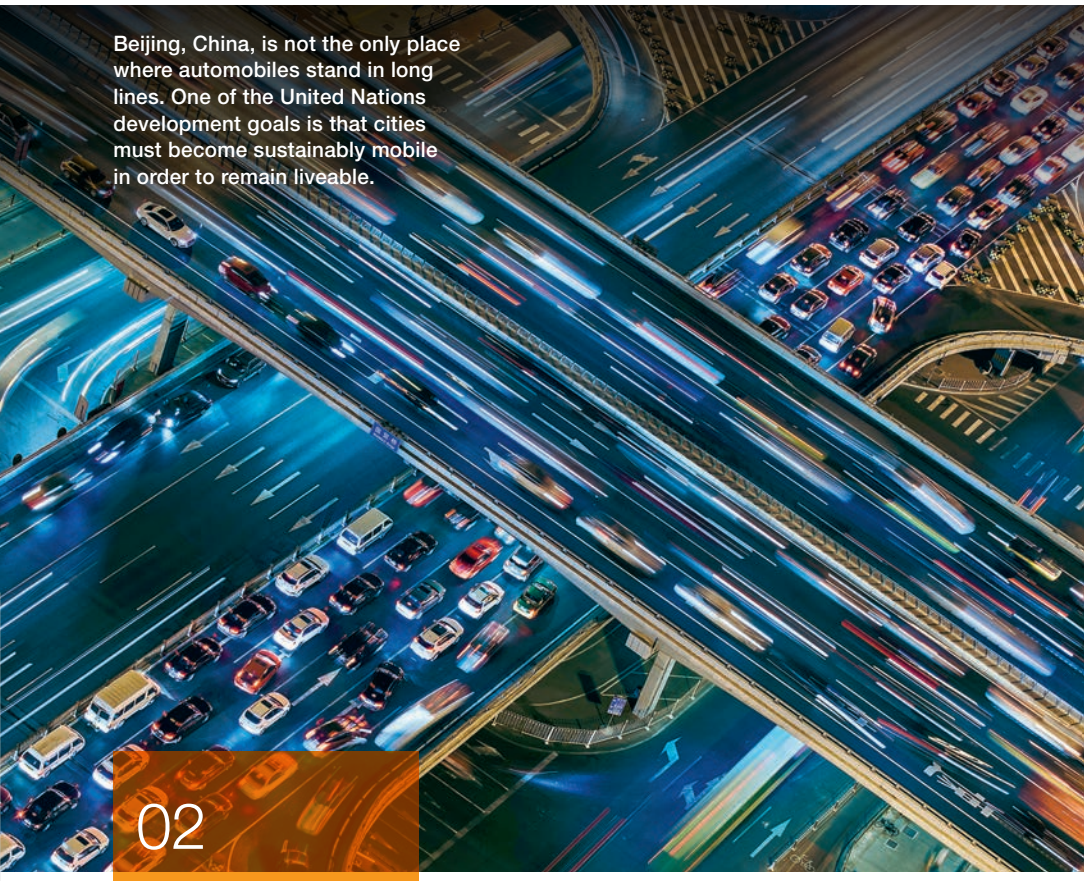
There are around 290 skyscrapers in Dubai, UAE. The Burj Khalifa stands proudly above them all – the tallest building in the world.

Above the clouds

Humans have been building up toward the heavens for thousands of years. Four groundbreaking skyscrapers.



*Final height to be confirmed. Planned completion: 2020



Beijing, China, is not the only place where automobiles stand in long lines. One of the United Nations development goals is that cities must become sustainably mobile in order to remain liveable.

02

Cities in motion

Automobiles stand bumper to bumper, and everywhere horns are blaring and the air is thick with fumes. From Bucharest to Jakarta, traffic jams extending for kilometers are a fact of life. For instance, in Mexico City, which tops the international traffic jam league, congestion lengthens the average daily journey time by 66 percent. This means, for example, that instead of 60 minutes you need around 100. To remain liveable and be fit for the future, cities must become sustainably mobile – this is one of the development goals of the United Nations' Agenda 2030. "If you want to ensure a better quality of life and cleaner air in cities as quickly as possible, you have to be in favor of shared mobility," says Professor José Viegas, a Portuguese transportation expert. Until 2017, he was head of the International Transport Forum, the transportation policy think tank of the Organization for Economic Cooperation and Development (OECD). The motto is renting and sharing, not possessing. In countries like China, which set records for smog, sharing is becoming an important solution for mobility. Not only is car-sharing seeing a boom, with forecast growth rates of 45 percent by 2025, but bicycle-rental systems are likewise flourishing. In just two years, companies like Mobike have placed 19 million brightly colored rental bicycles in China and hundreds of other cities on every continent.

> **"Traditional transportation behavior is going to be changed by shared mobility offerings."**
>
> **Claire Depré**
> Head of Unit for Sustainable and Intelligent Transport, European Commission, Brussels, Belgium

Transportation experts are in agreement here. "Traditional transportation behavior is going to be changed by shared mobility offerings and easier switches between transportation modes," says Claire Depré, Head of the Unit for Sustainable and Intelligent ▶

Urban mobility rethought

Three cities that are taking a new direction to get their residents more smoothly from A to B.

Tallinn, Estonia
Local public transportation has been free for residents since 2013. Free travel for all is to be made available in other parts of Estonia soon.

+ enables the socially disadvantaged to get around
+ better air, less noise
+ less congestion
- high cost to the city budget

La Paz, Bolivia
The longest urban aerial cable car system in the world connects La Paz with the workers' housing estate of El Alto. Seven lines are in operation, and four more are at the planning and construction stage.

+ low fares
+ cuts road congestion
+ densest urban cable car network in the world
+ reduces rush-hour journey times by around two-thirds
- operating radius is limited to distances of less than 5 kilometers

Istanbul, Turkey
Dedicated routes have been set up on highways for the bus rapid transit (BRT) system known as Metrobüs. Large express buses run on these routes every half a minute.

+ one of the fastest service frequencies worldwide
+ BRT is also being used successfully in other Asian cities, such as Jakarta, Indonesia, and Guangzhou, China.
- buses are often overcrowded

Photos: Getty Images (2)w

Transport at the Directorate General for Mobility and Transport of the European Commission in Brussels. Commuters will drive by automobile to the city limits, where they will change onto a train. Within the city, they will continue their journeys by urban railway or subway and then switch to a bus or rental bicycle for the last stretch to their places of work.

New digital mobility services will make it easier, more efficient and cheaper to get from A to B, as is happening in Helsinki, Finland, a pioneer in this area. Since 2016, people living in the Finnish capital have been able to use an app called Whim for intelligent travel planning across all transportation modes. Taxis, trains or car-sharing are booked and paid for through a common digital platform. What are known as Mobility as a Service (MaaS) solutions, like Helsinki's, are being trialed worldwide in cities that suffer from heavy traffic, such as London, Los Angeles and Singapore. The vision is one of less traffic but more mobility.

"Like digital networking, electromobility is creating possibilities that nobody can ignore," Viegas says. This is because, in e-mobility, both startups and the R&D departments of major companies worldwide are surpassing themselves in coming up with innovations. Thanks to batteries that are longer-lasting and have a wider range, plus a well-developed network with smart charging stations, e-mobility is an important factor in cutting traffic-related greenhouse-gas emissions, if the electricity comes from renewable sources. Across the whole E.U., these gases that are harmful to the climate are set to be reduced by 80 percent by 2050, compared with 1990 levels. "This is why the Commission is driving the electrification of all transportation modes, on land and water and in the air," says Depré, the E.U. transportation expert.

There is still room for improvement in the sales figures. In 2017, a total of 54,492 plug-in hybrid and electric automobiles were sold in Germany, the country with the fourth-highest number of sales in the world. The market leader, with 777,000 vehicles, was China, which had toppled the United States from top position in 2016. China is using a quota that obliges automobile manufacturers to make clean vehicles from 2019, as well as offering financial incentives for buyers to boost the 2.7 percent market share that e-automobiles already have.

Transportation transition: E-bikes, with bike-sharing, are on the up.

Electromobility is meant to cut greenhouse gas emissions, but there is still room for improvement in the sales figures.

$24.4

billion is the expected value of e-bike sales worldwide by 2025. That would be an increase of more than 50 percent on the 2016 figure.

E-bikes faster in city traffic

One potential solution for a sustainable transition in transportation is often underrated – the electric-powered bicycle. This makes the new, old transportation mode attractive to commuters, for, as the German Federal Environment Agency says, e-bikes are usually faster than automobiles in city traffic over distances of less than 10 kilometers. Up to 30 percent of automobile journeys in conurbations could be made by bicycle, experts estimate. It is no wonder, then, that the e-bike market is growing at record speed. Navigant Research, an international market research company, expects global e-bike sales to rise from

Photos: PR/bycyklen/Jon Ram Bruun-Pedersen, Lukasz Palka

Local public transportation in Asia is regarded as extremely efficient. Tokyo, Japan, for instance, has the most extensive network in the world. It carries 40 million passengers daily.

more than $15.7 billion in 2016 to some $24.4 billion in 2025.

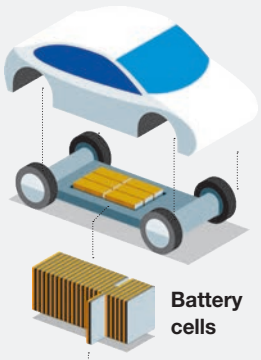
Cities such as traffic-plagued Barcelona are already steering a course toward sustainable mobility. City and transportation planning are being thought through together. The city aims to create 300 kilometers of new bicycle paths, buses are to run more frequently and more stops are to be set up. However, the heart of the reform lies in what are known as superblocks – squares measuring about 400 meters by 400 meters, from which traffic will largely be excluded. Automobile drivers – with the exception of residents and delivery vehicles – will be diverted around the outside, freeing up the roads within the blocks for pedestrians and cyclists. Residents and passersby will receive a new space in which they can meet up and have a stroll.

"We aim to double the real driving range of medium-sized battery-powered cars from 300 to 600 kilometers by 2025."

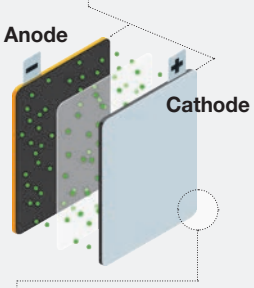
Markus Hölzle, PhD
Director Battery Materials
Product Development, BASF

Small particles that shape e-mobility's future

E-Mobility How long does it take to charge an electric car battery, how far can I drive on a single charge, and what are the costs? BASF research into high performance lithium-ion battery materials is contributing to improvements in all three areas – shaping the way for e-mobility to become suitable for daily use.



Most modern electric vehicles are powered by lithium-ion batteries. It currently takes on average more than 60 minutes to fully charge a medium-sized electric car and the average range under real driving conditions is 300 kilometers.



The battery consists of cells, each with a positive and negative electrode. The cathode is made of Nickel Cobalt Aluminum (NCA) or Nickel Cobalt Manganese (NCM), the anode of graphite. Lithium-ions carry the battery's charge between the electrodes, creating electric energy which is converted into mechanical energy to drive the vehicle.

The properties of the cathode materials are critical to the charging time and energy content of the battery. The individual particles (here NCM) are just micrometers in size.

A porous surface and open structure allows the lithium-ions to leave the cathode more quickly, speeding up charging. The aim is to be able to charge a midsize electric car in 15 minutes by 2050.

Particles with a broad distribution of sizes can be packed into a given volume more tightly, resulting in increased energy storage. The higher the energy density, the longer the vehicle's range. The aim is for a real driving range of 600 kilometers by 2025.

BASF is partnering with its customers to help them reach these ambitious e-mobility targets by adjusting chemical composition, form and structure, as well as production process of the cathode materials.

Explain-it video: How a lithium-ion battery works
on.basf.com/lithium-ion-batteries

New life for cities

Reclamation **How cities can win back and find new uses for lost or residual urban spaces.**

1 Skate parks under bridges and elevated highways

Physically active city residents are reclaiming unused land under bridges or elevated highways by using it for skate parks. In this way, they can take centrally located plots that are unsuitable for building and put them to public use – and stay dry during their open-air sporting activities even in heavy rain.

Implemented *Jutland Avenue Bridge, Cape Town, South Africa*

2 Disused subways as bicycle paths

Unused subway tunnels make good cycle paths, through which cyclists can get from one place to another quickly, irrespective of the weather. Panels could be laid on the paths, which would produce electricity as cyclists put pressure on them. This idea earned Gensler, an architecture firm, the prize for best conceptual project in the London Planning Awards in 2015.

Concept *London Underline, London, United Kingdom*

3 Picnicking above the city's trees

Tearing them down is expensive, and leaving them to deteriorate is no alternative, so why not provide disused electricity pylons with stairs and viewing platforms and turn them into new visitor attractions? Kiosks would be built into the base of the towers, selling everything people need for a picnic above the trees. This idea came to architect Anders Berensson during an architecture competition held by the Royal Court of Sweden, which owns the park where this concept is set to become a reality.

Concept *Power Tower, Norra Djurgården city park, Stockholm, Sweden*

03

Infographic

4 From derelict buildings to fresh farm produce

Urban farms are no longer just a nice-to-have. In some cities they provide fresh produce to local people. They also help strengthen communities by bringing residents, businesses and organizations together with a common aim. That's why BASF is partnering with local businesses in Detroit, USA, to create a multi-functional community space that serves as a model of how city-dwellers can learn to get the most out of their land.

Implemented *Michigan Urban Farming Initiative, Detroit, USA*

5 Recycle and recreate

Waste-recycling facilities make an important contribution to a city's sustainability, but the buildings themselves are very unappealing and unattractive. They often tower over local buildings and take up space on the edge of cities. What if the recycling facility doubled as a recreation area? Imagine a climbing wall up one face, or even a ski slope on the roof. Sounds incredible? In Copenhagen it's already being built.

Implemented *Amager Resource Center, Copenhagen, Denmark*

6 Underground garbage collection

Trash cans are an essential part of public urban spaces. But when they overflow, they are not just an eyesore but an environmental hazard. Wouldn't it be good if they were out of sight? Raipur, India, is installing underground trash cans that not only have space for more garbage, but also signal automatically when they need to be emptied. The next step could be a system of underground "trashbots" to haul the waste away.

Implemented *Raipur, India*

Concept *Sidewalk Labs, Toronto, Canada*

Illustration: Jörg Block

The five E's of a city planner

04

Interview

Planning longterm Dr. Liu Thai Ker, Singapore's former chief city planner, transformed the island state from a collection of slums into one of the world's most liveable megacities. Here, he explains what really counts.

Creating Chemistry: Urban areas around the world are growing in size and number. How can we make megacities into liveable places where individuals feel at home?
Liu Thai Ker: When I started work as an urban planner in Singapore in 1969, the city had a population of 1.6 million. Today its population is nearly 6 million. There was a sketchy but well-conceived concept plan prepared in 1971. My role was to fill in the details of the new town plans in line with the broad framework. The plans we laid down over those decades have stood us in good stead, despite our rapid growth. The key is that we subdivided the city into smaller urban cells. In this way, the population of 6 million is broken down into smaller and smaller communities until you feel as though you are living in a high-rise village.

How does that work in detail?
We divided the city into five regions each of 1.1 million people. Each region is like a small city. Each region is then divided into new towns of 200,000 to 300,000 people. You can live your whole life in a town of that size: be born there, go to school and work there and, if you need to, go to hospital. The towns are divided into neighborhoods, defined as an area you can walk to. We then divide these neighborhoods into precincts with an area of 2.5 to 4 hectares each. Sociologists say this is small enough for people to develop an emotional tie to the land. With less than a thousand families in a precinct, people know each other and develop community cohesion like those in traditional villages

What other benefits does this bring?
Between 1960 and 1985 people were being moved into public housing for the first time in massive numbers. They were strangers to each other, many from different social-economic strata and ethnic backgrounds. Creating a sense of

Photo: Stefen Chow

Dr. Liu Thai Ker has spent five decades planning cities. For him, creating a sense of belonging is paramount.

belonging was therefore very important. The precincts meant that people soon got to know each other and began treating each other as friends, rather than strangers. That is one reason why Singapore is a safe place today.

How does this apply to other cities around the world?
In Asia many cities have a population of over 10 million; Shanghai's population is more than the whole of Australia. My advice for those cities was not to treat each as one city but as a constellation of smaller cities, independent from each other and yet related, with facilities distributed to each of them. This means a person can walk to their neighborhood center to get what they need; they don't need to drive. That cuts down travel time, uses less fuel and improves air quality. In China, I have planned three cities with populations of 12 million each on this basis. Urban planning affects human behavior – if we plan well, that will encourage behavior that saves time and energy, and improves the lives of citizens.

Much of Singapore's planning was based on densely populated high-rise towers. When planning for the number of people per square meter, is there a figure we should not go beyond?
This issue is more acute in Asia than in the West. Asia has 60 percent of the world's population living on around one-third of the world's land mass. We therefore have no choice but to consider high-density living, but we also have to create good, liveable environments. No government, no matter how powerful, can stop people moving to a city that is growing well. The job of a planner, therefore, is not to determine what population size the land can bear, but to project on a long-term basis the likely population size that the city may grow to and consider the floor areas required equivalent to those of a highly developed city, for all the daily activities of each citizen. Only then can the planner allocate the various types of land use and sizes required within the land constraints.

How do you calculate the optimal floor space per person?
When I came back to Singapore in 1969, the city was desperately poor, but I had to plan new towns with proper housing for the lower income group. I believed that we had to try to plan our housing and facilities to match, as closely as possible, the first world standard. So, I took a study of the floor area occupied by people in America and used that as a guide. Even in a third world country you should plan for first world standards. It is too expensive to go through the various steps of transition and upgrading, demolishing substandard buildings and replacing them with better ones.

Many cities are growing faster than the infrastructure needed to support them. How do we tackle this challenge?
Good long-term planning is the starting-point. When I plan for cities now, I plan for 2070, because that is when the global population is predicted to peak. We plan for the whole area and then implement the plan in phases, so that there is continuous expansion, rather than leapfrogging. This is what we did in Singapore. Once the first phase of infrastructure was laid, people moved in and we started collecting taxes – so were able to develop a city without borrowing money from the World Bank, despite starting as a very poor country. You need intelligent planning plus intelligent administration for a good urban environment.

How do citizens play a role in urban planning?
A planner or a government cannot know everything. You need constructive feedback from citizens. Working in public housing, we not only planned and supervised construction, but also managed completed buildings. The beauty of this is we got lots of complaints, so we organized research units to sort out the ones highlighting flaws we had made in the design and planning. Every month we plowed back

Five decades designing cities

Dr. Liu Thai Ker
Architect and former master planner of Singapore

The son of an artist, Dr. Liu Thai Ker trained first as an architect at the University of New South Wales, Australia, before obtaining the Master of City Planning at Yale University, New Haven, USA.

After returning to Singapore he served as Architect-Planner and Chief Executive Officer of the Singapore Housing & Development Board from 1969 to 1989, and Chief Executive Officer and Chief Planner of Urban Redevelopment Authority from 1989 to 1992. He was a Director of RSP Architects Planners & Engineers from 1992 and left in 2017 to found a new architectural and planning practice, Morrow, in Singapore.

He is also the founding Chairman of the Centre for Liveable Cities in Singapore and has planned around 50 cities. He has an honorary doctorate from the University of New South Wales and is the recipient of many awards in Singapore and elsewhere.

60%

of the world's population lives in Asia on around one-third of the world's land mass.

Photos: Stefen Chow (4)

“As a planner you have a very sacred responsibility to the people in your city.”

Dr. Liu Thai Ker
Architect and city planner

Left: **An open corridor in an apartment block in Ang Mo Kio, one of Liu’s planned towns in Singapore. Public transport is in close proximity.**

Right: **The Bishan Park, behind Liu, was designed with a naturalized river to increase biodiversity in the city.**

the gems of these complaints into new urban planning and design. This process continued for 20 years. You can imagine how much I learned.

Over the past decade many cities have adopted the idea of the “smart city” to tackle their challenges. What does a smart city mean to you?
To me a smart city is like the vitamin to a body. The job of a planner is to make sure the body is healthy. That requires careful, intelligent planning. Only on that basis can you then take on vitamins to make the city stronger. The vitamin is the smart part of it, the technology. My biggest fear is that people think that technology can solve urban problems. It can’t. Urban needs must be met through intelligent planning and design, which requires real hard work. The ideal situation is to combine smart technology with good planning, but there are not yet many good examples of that in the world.

You have said the ultimate purpose of a city is to raise the self-esteem of each citizen. How do we achieve that?
The goal of a city planner is guided by five E’s. You need Ecology so that you do not contribute to global warming. You need Education, because you want a strong work force. You need a good Environment for people to live happily. Then you will get Economic growth because you will attract investment and talent to the city. If you achieve these first four E’s, the citizens of that city gain Esteem, and to me, that must be the ultimate goal of an urban planner. Just focusing on environment and ecology is too low a goal. As a planner you have a very sacred responsibility to the people in your city and you have to do your level best to achieve that.

What do we need to do to meet the urban challenges of the future?
The strong emphasis on technology as a solution for urban problems worries me a lot. We must place more emphasis on intelligently planning a city. Architects and planners tend to think of themselves as imposing their creative ideas on the land. I don’t think like that. I consider myself a servant of the land and its people. If planners, politicians and architects see themselves in this way, then maybe the world will have better cities.

Picture slider: Istanbul, Turkey, is another fascinating megacity. Find out how its image has changed over the past centuries.
on.basf.com/istanbul

Urban resilience

BASF Torrential rain, bursting river banks, rising sea levels: Flooding is a threat for many cities around the world. With climate change, that threat is increasing. BASF helps protect cities from the elements.

Urban floods are a growing problem. When drains clog and stormwater has nowhere to run off, pavements, roads and public spaces become impassable. Rising water levels can damage infrastructure, put people at risk and even cause loss of life. Climate change means there are ever more extreme weather events around the world. With urban populations swelling, cities need to be made resilient to these risks.

One solution lies in the materials used for public spaces. "The problem arises because excess water cannot drain off," says Christof Grieser-Schmitz, Segment Manager for Construction Infrastructure at BASF. "Many city surfaces are covered in non-porous asphalt or concrete, so water gathers in pools. It's not just inconvenient, it's also a hazard."

Absorbing not sealing

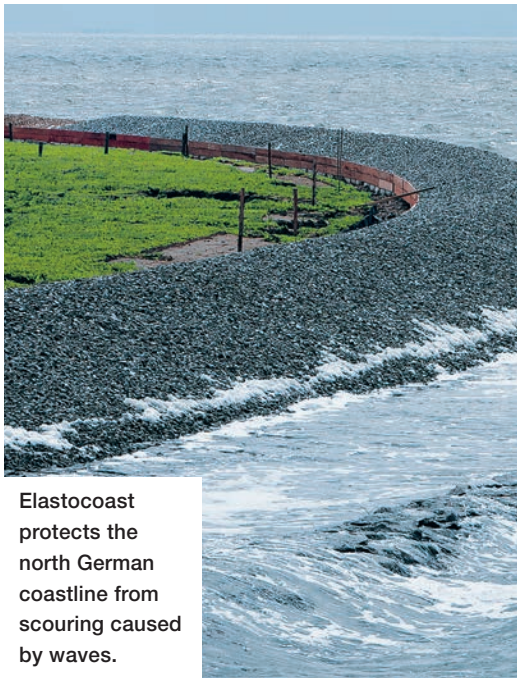
To prevent this happening, BASF has developed Elastopave®, an innovative paving material that is durable, firm and water-permeable.

In Europe, Elastopave has been used for sidewalks, cycle paths and parking lots, such as in Lemförde, Germany. Rainwater is channelled efficiently to the water-table below. No pooling means no frost damage, fewer potholes and no slippery surfaces. "Elastopave makes paths and roads safer, and improves a city's water circulation system," says Grieser-Schmitz.

The idea of making city surfaces that absorb rainfall, like a sponge, is taking hold in China, where rapid urbanization and increased flooding have led the government to launch a "sponge city" construction program. Hangzhou, a city of 9 million, has to cope with heavy rainfall and typhoons, as well as tidal surges from the Qiantang River. As the population has grown, more of the surface area has been paved over, and the city's drainage system can no longer cope. As part of the solution, Elastopave has been installed along the city's West Lake.

4,000

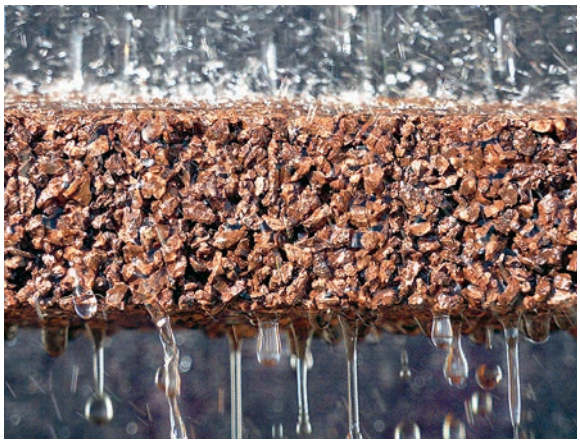
liters An Elastopave surface can absorb 4,000 liters of water per hour per square meter.



Photos: Alamy Stock Photo, BASF (2); Illustration: Jörg Block

Elastocoast protects the north German coastline from scouring caused by waves.

The famous West Lake in Hangzhou, China. Elastopave was installed on a path next to the lake and along one of the city's main roads in 2016.



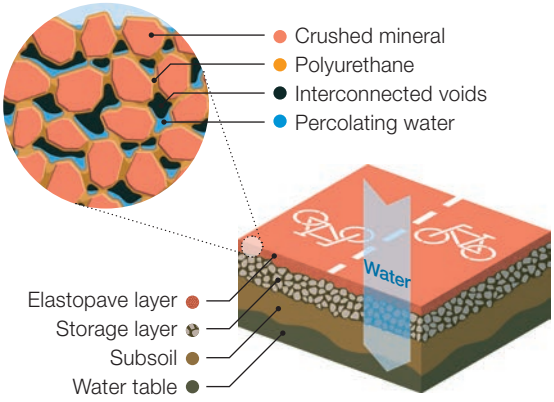
Elastopave creates a surface that is both stable and porous.

05

Resilience

How Elastopave works

Crushed gravel or stones and polyurethane create interconnected voids that allow water to percolate through, replenishing aquifers and improving water circulation.



Dispersing water

Like Hangzhou, many cities are built on rivers or near the sea. Tokyo, Shanghai and Mumbai – some of the world's biggest cities are located by the coast for the good reason that waterways provide natural transport routes for trade. But rising sea levels, storms and tidal surges are increasingly threatening these areas.

Elastocoast® helps meet this challenge. Like Elastopave, it is a water-permeable polyurethane system. Installed along river banks and coastlines, its open structure absorbs and disperses water, reducing the velocity of the current and providing a suitable habitat for vegetation. Elastocoast is being used in Europe and Asia to ensure that rivers running through urban areas stay within their banks and oceans do not damage or flood coastlines and cities.

"By reducing risks associated with flooding, BASF helps make cities more resilient," says Seung Hun Lim, Manager Construction Infrastructure, Asia, at BASF.

360° Video: Shanghai from the waterfront
on.basf.com/shanghai360

Have you seen this yet?

New discoveries Inspiring innovations that make our daily lives easier and create more sustainability.

The bicycle saddle rethought

Product Two shells are better than one – a completely new bicycle saddle design supports pedaling movements actively and in a way that is kind to the back. This is made possible by two shells that work in isolation from each other. The lower shell performs a load-bearing function, while the upper, flexible one supports the padding. This allows it to follow the natural pedaling movements. The saddle's ergonomic core is made of Infinergy® from BASF, which uses thousands of lightweight and highly elastic foam particles to provide optimum shock absorption and suspension while cycling – and thus eases strain on the back. The saddle was developed by the company Ergon in collaboration with BASF.

infinergy.basf.com

Music from a cardboard box

Product It took Gerd Falk and Markus Blandl from Stuttgart, Germany, more than five years to create Bango, a sound distributor made from carbon. What is special about their invention is that the carbon fibers of the spider-like composite system can transmit sound waves to the most varied objects. This means that even simple cardboard boxes can become a new type of speaker.

bango-music.com

carretonpowerhub.com

Mobile energy source

Product Renewable energy straight from a market stall. Hurricane Maria, which struck Puerto Rico in 2017, gave Alexandre Díez Gradín an idea. It is that, during emergencies resulting in an interrupted power supply, a two-wheeled market stall called CarretOn will provide the necessary energy for small devices such as smartphones, laptops or medical appliances. The power is generated by two 25-watt solar modules, and it is sold at markets or outside people's front doors.

Photos: BASF, Alexandre Diez Gradin/Careton, Bango Music

Fuel-free cooker

Product Around 3 billion people cook on an open fire every day. The health effects of breathing smoke in enclosed spaces are devastating, and burning wood is a significant cause of climate change. Wonderbag is an insulated container allowing food that has first been brought to a boil on a conventional cooker to continue cooking for up to 12 hours. Slow cooking this way not only reduces indoor air pollution, but also makes nutritious meals and leaves the cook with free hands.

wonderbag.org

40 percent of the world's population does not have access to clean cooking fuels or technologies.*

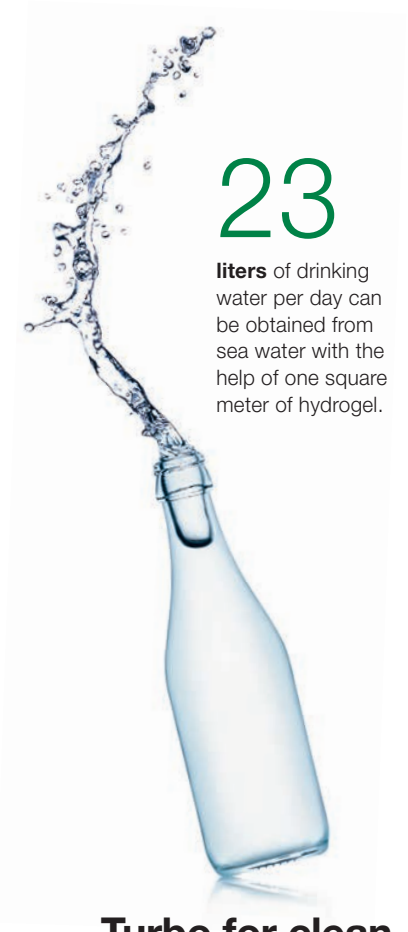
3.8 million people die each year as a result of household air pollution from burning biomass for cooking.**

Burning solid fuel in homes accounts for **25 percent** of global black carbon emissions.***

Sources:

*World Bank
**World Health Organization
***Global Alliance for Clean Cookstoves

Photos: Wonderbag SA (2), Getty Images



23

liters of drinking water per day can be obtained from sea water with the help of one square meter of hydrogel.

Turbo for clean drinking water

Concept The black, floating gel disk that aims to create clean drinking water from sea or waste water is slightly smaller than a long-playing record. According to Guihua Yu, PhD, University of Texas, USA, this invention aims to create up to 23 liters of clean water per square meter of hydrogel with the help of the sun. A patent application has already been registered. The light-absorbing, extremely fine-pored hydrogel accelerates the process whereby the water evaporates and condenses on the surface. Salts, bacteria and harmful substances are left behind in the gel. The idea is to use the mobile drinking-water producer in disaster zones, for example. Yu and his team are currently working on suitable manufactoring processes with partners from industry.

Waste not, want not

Shelf life Food preservation began with simple salting and heating. Today it is a high-tech industry in a balancing act between technology and the garbage can.

Thousands of years before ready meals and E numbers, humans were applying natural processes to stop food from spoiling and keep it safe to eat for longer. Traditional techniques of food preservation worked well, even if people did not understand the science behind them. Today we know that salt removes moisture, thus slowing down decomposition caused by bacteria; wood smoke contains phenol, a preserving chemical found in coal tar; and pickling vegetables in brine creates lactic acid, high acidity being another great way to keep food fresh.

From the 18th century, chemicals that stop food spoiling, including the useful family of organic carboxylic acids, were extracted from naturally occurring substances such as ants, saltpeter, salt, berries and coal tar. These molecules and their derivatives gave us many of the classic preservatives that accompanied food mass production – including nitrates, sulfites, benzoates and sorbates – many of which are still in use today. By the end of the 19th century, they were being produced on an industrial scale by BASF and others, while scientists had isolated and named the principal bacteria that cause food poisoning, including *Clostridium botulinum*, *Escherichia coli* and the *Salmonella* species, and food safety legislation was introduced in many countries.

"Consumers want to move away from chemicals, while food safety legislation is becoming more restrictive."

Mari Carmen Alamar, PhD
Cranfield University, England

Today, without food preservation techniques it would not be possible to provide consumers with fresh produce on a consistent basis year-round, and a large quantity of the food grown and produced would be wasted. Take apples, for example. By treating them with the synthetic plant growth regulator 1-MCP (1-methylcyclopropene), which slows

Wrapped and unwrapped

Longer life From foil-lined paper and aluminum cans to sophisticated plastic wrappings, packaging extends the life of many fresh foods and reduces food waste.

Photos: gettyimages, AdobeStock, shutterstock

ripening, they can be stored for up to a year, meaning that more of the harvest is enjoyed by consumers. Preservatives are not just an add-on. They enable the food industry to cope with fluctuating weather and peaks and troughs in demand.

Falling under suspicion

However, despite the benefits food preservation has brought, many of the chemicals used to keep food safe for longer have come under increasing scrutiny, and some traditional food preservatives have fallen from favor. Benzoates and nitrates, used to preserve beverages, pickles, fruit juices and cured meats, have been associated with carcinogenicity. Connections are being made between preservatives and hypersensitivity, hyperactivity, allergies and asthma. The list of causes of suspected food intolerance is growing. Sulfites, used to preserve dried fruits, as well as wine and beer, were banned from fresh produce by the American Food and Drug Administration in 1986, and since 2016 must be labelled for consumers in the European Union as potential allergens. Meanwhile, what are known as synthetic anti-oxidants are viewed with suspicion by the public.

In response to food regulation and consumer health fears, including the growing "clean food" movement, food ▶

"Fresh" apples

How long after picking are apples still fresh? That depends on how they are stored and treated. We compare three methods.

Cool storage (2 to 4° C)

2 months

Controlled atmosphere storage

6 months

Ethylene removed to slow ripening

1 year

Sources:

foodsafety.gov; modifiedatmospherepackaging.com; perfotec.com; cannedtuna.com; bpf.co.uk; vakuumverpacken.de; dairysafe.vic.gov.au; Petrus et al., 2010; thechocolatejournalist.com

5 foods that don't go off

Honey has been discovered by archaeologists in Egyptian tombs. It may become crystallized but remains safe to eat.

White rice maintains its flavor and nutrients for 30 years if stored in an airtight container at fridge temperature.

White sugar has an indefinite shelf life due to its resistance to microbial growth, if stored in a cool, dry place.

Salt has been used to preserve food since prehistoric times. In cool, dry storage conditions it will never spoil.

Vinegar has an almost indefinite shelf life, even without refrigeration. Its acid nature makes it self-preserving.

manufacturers are changing formulations. It is not just salt and sugar content that is being reduced. Nitrates and benzoate are being replaced with alternatives such as sorbates, citrates and the "natural" antioxidant vitamin E and its derivatives, tocopherols.

Mari Carmen Alamar, PhD, lecturer in postharvest biology at Cranfield University, England, says consumers are becoming more discriminating and increasingly averse to chemicals being added to what they eat. They are less concerned about physical imperfections in fruit and vegetables than in the past, and are looking instead for food that tastes good. This poses a challenge. "Consumers want to move away from chemicals in the final product, while at the same time food safety legislation is becoming more and more restrictive," says Alamar.

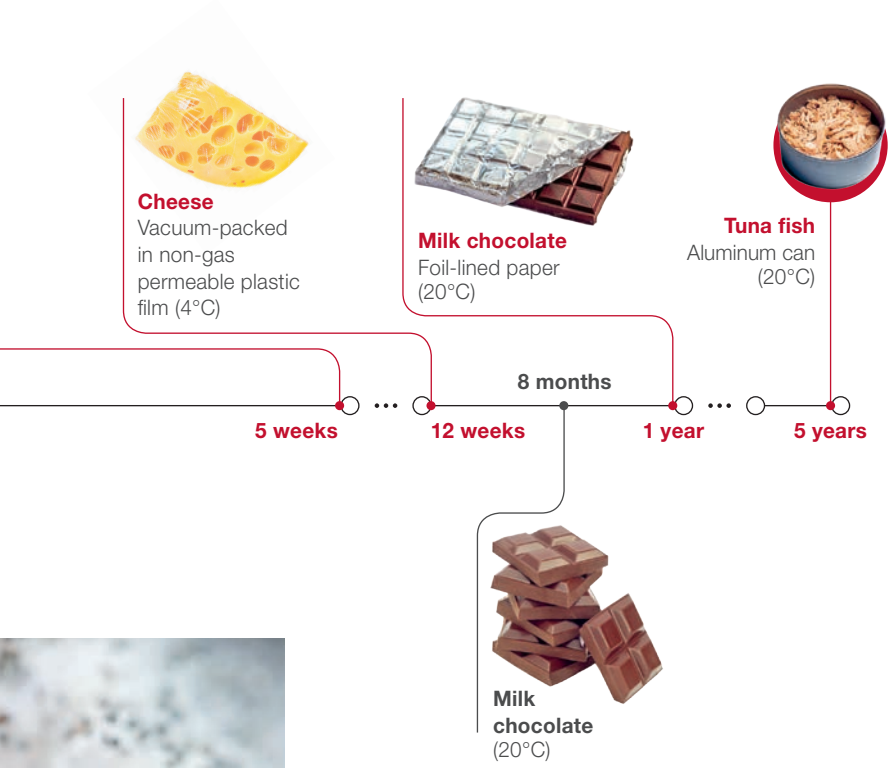
Packaging that preserves

One answer has been innovation in food packaging. Styropor®, a form of expanded polystyrene invented by BASF in 1951, has proven ideal for packaging chilled, short-shelf-life foods. Modified atmosphere packaging, which replaces the normal air in a package with a protective gas mix, provides another way of delaying the ripening of fruits, and thus reduces the amount that is thrown away before it is consumed. However, innovations such as these have come with an unintended side effect. "This is a good technology," says Alamar. "But while the gas mix may reduce food waste

"It is our job as food scientists to explain the science and dispel scare stories."

Professor Vibeke Orlien
University of Copenhagen, Denmark

Photos: shutterstock, Getty Images, Vibeke Orlien



Photos: shutterstock, Getty Images, Andrew Parry

without chemicals, the plastic film increases plastic waste."

Efforts are now focused on developing new forms of packaging with a lower environmental impact. One example is a biomass balanced version of Styropor, which is made using biogas from organic waste, rather than virgin fossil fuels. The concept, says Gregor Haverkemper, BASF's Director of Global Marketing for Styropor, is to reduce significantly the carbon footprint of a product which is indispensable to the world's food industry. "It has great insulation properties and retains a constant low temperature, so it's fantastic for products like ice cream, fish, and fruit and vegetables. It is also 98 percent air, and fully recyclable," he says.

Beyond recyclability, the hunt is on for compostable food packaging. Another new particle-foam food-packaging material developed by BASF, ecovio® EA, meets this challenge. It is manufactured from plant-based materials, including a biodegradable polymer, ecoflex®. "We are really excited about this," says Haverkemper. "The packaging breaks down naturally in municipal composting facilities."

Mechanical and electromagnetic technologies as an alternative

Ensuring food safety, reducing food waste, and minimizing the impact on the environment remains the ultimate goal, and some new solutions are emerging. Mechanical and electromagnetic technologies have already been adopted as an alternative ▶

Best before ...

Andrew Parry
Special advisor, Food and Drink, Waste and Resources Action Programme (WRAP), United Kingdom.

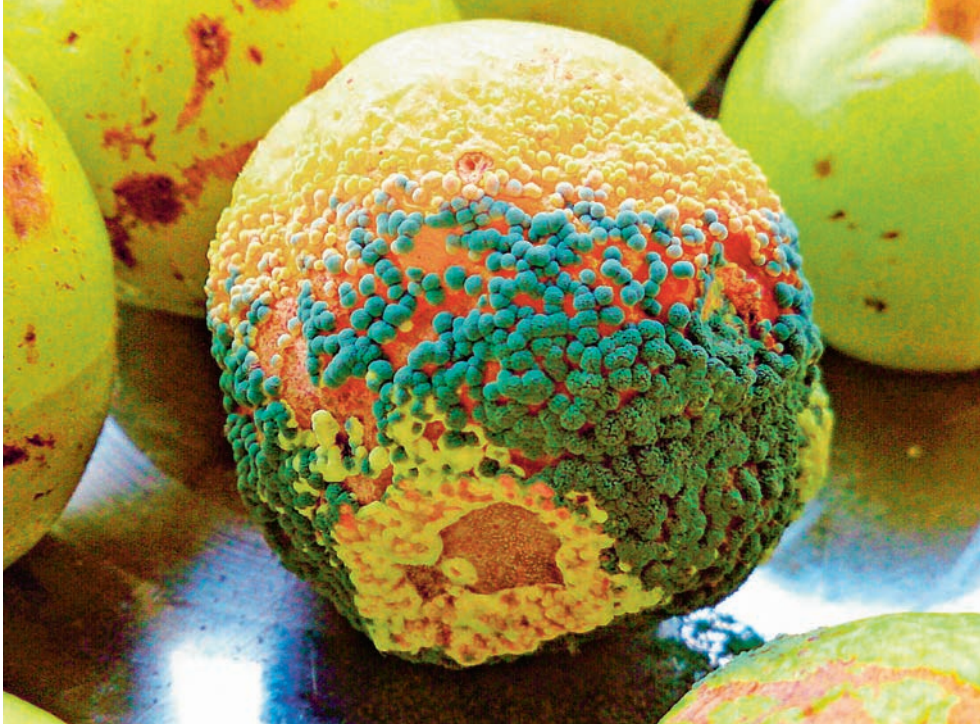
Is it still safe to eat? "Best before," "sell by" and "use by" dates on food labels are intended to help consumers make this decision. But confusion about what they mean results in food being unnecessarily thrown away. One of WRAP's missions is to help reduce this waste.

1 How much food do people throw away in their homes?
In the United Kingdom, people throw away 7 million tons of food a year. The bulk of this is inedible parts of food and leftovers, but at least 2 million tons goes straight into the bin because it is spoilt or thought not to be suitable or safe to eat. This is partly due to food being stored incorrectly – like putting bread in the fridge where it goes stale faster – but around a third is because people don't understand the difference between the "best before" date, which is about quality, and "use by," which is about food safety.

2 How are you tackling this problem?
We have produced new guidance on date labels and storage to make them less confusing for consumers. It includes some simple icons for businesses to use, such as a snowflake logo to indicate which foods are suitable for freezing, and it helps consumers understand what labels mean.

3 Is progress being made?
It is. Compared to 2007, over 1 million fewer tons of food are being wasted each year by households – a really significant drop. Also, retailers have moved away from "buy one get one free" offers in favor of lower everyday pricing, and it's now far more common for supermarkets to sell fruit and vegetables that are not aesthetically perfect. It's being marketed as "ugly," "wonky," or "less than perfect." Consumers like it.

WRAP is an organization based in the United Kingdom and established in 2000 to encourage recycling and reduce food waste.
www.wrap.org.uk



or in addition to chemical preservatives. High-pressure processing gives sealed fruit juices a longer shelf-life, and atmospheric cold plasma – which involves applying high voltages to products in their packages – kills harmful bacteria such as listeria without damaging the food. At the cutting edge of food preservation innovation, methods have been developed that use ultrasound, shockwaves, membrane filtration, and electrolysis to render the microorganisms that spoil food inactive.

The science is advancing, but the key driver of innovation in food preservation technology, according to Vibeke Orlien, associate professor in the University of Copenhagen's Department of Food Science, Denmark, will always be consumer expectations. New ways will have to be found to extend the shelf-life of fresh produce, she says, yet some innovations will be met with resistance by consumers. The public, she notes, tends to be afraid of anything new and "scientific" when it is yoked to the stuff of life. "Some people falsely believe that applying ionizing radiation to food, as we do in Europe for herbs and spices, makes it radioactive, for example. Yet the World Health Organization has confirmed that it is safe. Our job as food scientists is to explain the science so as to dispel scare stories," Orlien says.

Chemicals save lives

Whatever new technologies appear, we should be cautious about dispensing with chemicals that have a proven track record of protecting us from harm, according to Hugh Pennington, emeritus professor of bacteriology at the University of Aberdeen, Scotland. Food poisoning is still a globally significant cause of illness and death. In the United States alone, according to the Center for Disease Control, it causes 76 million illnesses, 325,000 hospitalizations and 5,000 deaths a year.

Pennington believes that, in our quest for the "clean" and "organic," we risk forgetting that chemistry has saved millions of lives. He says: "Unless there is robust scientific evidence for reducing or removing traditional preservatives, I think we should leave them alone."

Food that never reaches our plates

Unaffordable loss Roughly one-third of the food produced globally for human consumption is lost or wasted every year, according the Food and Agricultural Organization of the U.N. (FAO) – waste we cannot afford. How does it happen?

Which food groups go to waste most globally?

20% of oil seeds, meat and dairy

40–50% of root crops, fruits and vegetables

35% of fish

30% of cereals

At which stage in the value chain is food lost or wasted?

Developing countries **40 percent** of losses occur at post-harvest and processing.

Industrialized countries Over **40 percent** of losses happen at retail and consumer level.

Annual consumer food waste per capita varies from region to region.

Europe and North America

Sub-Saharan Africa, South and Southeast Asia

6–11 kilograms

Photos: Adobe Stock, Getty Images

How nature preserves

The inhibitors Fresh for longer – the powers of perservation that nature provides.

At some point after it has been harvested or produced, nearly all food starts degrading. Exposure to air starts the process of oxidation, or microorganisms begin to grow causing food to spoil and, in some cases, become poisonous. Preventing these processes or slowing them down keeps food fresh and safe for longer. Nature provides several ways of doing this that humans have adopted and adapted.

From fermentation to preservation

Propionic acid is a natural by-product of digestion. Cows and even humans produce it in their digestive tracts. The manufactured version is used to prevent the formation of mold in feed grain and silage. Transformed into its calcium salt it also helps keep packed bread fresh. BASF is the world's leading producer of propionic acid.

Vitamin E

The great antioxidant

Found in wheatgerm oil, egg yolk, and leafy vegetables, vitamin E is a fat-soluble chemical with antioxidant properties. It extends the shelf life of many foods, like baked goods and dairy products, as well as fish, vegetable and citrus oils, by preventing oxidation. BASF is the world's original supplier of natural Vitamin E and mixed tocopherols, under the product name Covi-Ox®.

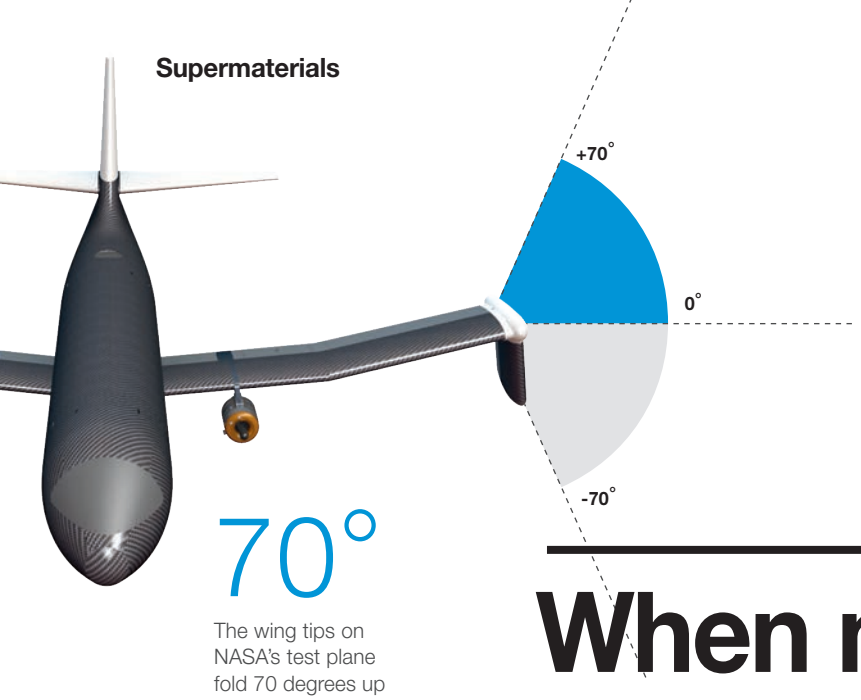
An antibacterial agent

Ants spray acid to ward off their enemies and anaesthetize their prey. Known as formic acid, after the Latin name for ant, formica, it is a natural preservative and antibacterial agent. The English naturalist John Ray first distilled formic acid in 1671 by heating dead ants in a flask. Today, it is manufactured industrially from carbon monoxide and water as a preservative for the animal feed industries. The world's biggest producers of formic acid are still the ants, but in the human world, it's BASF.

The secret of eternal life?

Honey not only has a seemingly eternal shelf life, it can also be used to preserve other foods and organic matter. The ancient Egyptians used it to preserve precious seeds, as well as to embalm the bodies of their dead. Archeologists recently found 4,000-year-old berries and nuts preserved in honey in a grave site in Georgia. The preservative effect is believed to be not just because of the high concentration of sugar, which is antibacterial, but also because of the natural antibiotic substances found in honey.

Photos: Getty Images



70°

The wing tips on NASA's test plane fold 70 degrees up and down in flight without heavy hydraulic systems.

When materials think, too

Intelligent products Materials are becoming ever smarter. Researchers are working on enabling them to react to their environment in a similar way to living organisms. A glimpse at self-organizing material structures.

Fly like a bird

Self-folding

Aeronautical engineers have long sought to imitate the aerodynamics of birds. But whereas birds' wings change shape fluidly to the perfect form for different flight conditions, airplane wings are rigid structures whose shape can only be changed by opening slats and flaps. These are activated by hydraulic mechanisms that are heavy and bulky. Getting rid of them would make aircraft lighter and more fuel-efficient. With shape memory alloys (SMA) in the wings, this may be possible. An SMA, or smart metal, is an alloy that "remembers" and springs back to its original shape when triggered by a stimulus such as heat or electricity. Embedded in the wings, it can be activated to alter their shape inflight. NASA, Boeing and Airbus are working with researchers to test the idea, with the aim of creating wings that bend as smoothly as a bird's, making the most of air conditions at every stage of flight.

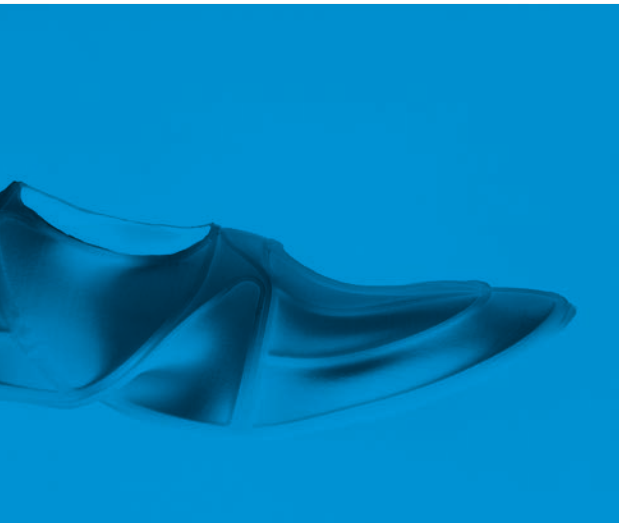
bit.ly/foldingwings

No more cracked screens

Self-healing

Self-healing like skin and as hard as tooth enamel – cell phone displays will in the future repair their own damage along the lines of these models from nature, that is the vision of researchers from the Harbin Institute of Technology in China. Researchers worldwide are working on such self-healing coatings, but the solutions developed so far are relatively soft and can therefore be used only on a limited scale. The team around researcher Xiadong Qi now promises to make a hard surface smart. To do this, they first applied a soft plastic to a base and coated that layer with another plastic. This coating contains graphene oxide, which provides the necessary hardness and strength. If the surface is damaged, the crack is refilled by the movement of the soft polymer layer, helped by humidity. However, this new material from the Chinese researchers is not yet transparent enough to be used in display screens.

Photos: NASA, Shutterstock+Google Pixel, Active Shoes MIT, BASF



10%

more effective
Cooling with the BASF superabsorber fleece can boost the body's performance in hot weather by up to 10 percent.

3D printed shoes

Self-forming

It can take more than 200 process steps to make a pair of shoes – and they still don't always fit perfectly. Inspired by the tradition of craftsmanship combined with a desire to change and challenge the processes and materials used, product designers Christophe Guberan and Carlo Clopath have taken a new approach to shoemaking. Together with Skylar Tibbits at MIT's Self Assembly Lab in Cambridge, USA, they have developed a production method that reduces the complexity and results in a pair of shoes that is self-forming and adaptive. A 3D printer extrudes a line of plastic on a stretched fabric in a precise pattern that varies in thickness. When the fabric is cut and released from its stretched position, the two-dimensional pattern "jumps" into the pre-programmed three-dimensional shape of the shoe upper – a geometrically complex shape that is both flexible and stable.

christopheguberan.ch

Ready-to-wear air conditioning

Self-cooling

When we exert ourselves physically, we need around 75 percent of the energy just to protect ourselves against overheating. This is where Luquafleece® from BASF comes in. This innovative material can be used as an inner layer for functional clothing for sports, work or the medical sector. Water molecules are absorbed directly into the three-dimensional superabsorber fleece. With this network of macromolecules, the material can take in 20 times its weight in water and retain it so firmly that the functional textiles stay dry on the outside. When it becomes warm, the water evaporates, thereby cooling the body. The higher the ambient temperature and exertion, the greater the effect.

on.basf.com/luquafleece

Let there be light

It boosts performance, brightens the mood, and even has healing powers – in correct doses, daylight is astonishingly good for humans. Experts from a wide range of fields are lighting up the darkness and building on nature as they do so.

Daylight can save lives – this is the conclusion of researchers who observed female patients in the intensive care unit of a hospital in Alberta, Canada. Those who were in a sun-drenched room survived a heart attack much more often than their fellow patients in dark rooms – and they also recovered more quickly. Admittedly, this is just one piece of the jigsaw, but the knowledge assembled over time does, bit by bit, form a consistent picture – which is that natural light has a positive effect on health and well-being. As far back as 125 years ago, Scandinavian physician Niels Ryberg Finsen treated diseases including smallpox with daylight, and this earned him the Nobel Prize for Medicine. Today, the researcher and professor of architecture Mariana Figueiro from the United States is using her light table to add to the body of knowledge. The rectangle radiating light into the room is slightly reminiscent of an oversized smartphone lying on four gleaming metal legs. In a retirement home, its glow helped Alzheimer's patients sitting at it to become calmer, sleep better, and be less depressed.

Figueiro observes the positive effects of daylight in environments where most confounding factors are controllable, such as hospitals or retirement homes. This is much more complicated in an office environment, yet she is seeing positive results even there. "Our studies show that office workers who receive a higher amount of daylight have better sleep, and lower levels of depression and stress, than those who spend their days in bad lighting conditions," says Figueiro, who conducts research at Rensselaer Polytechnic Institute in New York. It is, however, more difficult to prove the link between increased light exposure and improved performance, she adds.

"Today, we have the technological tools for unlocking the many effects of light," Figueiro says, adding that it is unfortunate that this resource is still so little used. According to Hamburg-based light planner and engineer Professor Peter Andres, "light is a basic foodstuff." At BASF, expertise on the subjects of light and energy in various specialist areas is pulled together by the architect Cristobal Garrido. Smart Daylight Management is the name of his project, similar to a startup, which is developing solutions to find the best way of managing daylight. "Thanks to new discoveries, architecture is on the threshold of a new era in light," Garrido says. "It means that we can at last put the focus on people, and no longer on buildings."

Lighting according to biorhythm

There are three letters that are electrifying the widest possible range of lighting experts – HCL. This acronym stands for human-centric lighting – meaning lighting that is geared to the needs of the human biorhythm. There are also three factors that could help the global HCL trend make its breakthrough. The first is the discovery by American neurologists who found a receptor in the eye that is not there for seeing but controls a human's internal clock. This is a discovery on which researchers such as Figueiro are building – and through which they are constantly finding fresh knowledge. Second, building designers have for a long time now had the efficient management of energy by using natural resources such as daylight on their agenda. Finally, a more recent innovation is now making it possible to put these discoveries to practical effect – light-emitting diodes, or LEDs for short. These are now so far advanced that, even

Lighting concepts then and now

In both ancient and modern times, architects have always had a special relationship with light.

Egyptian miracle of the sun
The ancient Egyptians planned the rock temple at Abu Simbel so that the sun's rays would penetrate it only twice a year, for about 20 minutes. Only at the time of this miracle of the sun does light fall on three statues of gods from the 13th century BC.

Gothic light
To make church buildings transparent for the divine wisdom – this is the idea at the heart of the Gothic cathedrals of the Middle Ages. The light entering the interior through large, stained-glass windows was intended to give believers a sense of a higher reality.

Artificial lighting
Electric light was used to illuminate architecture in a big way for the first time at the 1900 Exposition Universelle in Paris, France. The Eiffel Tower was bathed in artificial light and was visible over a wide area. From then on, new building shapes that did not have to be dictated by daylight became possible.

Photos: Serge Najjar, Getty Images

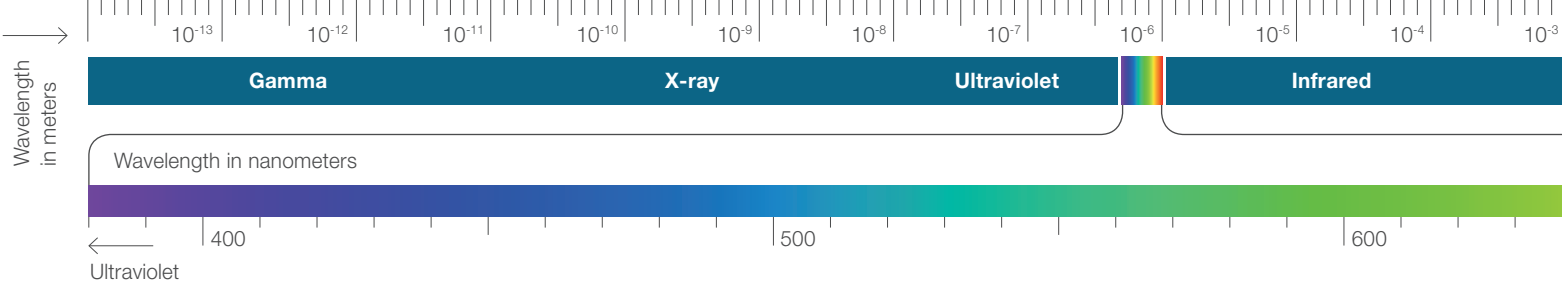
Since its reopening in 2014, a skylight dome made of steel and glass has arched over the Fulton Street train station in New York, USA.

"Architecture is on the threshold of a new era in light."

Cristobal Garrido
Expert on smart daylight management in buildings, BASF

where there is a lack of sunlight, indoor spaces can be illuminated in a manner identical to natural light. This HCL-supporting technology could receive an additional boost from the fact that many old lamps and light fixtures have now reached the end of their natural life and need to be replaced. "Especially in public buildings, there is now often pressure to get the lighting refitted," observes Andres, who is bringing bright light to Hamburg Airport or the entrance areas of the Alte Pinakothek art gallery in Munich, Germany.

At the same time, light planning that is geared to human needs is no mere aesthetically pleasing feel-good project, as large residential and office buildings are now competing worldwide for investors. "Everyone wants to be out in front here," says Garrido. This means that he and his competitors are increasingly preoccupied by human criteria. For example, do workers feel comfortable in these buildings? Is the design contributing to their productivity? A qualified architect, Garrido has little faith, aesthetically, in past solutions for bringing daylight into buildings. "They were violent interventions that either destroyed façades or limited the creative freedom of architects," he says. ▶



Light – what is it?

A look at the spectrum of visible light, adjacent wavelengths, and how light affects us.

Light is the part of electromagnetic radiation that we can see with our eyes. The visible part of daylight consists of waves with a length between 380 and 780 nanometers. In addition to this, there is the invisible ultraviolet (UV) region (100 to 380 nanometers).

UV light stimulates the formation of vitamin D, which is important for the bones, but too much of it can be harmful to the skin. The infrared light region between 780 and 1,000 nanometers, which is also invisible, is perceived by humans as heat.

Rather than take a sledgehammer to the problem, Garrido and his BASF team are now developing finely tuned, modular light management solutions that can both be fitted on a small scale into existing buildings and installed as a complete system in new structures. The first element here is a special film on the façade with millions of tiny mirrors, and researchers like André Kostro, PhD, are now working on the best angle of inclination for these. The film needs to direct as much solar radiation as possible into the interior of a building through a light shaft. This is challenging because, on the one hand, it is essential to lose as little natural light as possible in the process, but on the other, the sky changes regularly. "With regard to the amount of light coming in, every year and every day – and even every hour – is different," says Kostro, innovation researcher at BASF. So, too, is every building, which is why the BASF team and the Austrian lighting specialists from the company Bartenbach have calculated together how thousands of parameters – from room height to area and construction materials – affect how the system functions. The researchers are now planning to take two to six different combinations of film and match them to varying spatial and geographical conditions ranging from north Sweden to South Africa.

Mirror, mirror – in the film

Reflective film is also used on the light tubes, which direct the rays of light from outside into the depths of the building. This natural light is absorbed by what are known as luminaires, light fixtures on the ceiling, and directed into areas that are far away from windows. They are framed by LEDs that step in if there is not enough natural light. BASF's Smart Daylight Management is intended to work with a sophisticated measuring system that is capable of learning, stores people's individual lighting preferences and needs, and responds according to the situation.

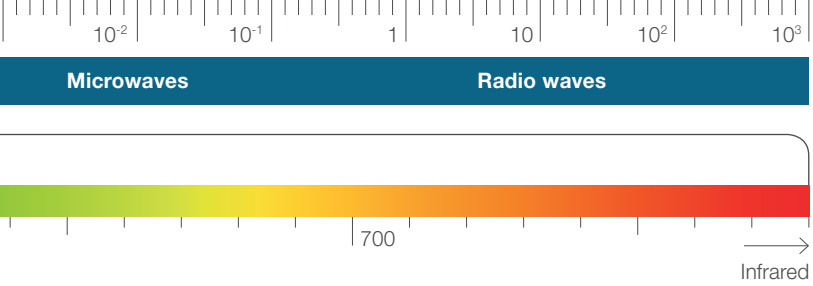
"Light is a basic foodstuff."

Professor Peter Andres
Light planner, Hamburg, Germany

Is this a dream of the future? Not at all. Researcher Figueiro is already experimenting with a sensor wristband that measures how much daylight the wearer receives over the course of a day – and what effect this has on their well-being. One astonishing result is that, although office workers were working in areas with light levels that meet accepted standards and recommended light levels, they were not receiving enough light to stimulate their circadian system during the day. "In such cases, a personalized sensor could be helpful," she says. "It would communicate with the lighting system at home, which would then make up for that shortfall."

However, according to Figueiro, what does not work is trying to compensate for the morning deficit by topping up with evening rays. "Light that has a stimulant effect in the morning could significantly delay sleep in

Photos: Getty Images



A receptor in the eye discovered only a few years ago reacts specifically to brightness and the blue part of light. In response to such "blue light," the hypothalamus – a control center in the brain – starts up and suppresses the secretion of the hormone melatonin, which controls the day/night rhythm.

Left: **With its glass fronts stretching up to the ceiling, Hamburg Airport, Germany, is truly full of daylight.**

Right: **Abstract light lines pervade the Pinakothek der Moderne art gallery in Munich, Germany.**

Photos: Getty Images

the evening," the scientist explains. For this reason, she advises against using tablets and smartphones shortly before going to bed. "Good light planning replicates the natural daylight rhythm and supplements it where necessary. It does not manipulate," Andres says. If you subject school students to a massive light shower when they become tired, for example, you are engaging in light doping, he says. "It is roughly the same as putting espresso in children's school milk." That is unacceptable, of course. "Rather," Garrido adds, "smart light management means using the natural day/night cycle as our model." ■

Three places that direct light intelligently

Smart mirror technology illuminates historic edifices, ultramodern building complexes and entire villages.

Beacon for democracy
It was the British star architect Sir Norman Foster who conceived the cupola of the Reichstag in Berlin, Germany, as a "beacon for democracy." Within the steel and glass structure there is a funnel-shaped light-reflecting element. Thirty rows, each containing 12 mirrors, direct the diffuse daylight into the plenary chamber 10 meters below. A computerized control system adjusts the amount of light coming in through the glass windows according to the time of day and season.

Communicating mirrors bring illumination
A rectangular, reflecting structural element extends to a length of 42 meters from the 28th floor of the One Central Park high-rise complex in Sydney, Australia. At first glance, this cantilever, as it is known, overshadows the adjadent building. On closer examination, it can be seen that the two towers are communicating with each other by means of mirror elements. Motorized mirrors are positioned on the roof of the lower building, and these direct the sun's rays to the cantilever according to the angle of incidence. From there, light is channeled to the business center below, the communal areas and the pool terrace.

Heliostats lighten the darkness
Until five years ago, the small Norwegian town of Rjukan led a life in the shadows. From October through March, this settlement, which lies in a narrow valley, was almost cut off from direct light. Relief is now coming from three heliostats installed on a mountain overlooking the town. Digitally controlled mirrors following the sun's path during the six months of winter direct its rays down to the 600-square-meter marketplace. The sun's energy is also used to operate the machinery: solar cells provide the electricity to steer and automatically clean the mirrors.

Products with a twist

Design Everybody has bags made from leather – but what about wood? A global look at objects that are composed of unusual materials.

NEW YORK, USA

1. Luminous mushrooms

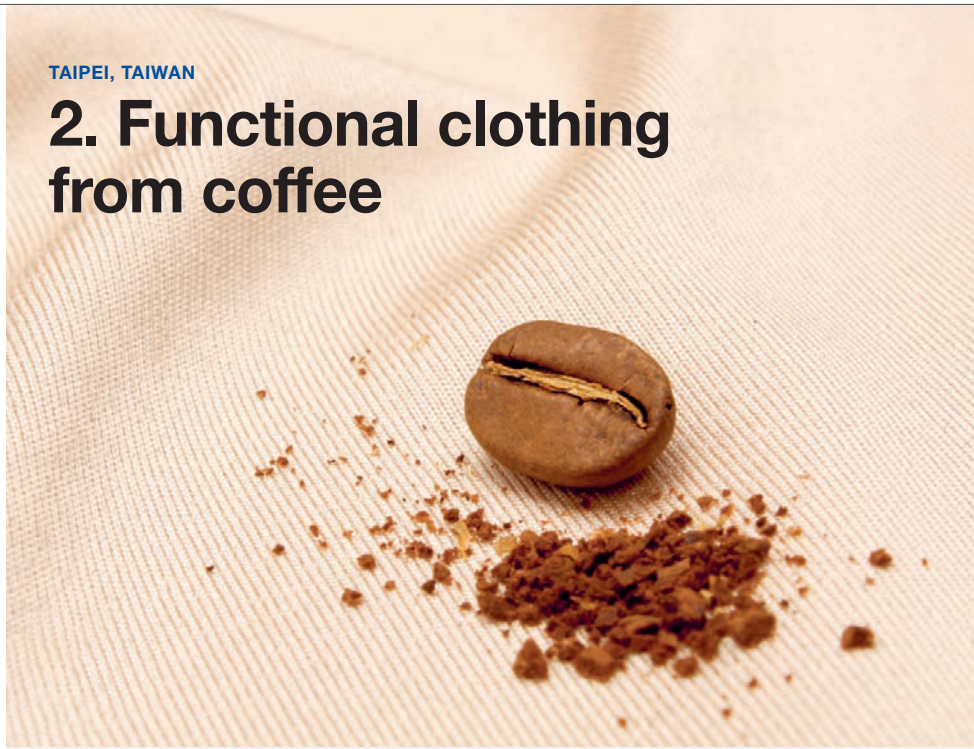
Product

Fungi in your apartment? Normally something unwelcome, but not for New York designer Danielle Trofe. She grows them as lampshades. To make them, she mixes liquid fungus mycelium with agricultural waste products such as the husks of grain kernels and corn stalks. As the mushroom grows in special molds, it binds with the stabilizing biomaterial. This takes just a few days, and then the material can be heated and dried so that the mushroom does not sprout any more spores. Finally, it is coated with milk-based paint, and the organic mushroom lampshade – called the Mush Lume – is ready.

danielletrofe.com

TAIPEI, TAIWAN

2. Functional clothing from coffee



Product

In the Taiwanese capital Taipei, coffee grounds from Starbucks or the 7-Eleven chain are no longer put out as waste but go to the textiles company Singtex. There, they make sports and leisure clothing from the grounds, which are crushed and mixed with recycled polyester fibers from old plastic bottles. The material made from coffee is odor-reducing and quick-drying, and offers protection against UV light. Singtex supplies it to brand-name manufacturers such as Hugo Boss, The North Face and Nike.

scafefabrics.com

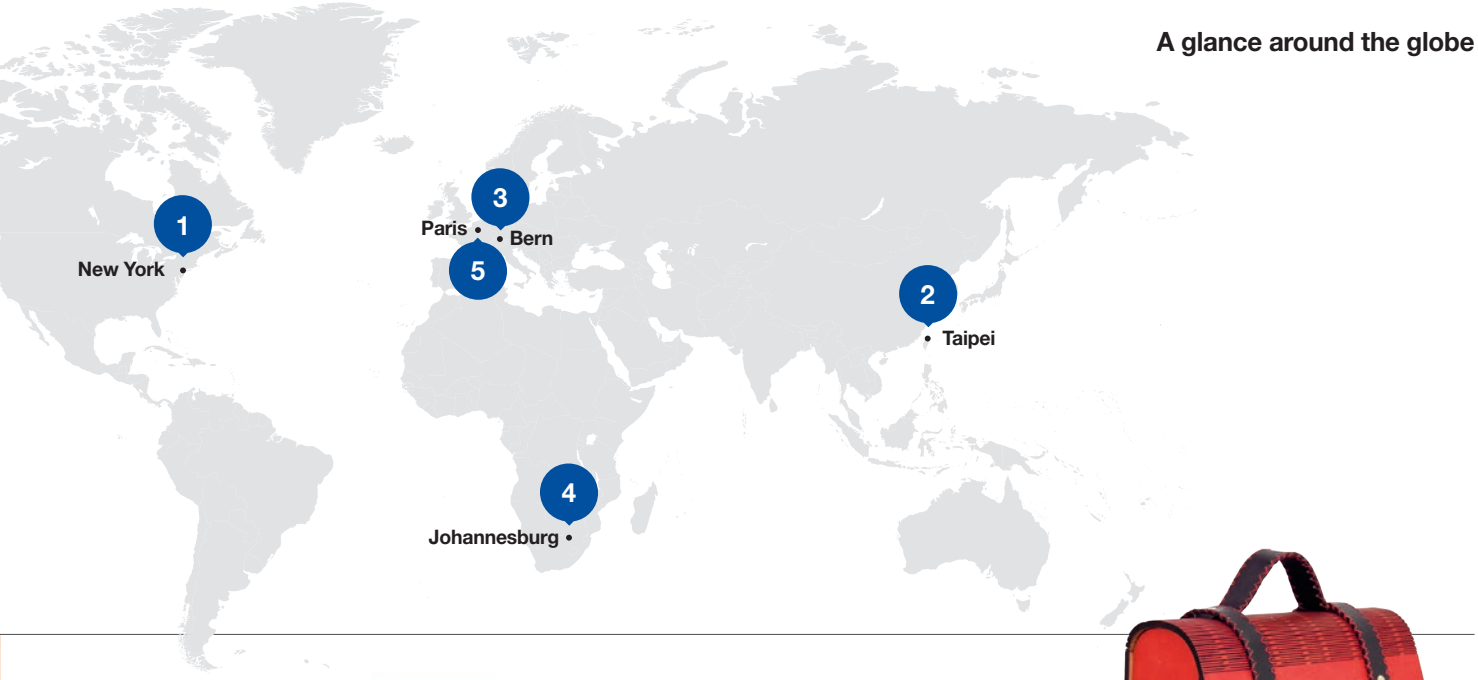
500

kilograms

of coffee grounds a day are not thrown out as waste but go into the textiles of the S.Café® line.

The waste from three cups of coffee and five plastic bottles produces one T-shirt.

Photos: JAM Editions/Danielle Trofe, SINGTEX® INDUSTRIAL CO., LTD.



BERN, SWITZERLAND

3. Castor oil stabilizes watches

Product

Almost everybody recognizes it and quite a lot of people wear it on their wrist – the Swiss Railways clock, whose iconic design has been offered in a smaller size by the watch maker Mondaine since the 1980s. The new range of this timeless model was developed in collaboration with BASF's designfabrik®. Mondaine uses renewable raw materials in this process. In the essence range, the watch case is composed of the high-grade polyamide Ultramid® S Balance, more than 40 percent of which is made by BASF from castor oil. It is being used in watches for the first time, but it can already be found in items such as the quick couplings of fuel lines of vehicles.

designfabrik.basf.de

JOHANNESBURG, SOUTH AFRICA

4. Wooden designer bags

Product

Bags come in every shape and color under the sun. In such a saturated market, it's hard to imagine anything new. However, the designers at Indalo in South Africa have found a novel approach with a range of bags made of a highly sustainable material – wood. At the studio in Tembisa, Johannesburg, backpacks, clutches, purses and cardholders are laser cut out of medium-density fiberboard made from hardwood and softwood off-cuts, then finished with dyed leather straps and ethnic patterns and prints.

indalodecor.com

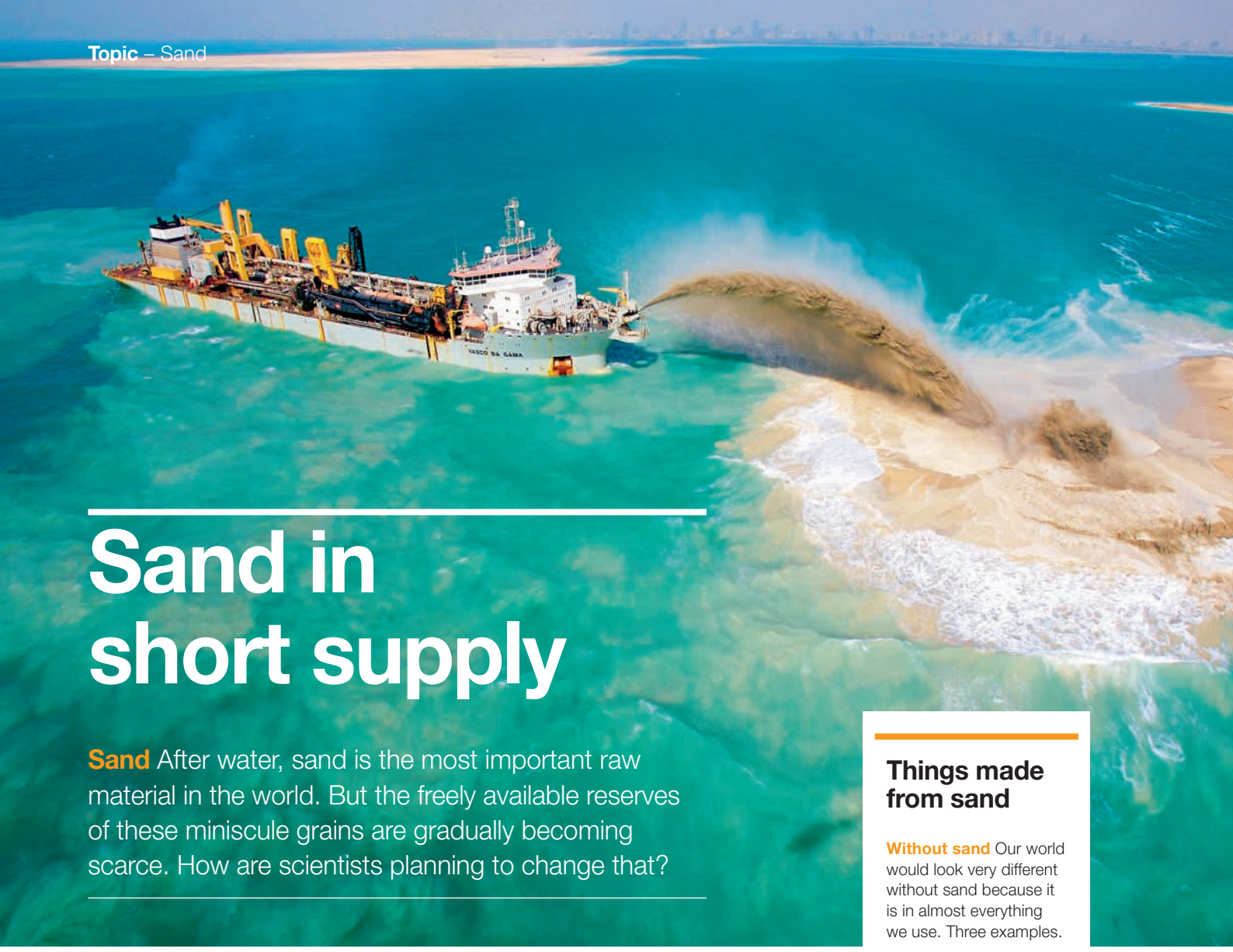
PARIS, FRANCE

5. Silkworm cocoons for organic shapes

Concept Inspired from an early age by the creativity of insects, French experimental designer Marlène Huissoud uses their by-products, such as silk cocoons, as materials in her work. Silk cocoons have traditionally been used in Asia as a beauty treatment. Dipped in water, they release sericin, a substance that helps keep skin hydrated. For this piece, Huissoud made a water container, a cocoon container and a stool out of hundreds of silk cocoons. The organic shapes were then cast in bronze to create permanent objects.

marlene-huissoud.com

Photos: Mondaine Watch Ltd. Switzerland, Indalo decor, Studio Marlène Huissoud



Sand in short supply

Sand After water, sand is the most important raw material in the world. But the freely available reserves of these miniscule grains are gradually becoming scarce. How are scientists planning to change that?

Our daily lives are built on sand. Literally. You can find it almost everywhere: in glass, toothpaste, hairspray, and even in aircraft engines and microchips. And, of course, in concrete. A report by the United Nations Environment Programme (UNEP) found that no solid raw material is used more than sand and gravel. But these fine grains are in short supply. "It's not so easy to find good-quality sand anymore," says Professor Dietmar Stephan, Head of the Department of Building Materials and Construction Chemistry at TU Berlin, Germany. This is primarily due to the construction boom. "When it comes to concrete production, roughly 3 metric tons of sand are needed to make 1 metric ton of cement," explains Stephan. In 2014, the UNEP estimated that between 26 and 30 billion metric tons of sand are poured into cement mixers every year worldwide.

Since then, these numbers will have only increased. The demand for this raw material in expanding metropolises such as Singapore, Shanghai, or Dubai is always growing. Mega construction projects in these cities are already devouring vast quantities of sand, as we see with the numerous major projects in Dubai. The raw material is not only needed to erect huge skyscrapers like the Burj Khalifa. The foundation for Dubai's Palm Jumeirah artificial island in the Persian Gulf is also formed from a massive deposit of these fine grains. According to media reports, more than 150 million tons of sand were delivered from Australia.

Desert countries rely on sand imports

Meanwhile, the sand from the surrounding deserts remained untouched. "Desert sand simply cannot be used as a building material," says Oliver Mazanec, head of Product Management at BASF Construction Solutions. The wind sweeps it up and blows

Things made from sand

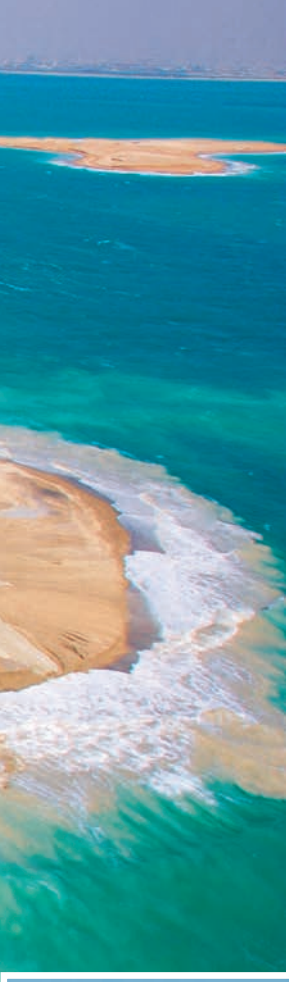
Without sand Our world would look very different without sand because it is in almost everything we use. Three examples.

Glass is over 70 percent quartz sand, which is melted at around 1,500 degrees Celsius to produce glass.

Microchips Cell phones wouldn't work without quartz sand. Quartz sand has a high silicon content and acts as a starting material in semiconductor production.

Toothpaste As a microparticle, sand is an important raw material in the cosmetics industry. It can be found in many shower gels, toothpastes and exfoliants. Sand acts as a mechanical cleaning agent.

Photo: Alamy Stock Photo



Left: **Coveted resource: It took huge quantities of imported sand to create the construction ground for the artificial island The Palm Jumeirah in Dubai, UAE.**

Above: **An almost endless amount of sand can be found in the desert, but it is useless for construction.**

Left: **Around 30 billion metric tons of sand are shoveled into cement mixers around the world every year – and this amount is set to increase.**

it away. The grains become small, smooth, and uniform. The result: "The grains of sand do not mesh and cavities form in the fresh concrete. This significantly increases the amount of water needed when mixing cement, which adversely affects the strength of the concrete."

Extremely rough edges are required for construction work. But this type of sand can only be found in quarries, riverbeds, and the ocean – with negative consequences for the environment. According to UNEP estimates, three out of four beaches could simply vanish in the future. This is due to the raw material being mined directly on beaches, which is often illegal, and because beaches are slipping as sand is being drawn off the seabed. Entire islands in Indonesia, for example, have already fallen victim to this phenomenon. The power of the waves also makes sure that sand drifts away. But there are also shortages inland. Easily accessible deposits of high-silicon quartz sand are slowly being depleted.

"The amount of affordable sand is drastically decreasing."

Professor Dietmar Stephan
Head of Building Materials and Construction Chemistry, TU Berlin, Germany

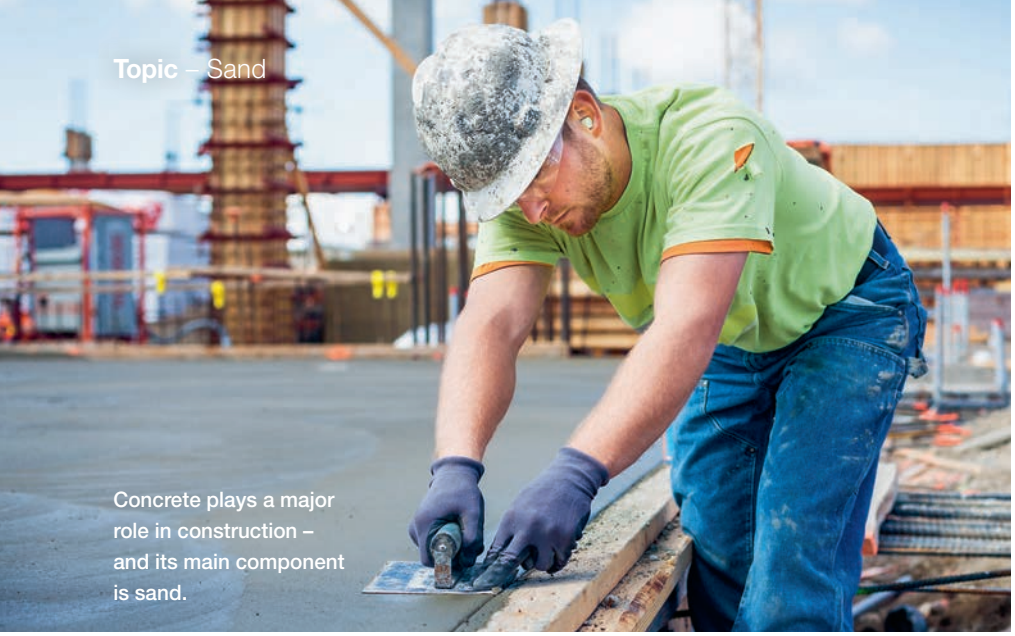
Looking for alternatives

This shortage has made sand a scientific priority. We are now looking for ways to make better use of the resources. One of these methods has been in use since 2016: a process developed by BASF to convert sand that was previously unsuitable for high-quality concrete into a valuable raw material.

This involves using clayey sand or sand with a high proportion of ultra-fine additives, such as mica. Clay and mica absorb large amounts of water due to their large surface area and their special, partially expandable structure – they also absorb the superplasticizer needed for concrete mixing. This has unwanted consequences: the concrete cannot be processed. "The MasterSuna sand blocker from BASF improves the properties of these challenging sands. It ensures that water and superplasticizer are not absorbed by the sand, and instead the concrete is generously liquefied," says Mazanec. Sands that were previously unsuitable can now be used, and existing deposits can be more intensively exploited. This new admixture is currently available in France, Spain, Germany, the United Kingdom and Australia. These countries are particularly affected by sand contaminated with clay.

Laboratories around the world are also looking into ways to exploit the abundance of fine desert sand. One idea, for ▶

Photos: Getty Images



Concrete plays a major role in construction – and its main component is sand.

Building material of the future: Recycled concrete is made using ground-down building rubble, meaning no precious sand is required.

example, is to enrich it with fly ash, so the cement adheres to the finely ground sand grains more effectively during concrete mixing. Another idea is to use plastics, such as polyester resins from crude oil, as a binder instead of cement. “This basically resolves the issue, but it isn’t feasible on a large scale. Or isn’t a permanent solution, as with the fly ash. This is because it involves coal combustion, which will be an increasingly rare method of power generation in the future,” says building materials expert Stephan.

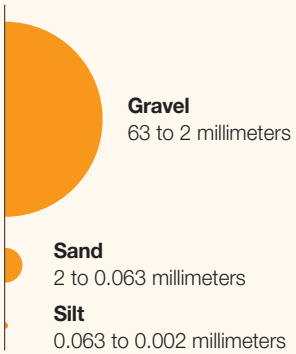
A far more promising solution than desert sand is old concrete. If building rubble is pollutant-free, it can be recycled relatively effectively in a process involving separation, shredding, and fine grinding. This mineral rubble sand needs to contain at least 25 percent concrete to bear the label “recycled concrete.” To date, recycled concrete has primarily been used to form sublayers in road construction. Recycled concrete is still the exception when it comes to house construction. “It’s technically feasible, but its success will be determined by price,” Stephan says. The price is generally higher, although it fluctuates considerably from region to region. And because rubble sand does not have the same ideal grain size as fresh sand, it is more difficult to process. According to the building materials expert, rubble sand accounts for less than 1 percent of concrete in new buildings. “But the amount of affordable sand is decreasing so drastically that the outlay required for recycling will probably be less expensive than for the raw material at some point in the future. More research could also speed this up,” Stephan says.

Switzerland and the Netherlands have already been rethinking the matter. These two countries are considered pioneers in recycled concrete. For example, new public buildings in Zurich are no longer being built without recycled building materials. Stephan is convinced that “recycled concrete is one of the building materials of the future.” ■

Explain-it video: 5 things you didn’t know about sand
on.basf.com/5sandfacts

Size matters

Sand and gravel are among the most important resources in the world. Diameter is one of the key factors used to differentiate them.



Gravel
63 to 2 millimeters

Sand
2 to 0.063 millimeters

Silt
0.063 to 0.002 millimeters

Gravel An accumulation of rounded small stones in rivers or streams. Together with sand, gravel is one of the most important raw materials for the construction industry – for use in concrete, for example.

Sand Most sand is not produced from ground-up shells in the ocean. It is far more common for it to be formed from stones that have been weathered and eroded over thousands of years, and transported to the ocean via rivers. Sand primarily consists of quartz, a compound of silicon and oxygen. Quartz appears in such large quantities in sand because it occurs very frequently in the earth – specifically in the earth’s crust. Being very resistant, quartz also withstands erosion well. It is harder than steel.

Silt This soil, which is defined only by its grain size (between sand and clay), is very rarely found in its pure form in nature. In most cases, it appears mixed in with sand and/or clay – and in this form it is known to us as mud.

Photos: Getty Images; Graphic: ASCS

Is banning plastic a good thing?

Two perspectives Almost 80 percent of the plastic waste ever produced now lies in landfills and dumps or is littered in the environment. To combat this, more than 60 countries have introduced bans or levies on single-use plastic products. But are such actions an effective response? We ask two experts: Erik Solheim and Professor Richard Thompson.

Professor Richard Thompson

is a marine biologist and Head of the International Marine Litter Research Unit at the University of Plymouth, England. He has contributed to the government legislation of the United Kingdom on single-use carrier bags and the use of microbeads in cosmetics, and given evidence to parliamentary inquiries on the issue of plastic waste and pollution.

Erik Solheim

was the Executive Director of United Nations Environment from 2016 to 2018. He was previously chair of the Development Assistance Committee at the Organization for Economic Co-Operation and Development (OECD) and was Norway's Minister of the Environment and International Development from 2007 to 2012.

Erik Solheim is the former Executive Director of U.N. Environment, which campaigns for solutions to tackle plastic waste.

SINCE EARLY 2017, U.N. Environment has been campaigning to reduce the impact of plastic pollution. Its goal is to eliminate "the excessive, wasteful usage of single-use plastic." We asked former Executive Director Erik Solheim to explain why the organization is encouraging governments worldwide to consider banning or discouraging the use of single-use plastic items.

Creating Chemistry: Why does the world need to take more action to tackle plastic waste?

Solheim: Plastic pollution is one of the most pressing environmental issues of our time. It is not only harming plants and animals on land and at sea alike, but also hurting the economies of many coastal communities, while potentially also harming human health. It's also a symptom of a wider problem, which is the totally unsustainable and wasteful way in which so many of us live our lives.

Several countries have introduced bans or reduction targets on various plastic products. What is the main aim of these?

Solheim: It's a response to what has become a visible blight and a serious pollution issue. In many cases it's a response to public pressure, because many people are changing their thinking and behavior around single-use plastic. It's a message to the private sector to innovate and come up with design solutions or alternatives. It's also a recognition that in order to solve the problem of plastic pollution in the long term, it is imperative that we have clear policy leadership.

"In many cases we simply don't need single-use plastics, and they can be eliminated."

What environmental, economic and social changes have these efforts brought?

Solheim: Rwanda was one of the first countries in the world to ban plastic bags. The country is now spotless compared to many of its neighbors. I'm convinced that's one of the many factors that contributes to its success in attracting businesses and investors. In Kenya, which more recently introduced a

Photos: Duncan Moore/U.N. Environment

ban, slaughterhouses are no longer finding plastic bags in the stomachs of cows, and safari guides are happier because the national parks no longer look like landfills. In Nairobi, there was less urban flooding this year too – even though the rainy season was more intense. There were no plastic bags blocking drainage systems. These are gains for tourism, for business, for urban safety, and for public health.

What role can different stakeholders play in reducing plastic waste pollution?

Solheim: Every stakeholder has a role to play. Governments need to pass robust legislation that incentivizes both behavior change and innovation. Consumers should take steps to reduce their plastic footprints, and also use their voices and wallets to pressure retailers to do the same – for instance by eliminating unnecessary plastic packaging, of which there is clearly far too much. Both product manufacturers and material manufacturers need to take a life cycle approach when they design their products, and stop designing plastic items that are designed to be thrown away immediately after use. To help all these actors play a more effective role, the short answer is that they need to realize the severity of the problem and start acting accordingly. That would be a very important first step.

Would improving waste management contribute to solving the problem?

Solheim: Waste management needs to be improved, yes, especially in the developing world, and in the field of recycling and repurposing, but it's not the magic solution. Plastic waste is a pollution problem, and the polluter needs to change. I would also love to see the plastics industry facing up to the fact that if they really want to be a part of the solution, they need to get away from single-use plastics.

How far do alternatives to plastic help solve these challenges?

Solheim: In many cases we simply don't need single-use plastics, and they can be eliminated. In other cases, there are sustainable alternatives, including plastic products that can be reused. I am not against plastic. It's a miracle product. It's us who need to change how we use it and how we manage it throughout its life cycle.

Do you believe we can reduce the environmental impact of improperly discarded plastic waste in the near future?

Solheim: I am optimistic in general, and particularly when it comes to plastic pollution. There is so much happening already, and it is happening very fast. When a ban on smoking in bars and restaurants was first introduced in my home country of Norway, a lot of people said that this was insane, and that it was destined to fail. Now, this has become the norm. I think we are seeing the same kind of change in attitude when it comes to plastic pollution. ■

MARINE BIOLOGIST Professor Richard Thompson has studied the impact of plastic waste pollution for three decades. His work has been instrumental in revealing the prevalence of small plastic particles – microplastics – in the environment, and demonstrating their impact on animals and ecosystems. Thompson believes the world needs to take a smarter approach to the challenge of plastic waste.

Creating Chemistry: Should we stop making and using plastic products?

Thompson: Plastics are not the enemy. They bring many societal benefits and have the potential to reduce our footprint on the planet. The reason why global production of plastic has risen from 5 million tons per year in the 1950s to 300 million tons today is because plastic is durable, inexpensive, lightweight and versatile. The problem is that while our use of plastics has increased so much, our ability to manage those products at the end of their life has not kept pace.

Are plastic bans an effective way to reduce the impact of waste plastics on the environment? Are there any real success stories?

Thompson: No country has imposed a total ban on single-use plastics, but several have banned or restricted some items, like plastic carrier bags. The evidence for the effectiveness of those bans is not always available, but some places, such as Wales and Northern Ireland, have studied their impact. Their experience shows that while there is some substitution – for example, sales of dustbin bags increased – overall, consumption went down. There's also evidence from beach-cleaning that there are fewer plastic bags on beaches in these regions, although obviously it takes a while for those effects to emerge because of the persistence of plastics in the environment.

How should we tackle the problem? What kind of measures would you suggest?

Thompson: The important thing here is to think about different use cases. There are some single-use plastic items that we could manage without. Given what we now know about the effect of plastic, I think it is the responsibility of all us to say, If I don't need it, perhaps I should avoid it. But there are other cases where if you do the cost-benefit and environmental impact analyses properly, you find that plastic is the best material for the job. In those cases, our task is to make sure we are designing for circularity, and thinking about what is going to happen at the end of the product's life, and where that end-of-life is going to take place. ▶

“I don’t think plastic pollution is a problem that can be fixed with a single explosion of action.”

Professor Richard Thompson’s research explores the global distribution of plastic waste and its effects on biological systems.

Are new product design approaches and solutions in waste management part of the answer?

Thompson: We shouldn’t be holding out for technological miracles. It is unreasonable to expect packaging to be tough, long-lasting and effective at protecting its contents, then suddenly to disappear when you dispose of it in the environment. If you take compostable materials, for example, they have clear benefits, but only if you have the right application, and access to a waste stream that can accommodate them. If such materials just get mixed with the residual waste steam and end up in landfill, those benefits are lost. We need to consider end-of-life from the outset, when we start to design a product. Yet when I speak to product designers, they tell me time and again that end-of-life considerations are not part of their brief.

What other measures would you like to see implemented?

Thompson: I don’t think plastic pollution is a problem that can be fixed with a single explosion of action, and I do worry that now the public has a strong appetite for change, a knee-jerk reaction by policymakers or by industry could lead to uninformed decisions that have unintended consequences. There are measures that I think would certainly help, for example putting incentives in place to encourage manufacturers to incorporate a certain amount of recycled content into their products. But this is a complex problem that needs an interdisciplinary approach. We need to consider the impact of changes in the round, and that requires us to bring together materials sciences, environmental sciences and behavioral sciences to evaluate the evidence and set the best direction for change.

Do emerging economies need to take a different approach to plastic waste?

Thompson: Several countries in the Far East appear high up in the table of places that produce the most plastic pollution, but actually their per capita consumption of plastic is relatively low. The problem is that they have poor waste-management infrastructure. There are some cases where we are exporting products to developing countries knowing that those communities have no way of dealing with the resulting waste. We have a responsibility to think about how we can help with that. But, ultimately, everybody needs to move towards using plastics in a more circular way. The solutions different regions adopt will not all be the same. The challenge today is to help developing nations get on to that trajectory more quickly than we have done in Europe or North America.

Are you optimistic that we can solve this problem?

Thompson: The vast majority of the benefits that plastics provide could be achieved in a more circular way, without the generation of long-lasting waste, and certainly without the emission of litter to the environment. At the moment there is immense interest and passion about this topic from the public, from policy-makers and from industry. In 30 years working in this area, I’ve never seen all those interests so aligned before. For businesses, I believe there is a market opportunity in starting to use plastics responsibly, and a market disadvantage from continuing with business as usual.

Photos: Guy Martin

Viewpoint BASF

Responsible handling is key

Garbage-strewn beaches and plastic waste in the world's seas have become a symbol of environmental pollution and the throwaway society. There is agreement that urgent action is needed. However, we will not overcome this challenge by banning individual materials or specific applications. What we need are functioning waste-disposal systems and responsible, sustainable handling of waste.

BASF says clearly that there is no place for plastic waste in the environment. For this reason, we support social and political initiatives to address the challenges of plastic waste. However, bans or levies on the use of specific plastic products are not an effective way of stopping the inappropriate handling of waste or improving the infrastructure for its disposal.

Plastics are valuable materials offering countless benefits: They help increase energy efficiency, save resources and are easy to process. Many solutions in the health care sector are entirely dependent on modern plastics. Their price-performance ratio is nearly unbeatable, and they are also indispensable for all designers of modern products. For many applications, there are no equivalent substitutes that possess these advantages. Before a decision is taken to reduce the use of plastics for specific applications, there should always be a comprehensive analysis of the environmental, economic and social impact, taking account of the whole life cycle of the product. It often turns out that the properties of plastic make it the most sensible material, environmentally and economically – for example, in lightweight automotive construction or building insulation. At the end of their productive life, all plastics can be utilized again. They can be turned into new plastics or chemical raw materials and also be used as sources of energy.

The inappropriate handling of waste and the littering of the environment have nothing to do with a particular material. The first step in combating environmental pollution by waste is to ensure that this waste is collected as completely as possible and appropriately recycled. This requires coordinated action by many participants and includes, for example, the development of suitable waste-management systems and landfill bans for plastics and other recyclable waste, the provision of comprehensive consumer information and the consistent enforcement of anti-littering laws. Waste pollution is a global problem, but overcoming it requires tailored regional solutions.

As a member of the plastics supply chain, BASF provides important answers here. We offer a range of high-performance solutions designed to reduce the environmental impact of plastics, be it in their design, their field of utilization or their potential for recycling at the end of their productive life. We are an active participant in Operation Clean Sweep®. This initiative by the plastics industry aims to prevent unprocessed plastic pellet material ending up in the environment during transportation, for example. BASF also participates alongside other stakeholders in numerous projects and initiatives across value chains to develop better waste-management processes or contribute to raising consumer awareness on the issue of littering. BASF is also driving forward the chemical recycling of plastic waste that has not traditionally been recyclable, so that it can be used as a raw material in chemical production and thus be utilized again in new, high-quality products. ■

Klaus Wittstock, PhD
Head of Environmental Policy, BASF, Ludwigshafen, Germany

"Waste pollution is a global problem, but overcoming it requires tailored regional solutions."

Photo: BASF

Ordering the world

IUPAC
The International Union of Pure and Applied Chemistry (IUPAC) in Zurich, Switzerland, is the guardian of the periodic table. It officially recognizes newly discovered chemical elements and regulates their naming.

The United Nations has declared 2019 the International Year of the Periodic Table of Chemical Elements. It was 150 years ago that Dmitri Mendeleev documented the natural law of chemistry with his fundamental order of the elements – with far-reaching consequences to this day.

It is said anecdotally that the idea came to him in a dream. What is fact is that, 150 years ago, Dmitri Ivanovich Mendeleev brought order to the 63 chemical elements known at that time. The Russian chemist presented the periodic table on October 28, 1869. It sorted the chemical elements into a table in ascending order by the number of protons – positively charged subatomic particles – in their nucleus. The number of protons simultaneously also became the atomic number.

The periodic table is a chart that makes the world and the properties of its elements easier to understand. As a rule of thumb, the elements in each column of the table display similar properties. So far, 118 elements have been described. Most were discovered in the 19th century. Only 10 natural elements were still unknown at the beginning of the 20th century. Today, the main new entries are radioactive elements that do not normally occur naturally but are the result of artificially created nuclear fusion processes. The last four new entries to date came in 2016 with nihonium, moscovium, tennessine and oganesson (numbers 113, 115, 117 and 118).

Despite this, however, the foundations of the world are still far from complete. Scientists are in the process of discovering new, super-heavy elements, using particle accelerators that propel nuclei into each other so that they may fuse to form a new nucleus. This is intended to open up a new, eighth row in the periodic table. Researchers from Japan and the United States announced at the Symposium on Super-Heavy Elements in Poland at the end of 2017 that they were starting the search for elements number 119 and 120. They hope to have found them by 2022.

On the next page, we have compiled some more information about the elements in the periodic table to mark this 150th anniversary.

Mendelevium

In 1955, Dmitri Mendeleev also got his name into the periodic table. When scientists at the University of California in Berkeley, USA, first artificially created the transuranium element, they decided to name the radioactive element mendelevium in his honor. However, its half-life, at just 51.5 days, is only a fraction of the lifespan of the 150-year-old periodic table.

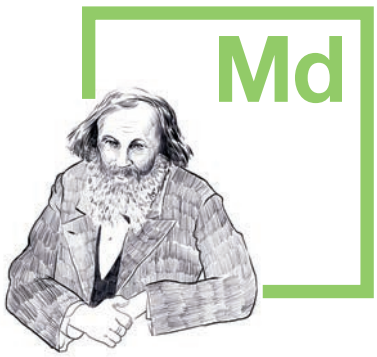


Illustration: Marcus Spiller (ASCS)

$27

million per gram Californium is the most expensive element. The price tag is explained by the high cost of production. Created in nuclear reactors and particle accelerators, it is a powerful neutron emitter that is used to detect oil or precious metals in inaccessible places.

6 **C**

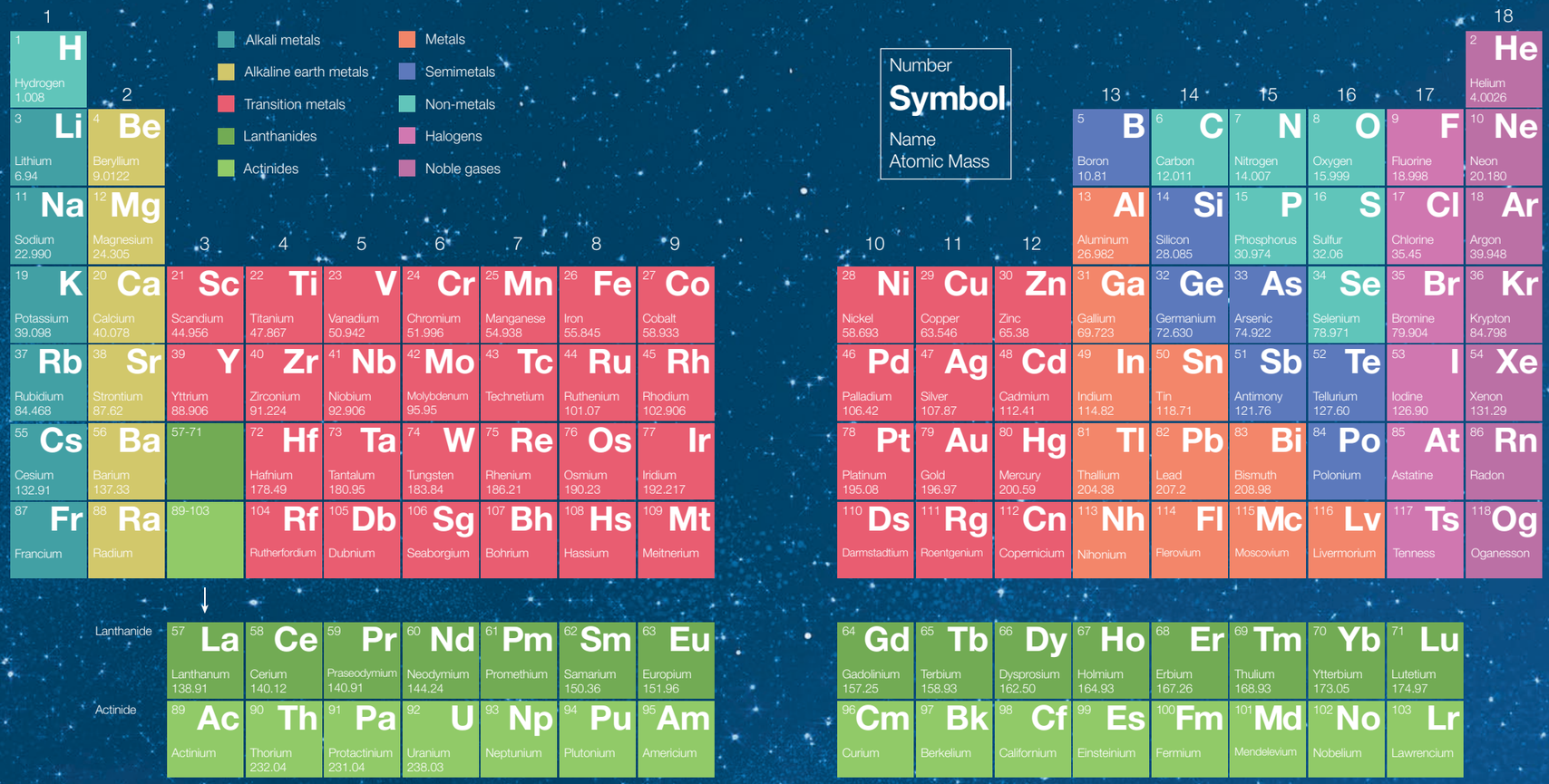
Carbon is the building block of life – every plant and animal contains it. But diamonds, charcoal, oil and graphite are also made of it. For BASF, carbon is an important element in the production of numerous products. The vast majority of carbon comes from fossil feedstock. In addition, renewable resources are also used as carbon sources in the existing Production Verbund, for example as part of the biomass balance approach.

Discovering elements

When the German alchemist Hennig Brand discovered phosphorus in 1669, he became the first person to isolate an element. His method involved evaporating urine and then heating the residue. Today, the hunt for element 119 requires smashing charged particles together at about 30,000 kilometers per second in the hope that their two nuclei fuse. To do this you need a linear particle accelerator and a small fortune.

Is that really it?

How do we know there are no more natural elements? Uranium, with 92 protons in its nucleus, is the last naturally occurring element in the table. The trouble with all the elements after uranium is that they have too many protons to be stable for any useful length of time. Their half-lives are just seconds or milliseconds. Heavier, unstable elements may exist elsewhere in the universe in more extreme environments, but here on earth they have to be produced by smashing atoms together.



3 **Li**

Lithium is a metal so light it can float on water. Lithium-ion batteries have a lot of power for little weight, which is useful for powering devices such as electric vehicles and laptops. But lithium can also be used as a psychiatric medication.

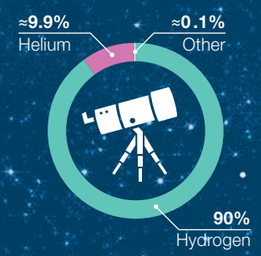
2 **He**

Helium, unlike all the other elements, was found on the sun before it was found on earth, which is why it was named after the Greek god of the sun. It is one of the noble gases, yet today you are most likely to come across it in a party balloon.

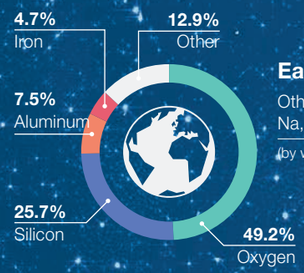
22.59

High density Osmium is the densest of the elements at 22.59 grams per cubic centimeter. Twice as dense as lead, it is used for fountain pen nibs and phonograph needles.

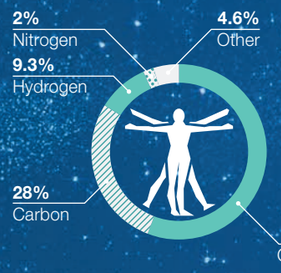
Occurrence of elements



Universe
Other: The remaining 116 elements are just a rounding factor in cosmic terms.



Earth's crust
Other: Mainly Ca, Na, K, Mg, H, Ti
(by weight)



Humans
Other: Mainly Ca, Cl, P, K, S
(by weight)

2019
150
years
of the periodic table

Around 490–430 BC
Empedocles of Acragas: Everything is composed of the four elements of fire, water, air and earth.

600 BC

700 BC

Around 624–545 BC
Thales of Miletus: Water is the original substance of which material is composed.

500 BC

400 BC ....

1700 It is thought that only the following 15 elements were known up to the 18th century: the metals iron, copper, lead, bismuth, arsenic, zinc, tin, antimony, platinum, silver, mercury and gold; and the non-metals carbon, sulfur and phosphorus.

1869
Mendeleev presents the periodic table.

1939 Francium is the last element to be discovered in nature.

2016 IUPAC approves the last new elements to date – those with the numbers 113, 115, 117 and 118. The new elements are super-heavy and extremely short-lived.

.... **1700**

1800

1900

2000

2050

1808 John Dalton publishes his atomic theory in "A New System of Chemical Philosophy." According to this, material is composed of atoms.

1850 About 45 percent of the elements known today were only discovered in the 19th century.

1937 Technetium, the first artificial element, is discovered.

1944 Curium and Americium are discovered. Both are highly radioactive.

BASF Digital

More content, interactive stories and additional information

Istanbul through the years

Istanbul is one of the fastest-growing cities in the world. In 1927, it had 680,000 inhabitants, today there are around 14.5 million. Pictures taken over that period show how the cityscape has changed with the passing decades.

on.basf.com/istanbul

Shanghai is exposed to flooding and high tides. The 360° video shows how the city is shaped by the power of water.

on.basf.com/shanghai360

Sand is everywhere, and yet it is a scarce resource. Why is this so, and what other characteristics make sand special?

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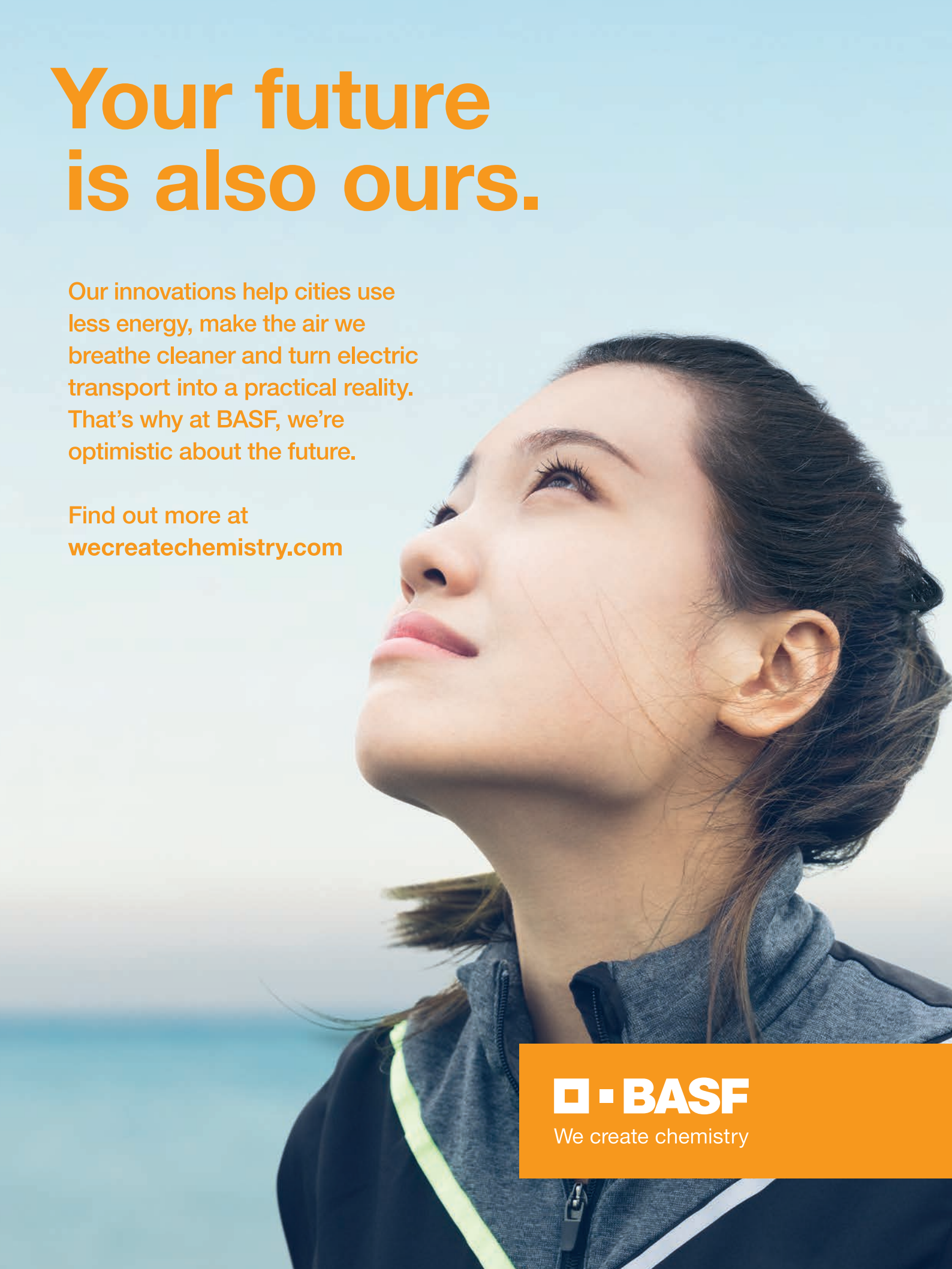

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