



We create chemistry

# Creating Chemistry

For a sustainable future

## Naturally good?

Searching for new bio-based raw materials for industry

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Free trade:  
Does it still matter?

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Outsmarting the fakers

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Issue six 2017

**“We need international cooperation to promote a circular economy.”**

Professor Du Huanzheng from China's renowned Tongji University explains why the new economic model will change our lifestyle.

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**Focus:**  
Bioeconomy  
and circular  
economy

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With a growing global population comes increasing demand for the products we use every day. In light of the Earth’s limited resources, meeting these needs sustainably will be a challenge we have to take on.

A helpful approach is the circular economy, which is gaining support worldwide. Circular economy is the idea of using products, materials and resources as often as possible, feeding them back into economic circulation. Goods are shared with other users and repaired, reused or recycled, rather than being thrown away. In the circular economy, growth is mainly made possible by the reuse of raw materials. For the past 150 years we have also been contributing to this with our BASF Verbund, which optimizes material and energy flows in our production system and prevents waste wherever possible.

Another part of the circular economy is the bioeconomy, the use of raw materials from renewable sources such as plants or bacteria. For several years, BASF has been conducting research on potential applications for renewable raw materials. These often enable us to produce substances and products with properties that are impossible or much more difficult to achieve with fossil-based resources. In detergents, for example, enzymes produced from fungi or bacteria can remove stubborn dirt, even in low-temperature and short washing cycles, thus saving energy and water.

As always, evaluating sustainability is also an important issue when it comes to the use of renewable raw materials. We have to determine on a case-by-case basis whether renewable or fossil-based resources are the better solution. Are they available and competitive? How do they rate in terms of land use and biodiversity?

We hope you find the latest issue of our magazine *Creating Chemistry* stimulating reading as it investigates these and many other interesting issues that affect us all.

Yours,

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

# The world in figures

**3** billion metric tons

is the **total mass of ozone** in the Earth's atmosphere.<sup>1</sup>

► "Maintaining a healthy flight environment" on page 58



It is forecast that the global **production capacity for bioplastics** will rise from 2,053,000 to 7,848,000 metric tons between 2016 and 2019. This is an increase of

**380**%<sup>2</sup>

► "Naturally good?" from page 6

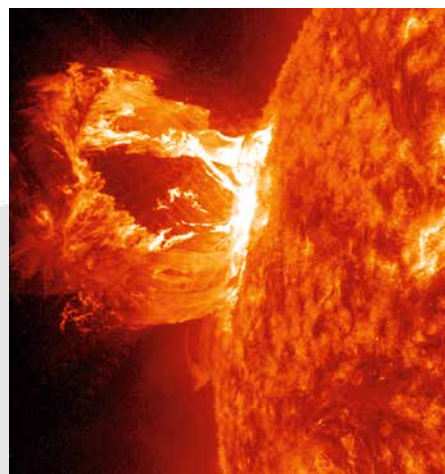


There are estimated to be more than

**30,000** types of apples

worldwide. But in all of them, three-quarters of the **healthy substances** they contain are found in or directly under the peel. These include easily digestible carbohydrates, vitamins and fiber.<sup>3</sup>

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In just over

**30** minutes

the **sun** radiates as much energy to the Earth as we use worldwide in one year.<sup>4</sup>

► "Storing sunshine" from page 46



# \$461 billion

is the estimated value of the annual global trade in **fake goods**.<sup>5</sup>

► “Keeping it real” from page 36

# 49%

Nearly half of world trade in goods and services took place **within global value chains** in 2011. The internationalization of production has led to increasingly global production networks, resulting in a geographically more diverse manufacturing base.<sup>6</sup>

► “Does free trade still matter?” from page 28

# 5 minutes

is all the time it takes to find a bike to rent in the city of Hangzhou, China. With over **84,000 public bicycles**, it is home to the world's largest bike-sharing program.<sup>7</sup>

► “Circular Economy” from page 20



Europeans consume

# 8–11 grams

of salt per day. But the World Health Organization recommends adults consume a maximum of **5 grams** per day.<sup>8</sup>

► “A very special compound” from page 52

- 1 National Aeronautics and Space Administration (NASA), *Ozone facts*
- 2 European Bioplastics, *Facts and Figures*, 2015
- 3 Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, *Hintergrund: Alte Sorten neu entdeckt*, September 2012
- 4 Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Die Kraft der Sonne*
- 5 Organization for Economic Co-operation and Development (OECD), *Global trade in fake goods worth nearly half a trillion dollars a year*, April 2016
- 6 World Trade Organization (WTO), *International trade statistics*, 2015
- 7 EcoWatch, *Eight of the world's best bike sharing programs*, September 2015  
China Daily, *Hangzhou abuzz over bike sharing*, September 2016
- 8 World Health Organization (WHO), *Salt reduction, fact sheet*, June 2016

**Fashion made of milk**

Microbiologist and fashion designer Anke Domaske creates clothing made of milk that is no longer suitable for consumption. Her QMilk fibers are based on the powdery milk protein casein. This biofiber is gentle to skin, completely compostable – and theoretically even edible.



# Naturally good? Searching for new bio-based raw materials for industry

TARAXA  
GUM



## Driving on dandelions

A car tire made of dandelions? Initial tests have determined that the roots of the Russian dandelion can be a raw material source for natural rubber. These are the findings of a joint project between the tire manufacturer Continental and the Fraunhofer Institute for Molecular Biology and Applied Ecology in Münster, Germany, along with other partners. It will take at least five years, though, before the first dandelion tires hit the streets.



**Wood, liquefied**  
A traditional material creates new possibilities: Liquid wood, largely made up of the polymer lignin, can be shaped into any form using injection molding. It can be used to make enclosures for headphones like these from the firm Audioquest, or casing for speakers and mobile phones. Around 50 million metric tons of lignin are generated as waste from paper production each year.



Limited resources and a growing world population require new ways of thinking. One example is the use of bio-based products like wood scraps, dandelions and glucose as complements to crude oil. Worldwide, the bioeconomy is gaining traction. But despite considerable successes, a lot of research and development still needs to be done. When are renewable resources truly good?

**F**rakta means transport – and that is just what the bag that carries this name is designed to do. Large, robust and simple to clean, the iconic blue shopping bag from the Swedish furniture retailer IKEA can be found in many households. It is used for all kinds of things, including storing bottles and moving house, or as a laundry basket, shopping bag or even a suitcase replacement. For now, this multipurpose bag is made of petroleum-based plastic, partly from virgin polypropylene. However, this will soon change: By 2020, IKEA wants to manufacture all of its plastic products – including carrier bags, children’s toys and storage boxes – from renewable and/or recycled materials.

It will not be an easy task. For applications in sensitive areas such as food packaging or children’s toys in particular, health protection requirements mean that today’s recycled plastics are not an option. Alternatives are needed. “Here, we are trying to replace oil-based plastics with those made from renewable raw materials. This could mean 100 percent bio-based polymers such as polylactide or else combinations of a variety of bio-based materials. In some cases, mix-

tures with oil-based plastics are also a possible first step,” explains Puneet Trehan, Material Innovation and Development Leader at IKEA. The initial target, he says, is a bio-based proportion of 40 to 60 percent.

#### Complements to crude oil

Bio instead of petro: IKEA is not the only company committed to bio-based plastics. Around 100 years after the invention and marketing of the first entirely synthetic plastic Bakelite®, which was soon followed by thousands of others, scientists and producers are now turning their research focus in a new direction. The products of tomorrow should be high quality but made from renewable resources, plants, organic waste or micro-organisms.

Toy manufacturer LEGO, for example, has said it wants to produce its building bricks from plastic made of alternative materials as of 2030. To do so, in 2015 the company announced it was investing the equivalent of around €135 million to found its own Sustainable Materials Center. In 2009, the Coca-Cola Company launched its PlantBottle™ technology and soon afterwards it licensed the technology to other major companies such as ketchup producer H.J. Heinz and Ford Motor Company. The polyethylene tere-phthalate (PET) bottle was initially made up of 30 percent plant-based material. Coca-Cola’s goal is to produce the PlantBottle using only renewable resources. In the next decade, this should be the case for all PET plastic bottles, which represent around 60 percent of all of Coca-Cola’s packaging.

One solution that enables plastic bottles to be made from 100 percent renewable raw materials is offered by the company Synvina. This recently established joint venture between BASF and Dutch company

Coca-Cola plans to increase its use of plastics made from renewable raw materials in its beverage bottles (top picture) and LEGO wants to do the same with its building bricks (bottom picture).



**For now, bioplastics still represent a small slice of the market. They make up less than 1 percent of the plastics produced worldwide each year.**

Avantium produces the chemical building block furandicarboxylic acid (FDCA) from fructose. FDCA can be used to make polyethylenefuranoate (PEF), which can be manufactured into beverage bottles and food packaging. PEF bottles have some unique features: Not only are they 100 percent bio-based, compared to bottles made of PET they offer improved barrier properties for gases like carbon dioxide and oxygen, leading to a longer shelf life for the packaged beverages.

The automotive industry is also aiming to go back to the roots: In its early days, the car industry worked with biomaterials – as demonstrated by a car developed by Henry Ford in the 1930s with a body made of hemp fibers. But after the passage of the Marihuana Tax Act in 1937 in the United States, the pressure on Ford grew too great and development was stopped. Today there is renewed interest in the idea of lowering a car’s carbon emissions by reducing weight through the use of natural materials such as hemp, sisal, kenaf and flax. Increasingly, components are being made from the relatively less expensive natural-fiber plastics instead of the light-weight building materials carbon or glass fiber.

**Lowering carbon emissions**

The fossil-based economy is increasingly reaching its limits. Climate change and the associated need to reduce greenhouse gases mean it is time for a rethink. “Bio-based products are now the only alternative. Without the bioeconomy, the G7 countries’ long-term goal of eliminating carbon dioxide emissions is probably not achievable,” says Waldemar Kütt, PhD, head of the unit Bio-Based Products and Processes at the European Commission’s Directorate-General for Research and Innovation. The reason for this is that plants absorb carbon dioxide from the air through photosynthesis. “When we use this carbon obtained from plant or microbial biomass in manufacturing our products, we are removing CO<sub>2</sub> from the environment, in harmony with the natural biological carbon cycle. This is not the case with oil, which has been created over millions of years and offers no advantages in CO<sub>2</sub> reduction,” explains Ramani Narayan, Professor of Chemical Engineering and

**Not every bioplastic is biodegradable**

The prefix “bio” for plastics is used for both the characteristics “bio-based” and “biodegradable.” Bio-based plastics are made partially or entirely of renewable raw materials, but they are not necessarily biodegradable. Biodegradability is dependent on the molecular structure of the plastic rather than the raw materials used to make it. For example, bio-based PE (polyethylene) and PET (polyethylene terephthalate) are just as non-biodegradable as their fossil-based equivalents, while plastics made from bio-based polylactic acid (PLA) are biodegradable. Plastics made from crude oil can also be biodegradable: After a certain period of time under specific temperature, oxygen and moisture conditions, and with the help of microorganisms or fungi, they can turn into water, carbon dioxide (CO<sub>2</sub>) and biomass.

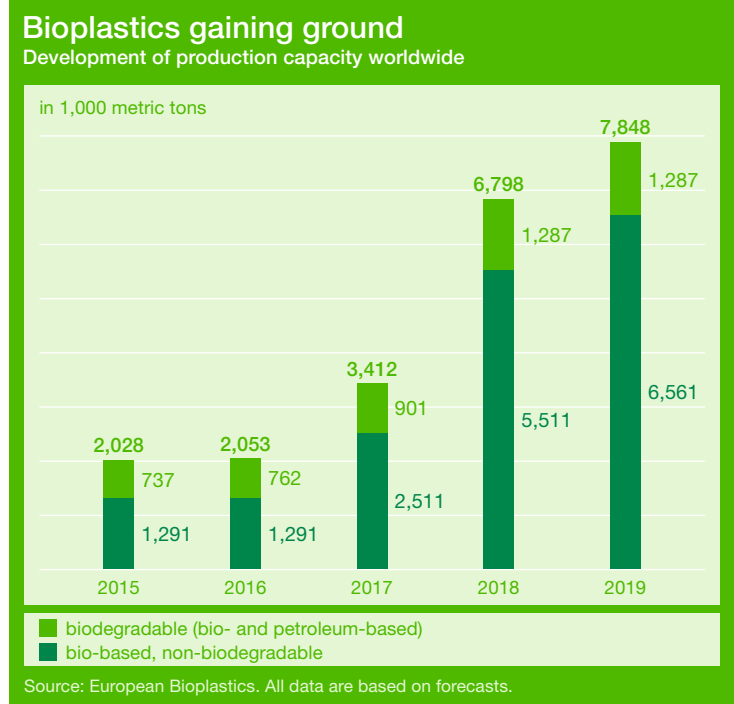
Material Sciences at Michigan State University, USA.

Oil will not be replaced completely, but even partial substitution is a positive step forward to reducing our carbon footprint. “If just 20 percent of the carbon in the 37.5 million or so metric tons of PET used in making bottles worldwide were to be replaced by bio-based carbon,

this would absorb 17.2 million metric tons of CO<sub>2</sub> from the environment. That would be equivalent to about 40 million barrels of oil savings,” Narayan says.

**Growing production capacity for bio-based products**

There are two phrases that consumers come across time and again



**Potato cultivation:** Chinese farmers who switched from using non-compostable mulch film to the biodegradable product ecovio® were able to increase their yields significantly.

when it comes to bioplastic: bio-based and biodegradable. Bio-based plastic is made from renewable raw materials but is not necessarily biodegradable. It can even be just as long-lasting as conventional plastic. On the other hand, plastic made from crude oil or natural gas can be biodegradable (see box). “We are seeing growing demand for bio-based products which we are addressing with new technologies and innovations. At the same time, we are expanding our portfolio of biodegradable materials,” says Carsten Sieden, PhD, head of BASF’s white biotechnology research unit.

For now, bioplastics still represent a small slice of the market. They make up less than 1 percent of the 300 million metric tons of plastics produced worldwide each year. But, according to market data from the industry association European Bioplastics, this figure should rise sharply in the coming years. The global production capacity of around 2 million metric tons (2015) should nearly quadruple by 2019 to about 7.8 million metric tons. The lion’s share (around 80 percent) consists of bioplastics which are made from bio-based raw materials but are not biodegradable or compostable.



## 3 questions for... Nikolaus Raupp

Since 2013, BASF has offered its customers the option of replacing fossil feedstock in the Verbund with renewable resources. BASF project manager Nikolaus Raupp, PhD, explains how the biomass balance approach certified by technical inspection board TÜV SÜD works.



**There is a growing interest in the use of renewable raw materials – also in the chemical industry. How can BASF’s biomass balance approach contribute to this?**

**Nikolaus Raupp:** With this process, renewable raw materials can be used as feedstock in our existing Production Verbund and then allocated to the respective sales products. The principle is similar to that of “green energy” tariffs, where the electricity coming out of the socket does not necessarily come from renewable energy. The important thing, though, is that the volume of renewable raw materials in the system overall is correct. Furthermore, an advantage of this solution is that the product will reliably offer the same level of quality. The unique feature is that the volume of fossil raw materials needed for production can be replaced by renewable resources.

**Depending on the customer’s preferences, up to 100 percent of the fossil feedstock needed can be replaced with renewable raw materials. How can you prove this?**

We can calculate all the way back along the raw material chain in the Production Ver-

bund. Here at the Ludwigs-hafen site, we have around 200 interconnected plants across an area spanning 10 square kilometers. And we can calculate exactly which of the various raw materials go in and come out of each of these plants. If a customer buys one metric ton of a biomass balance product, we replace the corresponding volume of fossil feedstock with renewable raw materials. TÜV SÜD carefully monitors these calculations. Even though the raw material prices are higher, there is a lot of interest in our biomass balance approach – especially in the construction sector, the furniture industry and among producers of hygiene products. There are now more than 40 BASF products, such as plastics or superabsorbents for baby diapers, certified according to this approach. And more are being added all

the time. A recent example is the use of binders sold under the Acronal® brand, which were processed by the architectural coatings producer DAW to make its newly launched Caparol and Alpina interior paints.

**Renewable raw materials are not necessarily always sustainable. What standards are applied?**

The TÜV SÜD standard applied here stipulates that the process must use only raw materials that meet certified sustainability standards. It is important to BASF that the highest-possible share of raw materials is derived from organic waste, such as agricultural residues.

Biodegradable plastics are used in organic waste bags and in agricultural mulch film, among other things. BASF's compostable plastic *ecovio*®, for example, proves its advantages in the Chinese agriculture sector. In China, the conventional technique of using mulch film made from non-biodegradable polyethylene plastic is becoming a serious environmental problem. The film helps plants to grow by keeping heat and moisture in the soil, but all of the film is left behind in small, thin strips on the fields. When plowed under, the plastic pieces hinder root growth and thus lower future yields. Farmers who have switched over to using biodegradable mulch film made from *ecovio* have been able to increase their yields again. This has also been proven by large-scale experiments that BASF has been carrying out for years in cooperation with local partners and organizations. For example, in one test field for potatoes in the province of

Guangdong, yield was increased by 18 percent, which also reduced harvest costs by 11 percent.

**Political strategies**

Given the limited resources, how can a growing population be provided with enough daily essentials such as food and energy? Policymakers and industry are looking to the bioeconomy to provide answers to a key question of the 21st century. All of the G7 countries have launched related initiatives and some have introduced very decisive strategies. The U.S. government, for example, published the National Bioeconomy Blueprint in 2012, which declared bioscience research and commercialization as a “major driver” of American economic growth. That same year, Japan passed its Biomass Industrialization Strategy, an action plan which sets out seven initiatives with clear timelines and targets. Japan's policies aim to advance the development of new

**Today, around 45 countries have developed a variety of strategies for a partial transition to a system with renewable raw materials.**

**Reactor with algae to generate biomass: Policymakers and industry are looking to the bioeconomy to provide answers to the issue of resources.**

biorefinery technologies as well as biological resources such as microalgae. The medium-term focus is on new industrial technologies, while the short-term priority is securing bio-based energy supplies.

Last but not least, the European Union is also an important supranational player in this paradigm shift. Nearly five years ago, it presented its Bioeconomy Strategy and policy plan for a European bioeconomy. Two years later, the European Commission launched the Bio-Based Industries Joint Undertaking as a central investment initiative in 2014. Around 70 companies from the agriculture, forestry, chemical and energy sectors are involved, as are technology suppliers as industry partners. Altogether, this initiative will invest around €3.7 billion by 2020 in the commercialization of new bio-based products and processes.

It is not only the leading industrial nations that are planning a partial



shift. A lesser known fact is that today around 45 countries have already developed very diverse strategies for a partial transition to a system with renewable resources and bio-based production processes. For example, Uganda is fostering the use of renewable energies, biotechnology and biomass, while in Malaysia the focus is on switching to bio-based products.

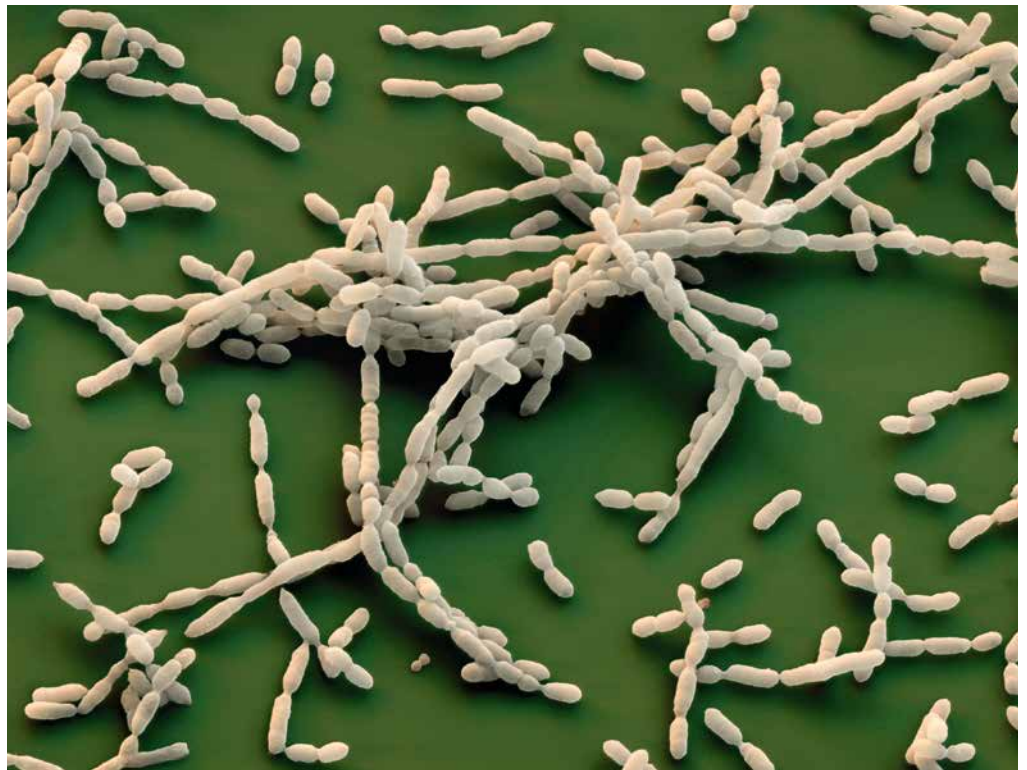
### The question of sustainability

Nevertheless, the move towards a bioeconomy is also the subject of critical discussions. Topics such as “food versus fuel,” land use and the corresponding resource inputs for cultivation, and fair working conditions play a central role in the current debate about renewable resources. At present, there are signs that second-generation biomass – made up of non-edible raw materials – is becoming increasingly important. Although this does not mean that canola (rapeseed oil), corn, and the like, as the first generation, have been superseded as a result. “Bioeconomy and bio-based industries have the potential to provide sufficient food, feed, fiber and other materials to meet our needs, if they are developed in the right way,” says Joanna Dupont-Ingliš, Director of Industrial Biotechnology at EuropaBio. “However, there will be no ‘one size fits all’ answer because the bioeconomy is incredibly diverse and therefore different feedstocks make sense in different regions for different applications. In addition, we are sure to see new solutions for both minimizing waste and using what is unavoidable more.”

Nylon from wood, tires from dandelions, lubricants from thistles – second-generation biomass is predominately made up of non-edible plants, organic waste and residues. According to the United Nations, around 5 billion metric tons of biomass are created annually in the form of agricultural residues. As these are not suitable for food, they can be used as raw materials.

### The price must be right

Theoretically, the bioeconomy has great potential: a boost to innovation from a key technology, better performance, new jobs and lower carbon dioxide emissions. Nevertheless, it should not be overestimated. “The bioeconomy is not a



**Microscopic image of the bacterium *Basfia succiniciproducens*. This micro-organism produces bio-based succinic acid, which is an important component for biodegradable plastics.**

silver bullet or the answer to all of our problems, but it can help us tackle some of the biggest societal and environmental challenges that we face,” Dupont-Ingliš says, adding: “All 100,000 chemicals that are currently in use can, in theory, be made from renewable carbon sources rather than from fossil carbon. However, of course we need to consider all three pillars of sustainability in developing the bioeconomy of the future, which means weighing up the environmental, societal and economic benefits in each case.” BASF researcher Sieden adds: “One lever to advance the bioeconomy is sufficient volumes at competitive prices. But most importantly, a strong bio-based industry is a major opportunity for innovations. We want to leverage this potential in our research network.” More and more customers are asking for bio-based products. “This is a great opportunity for us to expand our raw material base. But that won’t be possible from one day to the next,” explains Sieden. It took over half a decade of research and development work in order to make

### Plant-powered engines

Biomass is not only a raw material, it can be used as a fuel as well. Biodiesel is produced from plant oils, such as canola (rapeseed oil), soybean and palm oil, while bioethanol is created by the fermentation of the sugar in corn, beets or sugarcane. It is not without controversy, however, as the “food versus fuel” debates of recent years have demonstrated. The answer is clear: Food production must take precedence over energy generation. With that in mind, there will continue to be a role for canola, corn and sugar beets in the bioeconomy. But biofuels can also be made from organic waste, wood, straw and algae. These second- and third-generation processes, however, are still mostly in the development stage.

bio-based succinic acid – produced from the bacterium *Basfia succiniciproducens* – into a commercial product. The acid is an important component for biodegradable plastics, coatings and polyurethanes, which can be used to manufacture mattresses, flooring and automotive seating. Succinity, the joint venture between BASF and the Dutch company Corbion, has been operating a plant in Montmelo, Spain, since 2014 that has an annual capacity of 10,000 metric tons of bio-based succinic acid for the world market.

The issue of sufficient volumes is also a key challenge for IKEA executive Puneet Trehan. However, he sees significant progress for his sector even at the cost stage. “Our experience shows that if the value chain is organized correctly in a partnership, the costs will certainly be competitive,” he says. In his view, one thing is important above all else: “You need partners who are signed up to the same goal.” Business as usual is not an option in the world of bioeconomy. “‘Industrial evolution’ would perhaps be fitting for the transition which is currently under way,” says Joanna Dupont-Ingliš. “Producing renewable and resource-efficient bio-based solutions will involve previously unseen levels of collaboration across a diverse range of industries and sectors.” ■

# Renewable raw materials in use

It doesn't always have to be crude oil. We show how products made entirely or partly from renewable raw materials have already established their place in our everyday lives – or will in the future.

## Sportswear and underwear

Dextrose is not only good for a quick energy boost. BASF has developed a precursor derived from this sugar that can be used to produce elastic textile fibers such as elastane and spandex.

## Car interior components

Tequila in the car? At least the by-products of its production might be a possibility. When looking for renewable materials, Ford teamed up with tequila producer Jose Cuervo. Together they are testing the durability and heat resistance of agave fibers, which are a by-product of tequila production. Agave might one day be a component of the lightweight plastic composites used to make wiring harnesses or storage bins.



## Automotive roof frames

Flax, hemp, sisal and cotton are increasingly finding their way into cars as natural fiber reinforced plastics. The new Mercedes E-Class features the world's first automobile roof frame made entirely of natural fibers. The frame is stabilized with the BASF water-based binder Acrodur® 950 L. This revolutionary frame is around 40 percent lighter than a comparable one made of metal.



## Leather chairs

Olive leaves contain bitter compounds that protect the plants from pests. But these compounds can also be used in leather tanning as a biodegradable alternative to conventional tanning agents.

**Detergents and formulators**

Enzymes such as proteases and lipases help to remove dirt. The BASF protease Lavergy™ Pro for liquid laundry detergent ensures effective cleaning even at low wash temperatures and in short washing cycles.

**Shoe soles and heels**

A visionary twist for one of man's oldest materials: Mixed with fine natural fibers from flax or hemp, the lignin found in wood can be turned into "liquid wood." When heated and processed, it can be used to make anything from shoe heels to speaker and watch casings. Around 50 million metric tons of lignin are generated as waste each year in the paper industry.

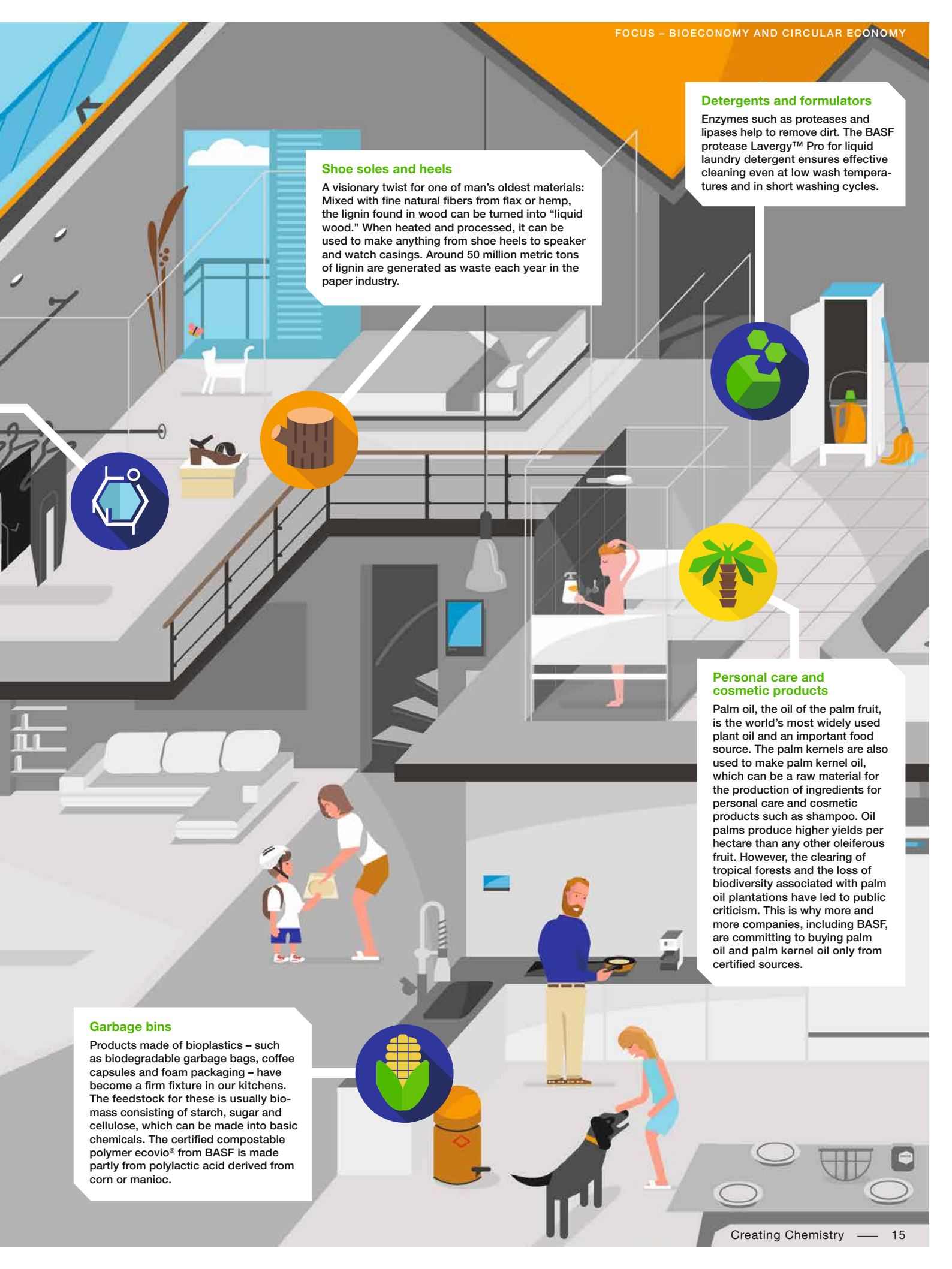


**Personal care and cosmetic products**

Palm oil, the oil of the palm fruit, is the world's most widely used plant oil and an important food source. The palm kernels are also used to make palm kernel oil, which can be a raw material for the production of ingredients for personal care and cosmetic products such as shampoo. Oil palms produce higher yields per hectare than any other oleiferous fruit. However, the clearing of tropical forests and the loss of biodiversity associated with palm oil plantations have led to public criticism. This is why more and more companies, including BASF, are committing to buying palm oil and palm kernel oil only from certified sources.

**Garbage bins**

Products made of bioplastics – such as biodegradable garbage bags, coffee capsules and foam packaging – have become a firm fixture in our kitchens. The feedstock for these is usually biomass consisting of starch, sugar and cellulose, which can be made into basic chemicals. The certified compostable polymer ecovio® from BASF is made partly from polylactic acid derived from corn or manioc.





1

**Nematodes are ideal for plant protection. They actively seek pests like slugs, weevils or caterpillars, invade and devour them.**



2

(1) Site manager Mark Downing (left) and fermentation manager Tom Goddard discuss the servicing of the fermenter tanks.

(2) Petri dishes with cultures of symbiotic bacteria (see info-box on page 18): They naturally occur in the nematode's gut, but at the lab nature is given a helping hand by introducing the bacteria into the vessel in which the nematodes will be bred.



# Using nature to protect plants

Biopesticides offer a way of using nature against itself. We take a look inside a BASF production site that breeds nematodes – tiny worms that can be used in plant protection to control a wide variety of pests.

It's not often you get to look inside a huge tank filled with eight trillion tiny worms. The worms in question are beneficial nematodes, bred in one of BASF's crop protection sites to be sold as a biological pesticide. Nematodes are ideal for plant protection. They actively seek pests like slugs, weevils or caterpillars, invade and devour them. The site has been located in Littlehampton on the English south coast for more than 30 years and is now the largest nematode production facility in the world.

Site manager Mark Downing oversees a team of 35 employees. "We're not out to replace chemical pesticides, there is a need in the market for both," he says. "But

with increasing demand for organic production and tougher regulations, we are getting a foothold." Downing is joined by fermentation manager Tom Goddard and formulating and packaging scientist Sarah James, PhD, to give us a tour of the factory floor.

The first room is filled with shiny cylindrical tanks and a bewildering array of pipes that snake their way around the site. The process starts by passing nematodes through an insect. "This is to prove their efficacy," explains Goddard. Only the nematodes that kill the host insect are used. They are transferred to a flask, where they are encouraged to feed on nutrients and then used to seed smaller tanks. The process is scaled up in ever larger vessels until the nematodes have multiplied from a few thousand to trillions.



(3) Aerating the nematodes can create a lot of foam, which has to be removed. Tom Goddard checks foam levels in "El Gordo," the 102,000-liter custom-built fermenter tank that stands about 12 meters high.

(4) Each batch of nematodes starts out in a flask culture. These cultures are then used to seed the smaller fermenter vessels.

(5) Fermentation technician Raj Ganthaji checks the number of bacterial cells of the nematode product.

### What is a nematode?

Nematodes are multi-cellular worms, around 1 millimeter in length. They live in soil and a wide range of other land and marine environments. Each species has its own symbiotic bacteria which live in its gut. Once a nematode invades a pest, it regurgitates the bacteria, which then digest the host. The resulting material has a distinctive color – from bright yellow to rusty red. The color can identify the species. They find their food by “chemotaxis,” their movements responding to chemical stimulation. After devouring one host, they look for more, but can survive for up to 10 days without a meal. There are nearly 20,000 known species of nematodes, and estimated to be many more.



(6) Sarah James, PhD, counts how many nematodes are in 1 gram of the product.

(7) Quality control: A bioassay is examined to check how effective the nematodes are.

(8) An enlarged image of the nematodes on the computer screen is used to check which stage of their life cycle they have reached.

6



7



8

The nematode lifecycle has five stages. Those that go on the market are the infective juveniles – the only stage where they can survive outside a host. Currently the facility produces six different species of nematodes to target different kinds of pests. Some are ideal for managing fungus gnats, root flies and western flower thrips in horticulture and vegetable production. Others provide control of slugs, codling moths and red palm weevils. BASF works with local and international researchers to discover new, potentially useful species.

In the middle of the production facility stands “El Gordo,” Spanish for “the fat one.” A 102,000-liter vessel, about 12 meters high, it is used to brew the *Steinernema feltiae* species, which is marketed under the brand name Nemasys®. “That’s our biggest selling product,” says Goddard. “We sell trillions of these nematodes a year.”

Once brewed to the right stage, the nematodes are mixed with a special formulation and packed into what look like microwave dinner trays. Goddard shows two packs containing over 1.5 billion nematodes which are destined for Florida, to help tackle pests that are threatening orange groves. “This will cover something like 15 acres, or around nine soccer pitches. It’s diluted in a tank with water, then sprayed on the crop,” he says.

James works in the formulating and packaging lab finding ways to overcome problems like overheating. The heat comes from the nematodes’ metabolism as they feed. With the tanks containing up to 200,000 nematodes per milliliter, this is a serious concern. She shows three containers of new formulations she has mixed as an experiment to find out what will improve the shelf life of a living product. James joined BASF as she was finishing her PhD. “I was studying ways of using nature against itself. I like the idea of using a natural predator to target what we consider pests,” she says. The Nemasys product typically kills 60 to 80 percent of the pests on plants.

“The market for nematodes started small but is growing every year,” says Downing. “We like to think we’re providing the technology of the future.” ■



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10

“The market for nematodes started small but is growing every year.”

Mark Downing, site manager

(9) Mark Downing (right) and Tom Goddard assess a bacterial plate in the laboratory.

(10) The nematodes are sealed in trays with a micro-perforated film lid which allows sufficient oxygen through to keep them alive. The product has a dough-like, open structure so that air can get in.

(11) Roxana Halalau (left) and Kristina Bandzinaite pack the product. Each tray contains around 1.5 billion nematodes.



11

# Circular economy: A visionary roadmap?

In a world of limited resources, new economic models are needed. The circular economy is an idea that is gaining ground. What does it mean and how does it work?

**G**lobally, we are facing the pressures of climate change, population growth and limited resources. The bioeconomy (see cover story from page 6) is part of a larger, holistic concept: the circular economy, which aims to transform the way we live so that we do not exceed our planet's boundaries.

The fundamental idea is to decouple growth from resource depletion by developing innovative business models. Moving away from the linear “take-make-dispose” to a more circular approach in production and consumption could be the biggest economic transformation since the industrial revolution. “The linear model, which has been very successful in delivering economic growth in the past, is no longer viable for continuing progress,” says Jennifer Gerholdt, Senior Director of the

Environment Program at the U. S. Chamber of Commerce Foundation Corporate Citizenship Center. She sees businesses embracing the circular economy approach as an opportunity to drive innovation within the broad sustainability framework.

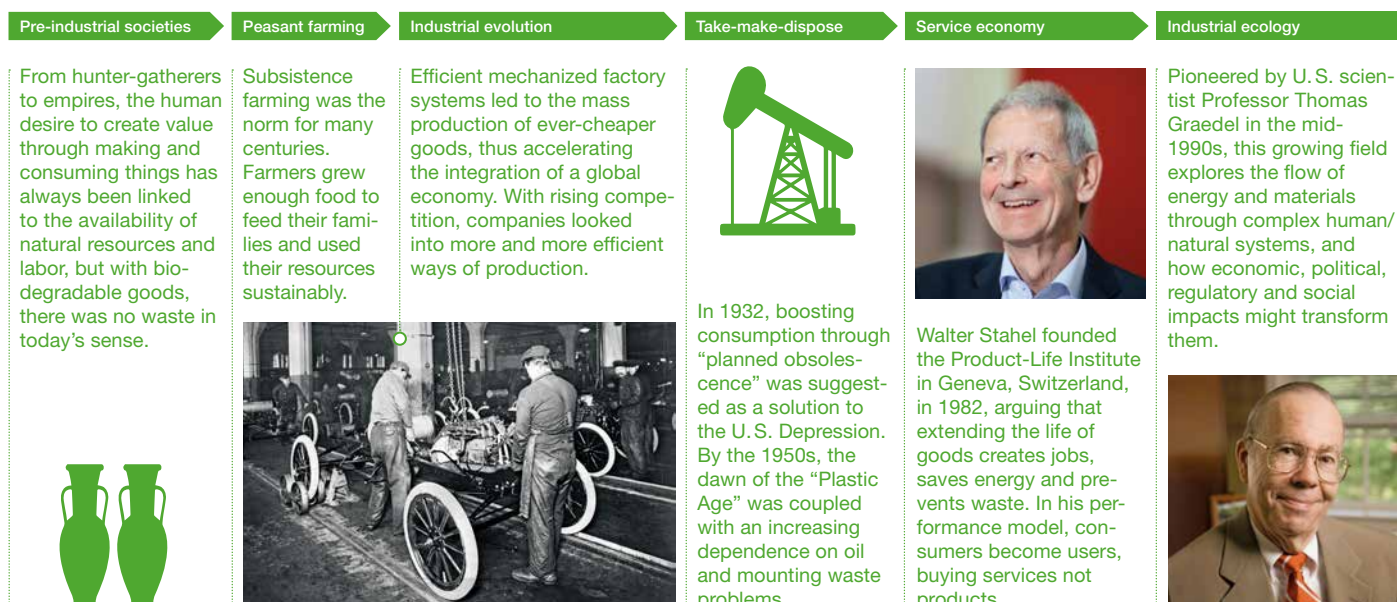
The aim of the circular economy is to use fewer resources by efficient processes, waste prevention, re-use, repair, remanufacture and recycling. It focuses primarily on material cycles and relies on energy from renewable sources. Design for durability ensures that technical products last as long as required, are easily maintained and have high second-hand value. Design for disassembly means that the products and their components can be repaired, remanufactured and recovered as raw material for another manufacturing process.

Through “industrial symbiosis,” by-products from one industrial process become the feedstock for

another. BASF has incorporated this idea from its very beginning in 1865. “The BASF Verbund is designed for efficient use of energy and resources. The excess heat produced in one production facility can be re-used as energy in other plants. Offgas or reaction by-products from one plant work as raw material for another. It means we are able to reduce emissions and waste, while conserving resources,” says Uwe Liebelt, PhD, President, European Site and Verbund Management at BASF.

Another pillar of the circular economy concept is growing fast: the new “service economy,” where sharing and leasing replaces ownership and consumers become users. For example, the shift from individual ownership to car sharing will lead to more intense usage over the car's service life, requiring new, highly durable and recyclable materials and technologies. Chemical innovations are essential for achieving this.

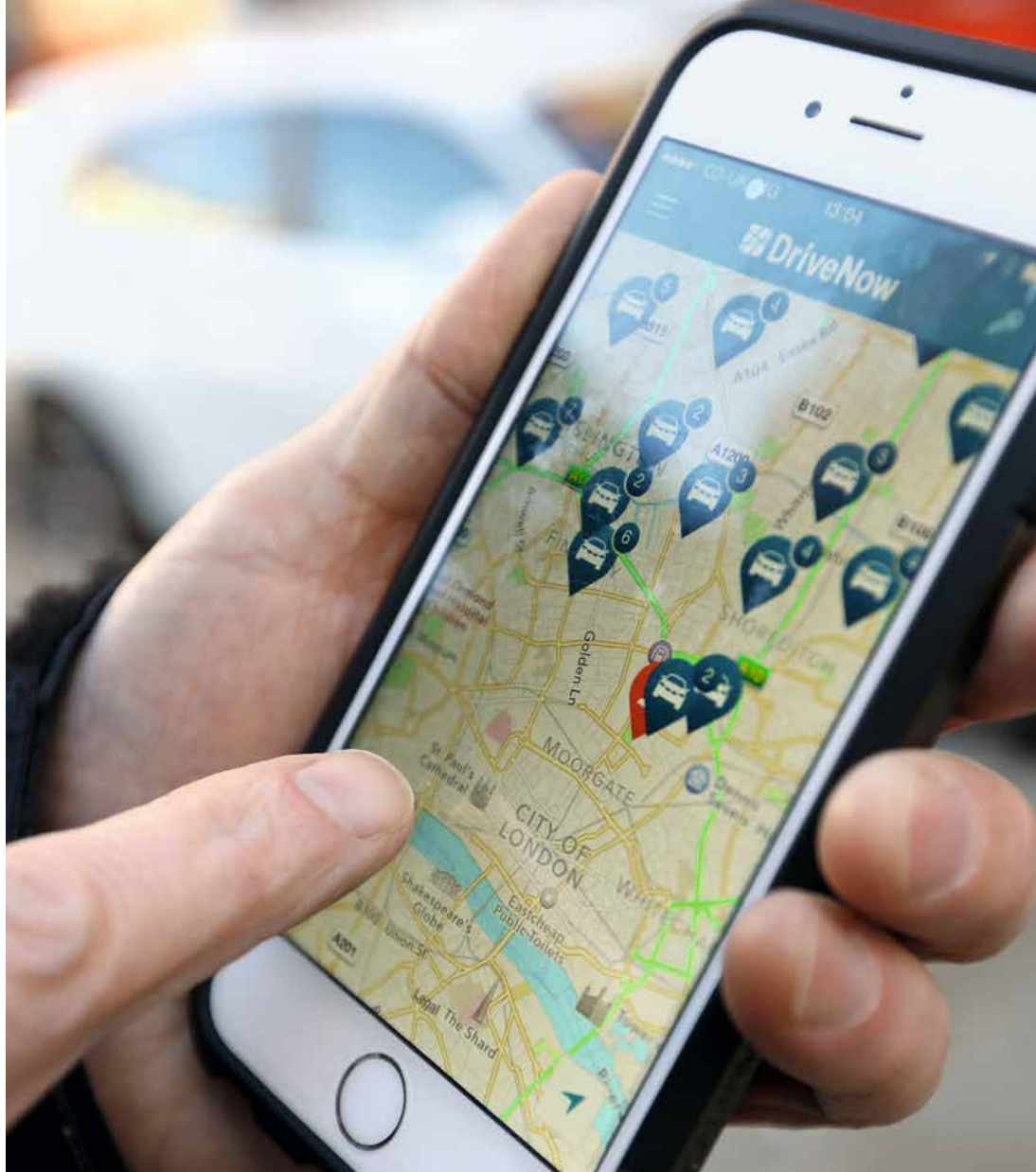
## Closing the loop – circular economy thinking from past to present



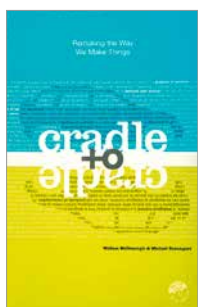
The Ellen MacArthur Foundation, which aims to support and accelerate the transition to the circular economy, estimates that these ideas could save at least \$1 trillion in materials annually by 2025 and create jobs through remanufacturing and recycling products.

The strategic potential of the circular economy to use as few resources as possible while supporting growth means that it is being rapidly incorporated by some of the world's leading companies and regional economies. For Gerholdt, this way of doing business is, simply, the “new normal” in the 21st century. ■

**Car sharing, as an alternative to car ownership, leads to more intense usage over the vehicle's service life, requiring new, highly durable and recyclable materials.**



Cradle to cradle



The 2002 book “Cradle to Cradle: Remaking the Way We Make Things” by German chemist Professor Michael Braungart and U.S. architect William McDonough challenges designers to consider a product's impact across its entire life cycle.

Project mainstream

Global companies working with organizations like the World Economic Forum and the Ellen MacArthur Foundation aim to scale up the circular economy by tackling the challenges too big or complex for individual businesses.



Global governance

In 2007, China made a circular economy an over-arching goal, and initiatives are underway in Japan, South Korea, France, Scotland, Canada and Scandinavia. In 2015, the European Union made “Closing the Loop” a key policy of the world's largest trading region.

Global challenges



We use 1.5 times the world's natural resources annually, the population is set to reach nearly 10 billion by 2050, and global temperatures are predicted to rise by an average of 3 degrees Celsius in the next 100 years.

Thinking into the future



Which ideas will lead the way to developing new industries and technologies that enable us to live within our planetary boundaries without limiting growth?

# Circular vision in the East

As China's economy grows, its approach to circular economy thinking matters to us all. Professor Du Huanzheng, his country's foremost promoter of the idea, believes China has a few things to learn but also a lot to share about this new economic model.

## Creating Chemistry: How do you define a circular economy?

**Professor Du Huanzheng:** In a linear economy you proceed from raw materials to products, then to waste. In a circular economy, there is a complete circle from raw materials to products and then back to renewable resources. Here in China, we go further and think about the circular economy as a new economic model that changes both our production methods and lifestyle. The tradition has been one of mass production, mass consumption and mass waste. What we need now is eco design at the beginning of production, environmentally friendly production, including recyclable and biodegradable

products, responsible consumption and recycling, all with the ultimate goal of achieving sustainable development for human society.

## How did you personally first become interested in circular economy thinking?

In 1985, I took some students to a small city near Wenzhou, one of the biggest manufacturing bases for low-voltage electrical apparatus in China. They collected old transformers from all over China, repainted and sold the good ones. From the rest, they split out the silicon steel sheets and made them into new, smaller transformers. So in China in the 1980s, we wanted to avoid

waste to address the problem of insufficient resources. Then at the beginning of 21st century, we started to think about resource recycling in terms of the impact on the environment. This is in contrast to Germany and Japan, which started from environmental concerns and are now also including resource issues.

## From a Chinese perspective, which areas of circular economy thinking are most urgently needed?

To guide the transformation, leaders need to change their way of thinking. The central leadership has already done that. Now local government leaders need to follow. China has developed so fast in the past 30 years

### Professor Du Huanzheng

Professor Du Huanzheng has been the Director of the Circular Economy Research Institute of China's renowned Tongji University since its founding in 2014. He is also the Vice Director of the Center for Chinese Circular Economic Assessment and Environmental Forecast of the influential Chinese Academy of Social Sciences (CASS). In 2005, he founded the Yangtze River Delta Research Academy of Circular Economy, one of the earliest circular economy research institutes in China.



In China, a great deal of industry is concentrated in industrial parks. One example is the integrated production at the BASF-YPC Verbund site in Nanjing. Its efficiency demonstrates the potential of circular economy thinking for China's chemical industry.

“In China, we think about the circular economy as a new economic model that changes both our production methods and lifestyle.”



because county leaders were promoted to mayors and mayors to vice governors on the basis of gross domestic product (GDP). But this has led to a waste of resources. Construction is GDP, demolition too. We need to adopt “resource productivity,” which is GDP divided by consumption of main resources, as a new assessment method for leaders. In China, these are represented by the 13 most widely used, main raw materials, like coal, steel and copper.

**China has announced ambitious plans to promote a circular economy and written them into its recent Five Year Plan. This is both**

**Employees disassemble electronic scrap at a waste recycling factory in Wuhan, Hubei province. The plastic parts will be reused for the production of wood-plastic composites.**

**“In the West, industrialization took almost 200 years. Here in China, we have had to compress this development into a much shorter period.”**

**admirable and surprising. Why is China, which is still catching up with western economies, already embracing these ideas?**

In the West, industrialization took almost 200 years. Here in China, we have had to compress this development into a much shorter period of just three decades, solving not only the problems that developed countries encounter, but also those that developing countries face. As a responsible power, China should play a leading role in global sustainable development by being at the forefront of wind, solar and other clean energies. We want to find a way of making a great leap forward in development that can be an example for other developing nations.

**While China is very good at planning and formulating goals, it often seems to have a harder time implementing them. In many cities there is not even basic garbage separation and recycling of consumer waste. What are you doing about this?**

It is a big issue. We started a garbage separation pilot program in 2000 in eight cities including Beijing and Shanghai. Sixteen years later, it still hasn't succeeded. There is always a call-to-action by the government, then a document issued, followed by media coverage and leaders showing up at the scene. But there is no long-term mechanism. We are now working on a system solution for urban waste in Guangzhou that includes initial garbage separation, collection and sorting, followed by classification and disposal by class. With the system in place, we will invite private sector enterprises to participate and make it sustainable.

**In order for the circular economy to work well, partners along the value chain have to work closely together to create and implement solutions. How does China support such cooperation?**

The circular economy solves both environmental and resource problems. Environmental problems are a public issue. The resource issue, however, is a market one. Resource recycling is only accomplished through cooperation between government and the market. If we want to recycle discarded milk cartons or glass waste, for example, the government can provide the missing part of the value chain by







Professor Du Huanzheng walks past the South West Dormitory, one of the oldest buildings on the campus of Tongji University in Shanghai, China.

subsidizing low-added-value waste or by Extended Producer Responsibility solutions.

**Undeniably, China's environmental efforts do not only concern China alone, but have implications for the whole world. Is there enough international cooperation?**

We strongly feel that we need international cooperation to promote a circular economy. We need to learn from other countries, but also need to show the world our good case studies. That is why we have set up various international cooperation platforms with major developed countries such as the United States, Japan, and Europe. The U.S.-China EcoPartnerships Program, under the U.S.-China Strategic and Economic Dialogue, is one of these platforms, and has launched 42 EcoPartnerships so far. The Yangtze River Delta Research Academy of Circular Economy, of which I am the director, has

**“With leadership from governments, the participation of the public, and implementation through private enterprise, I firmly believe that the circular economy can be achieved in China and globally.”**

partnered with the Coca-Cola Company to promote manufacturing eco-friendly bottles with local agricultural waste rather than petroleum-based ingredients. We have worked with Japan on recycling urban waste, and launched a project with Germany on recycling batteries. We also organize annual training courses on circular economy in developing countries so as to share successful case studies.

**Looking to the future, are you optimistic about achieving a circular economy?**

I think it is something we absolutely have to develop if mankind wants to exist and develop sustainably. With leadership from governments, the participation of the public, and implementation through private enterprises, I firmly believe that the circular economy can be achieved in China and globally. ■

# New discoveries

Inventive minds wanted! This section presents inspiring innovations that make everyday life easier while improving sustainability.



## Clear messages

When a train rattles by, it is often very hard to understand announcements in the train station. Researchers at the Fraunhofer Institute for Digital Media Technology (IDMT) in Oldenburg, Germany, have developed a software that significantly improves speech intelligibility – it works for loud-speaker announcements, for the voices of speakers at conferences or conversations on mobile phones. The software uses a microphone to analyze the background noise and adjust the speech in real-time. It is not sufficient to just make the voice louder. Instead, algorithms prioritize certain frequencies and selectively boost those that are particularly disturbed by the ambient noise. As well, loud parts of speech are systematically subdued while quiet parts are amplified. So you always know where to catch your next train.

[www.idmt.fraunhofer.de/en.html](http://www.idmt.fraunhofer.de/en.html)



## How polymer beads cut utility costs in laundry

Our daily laundry consumes huge amounts of water and energy. Researchers at the pioneering start up Xeros in the United Kingdom have developed a revolutionary solution addressing saving potential as well as quality improvements in laundry. Xeros uses polymer-based beads with a diameter of 4 to 6 millimeters to substitute large parts of the water used: The fabric massaging effect of the up to 1.5 million reusable polymer beads in a 25 kilogram commercial laundry machine can reduce water and detergent use by more than 50 percent. Xeros and BASF have been working together since 2013 to optimize the beads' effectiveness. Their ellipsoidal shape, their specific density and their smart functionalization provide for a gentle but efficient wash and have made them very popular among hotel launderers.

[www.xeroscleaning.com/xeros-benefits](http://www.xeroscleaning.com/xeros-benefits)



## Personal wind power

A wind turbine you can pack in the back of your car and take with you – nemoi, developed by Argentinean company Semtive, stands 1.5 meters high, weighs 25 kilograms and is easy to assemble. That makes it ideal as a backup for conventional generators in remote areas or for saving energy costs at home. Its vertical axis design means it can work even with light breezes. Made of 95 percent recyclable materials, it can be equipped with a solar panel and generate up to 450 watts per hour. A deep cycle battery stores energy for when the wind doesn't blow.

[www.semtive.com](http://www.semtive.com)



### Harvesting water from the air

The tower invented by Italian designer Arturo Vittori can collect an average of 50 to 100 liters of drinking water per day. Around 10 meters high and made of woven rushes, the delicate structure collects rain and harvests fog and dew from the air. How does it work? Water from the air condenses and raindrops are collected on a fine mesh made of bioplastic fixed inside the woven shell of the tower. The harvested water drips down, runs through a filter and is then collected in a 3,000-liter water tank. The Warka Water system has a one-time cost of around \$1,000. A prototype has been tested in Ethiopia since May 2015 and mass production is scheduled to start in 2019. Only around one-third of all Ethiopians have access to clean drinking water.

[www.warkawater.org](http://www.warkawater.org)



### Light from saltwater

Bringing light into Philippine huts and houses with saltwater is an idea developed by Aisa and Raphael Mijeno and their Asian startup SALT. They want to replace kerosene lamps, which are dangerous to human health and the environment. In their lamp, a battery generates electricity from water and salt. With each filling of saltwater, the lamp has enough power to shine for eight hours a day for six months and can also charge a mobile phone. After that, the Philippine inventors' battery needs to be refilled. In coastal regions, this can be done simply with seawater. Series production started recently.

[www.salt.ph](http://www.salt.ph)



### The color of hope

Almost half a million people died of malaria last year, many in Africa. Worryingly, the parasites from the Plasmodium genus that cause malaria, have developed resistance to most current medicines. A 19th century dyestuff, methylene blue, could provide an answer. First synthesized by BASF over 100 years ago, recent studies have shown it to be a safe and effective treatment against one malaria parasite, *Plasmodium falciparum*. In 2016, the German universities of Heidelberg and Munich and Jimma University in Ethiopia started a clinical study to test a methylene blue-based combination therapy to treat patients with another malaria parasite, *Plasmodium vivax*. This study was developed together with BASF scientists and will be supported by BASF.

[www.basf.com/methylene-blue](http://www.basf.com/methylene-blue)



# Does free trade still matter?

Multilateral or regional agreements? Professor Daniel Hamilton (left) and Karl Brauner, PhD, talk about the right approach to meet the challenges for international trade within our complex globalized world.



Trade is an engine of growth, promoting innovation and increasing standards of living. For the past 20 years the World Trade Organization (WTO) has led the way to trade liberalization. But with the progress of negotiations slowing, major countries are now pursuing regional agreements. Is this the right approach to meet the challenges of our complex globalized world? Creating Chemistry asked Karl Brauner, PhD, from the WTO, and Professor Daniel Hamilton of Johns Hopkins University in Washington, D. C., USA.

**Creating Chemistry:  
Why is global trade important?**

**Karl Brauner:** Trade is the instrument by which companies and countries engage on the world market. The evidence shows that the more a country engages on the global level, the higher the standard of living is in that country. You can see this very clearly if you compare the Northern European countries or North America with North Korea.

**Daniel Hamilton:** Trade has important effects within countries as well as between them. It encourages competition, which tends to promote more innovation. It means companies need to be more efficient, and that usually leads to better products. Over time, more open societies have

better paying jobs for their workers. Consumers benefit because they can choose a wider variety of goods and services at lower prices. All of that tends to increase standards of living.

**What are the WTO’s major achievements?**

**Brauner:** We are the organization that sets the rules multilaterally for trade globally and we can enforce them. Our dispute settlement system has handled more than 500 cases; we have a compliance rate of more than 90 percent and you get a court decision in a much shorter time span than you would get in national courts.

**Hamilton:** I absolutely agree that the WTO presides over a global system

of rules that are almost universally accepted and respected. Its dispute resolution system remains a gold standard and tariffs today are quite low on the majority of trade. But the organization is now facing a whole series of crises that will really challenge its role.

**What are those challenges?**

**Hamilton:** The nature of trade has changed significantly in recent years. Think about the digital economy. By some measures digital trade has eclipsed trade in real goods. What are the right rules to govern that sort of trade? Then there’s the development of global value chains, where trade is a series of tasks that are performed in a whole range of countries. Today, you can’t really say that something is “made in Germany” or “made in China.” You need different rules to take account of these new realities, which are about regulatory regimes and how differences between countries affect those flows.

**Brauner:** There are many more relevant players today. In the past, you might have been able to reach agreement with maybe four countries, and they would be able to move the rest of the membership along. Now this is no longer possible. You have to consider a much wider group. And the involvement of civil society is more intense than it was in recent years, with the anti-globalization and trade-critical trends. Democratic governments cannot take positions against a highly vocal civil society.

**Daniel Hamilton**

Daniel S. Hamilton is the Austrian Marshall Plan Foundation Professor and Executive Director of the Center for Transatlantic Relations at Johns Hopkins University’s School of Advanced International Studies in Washington, D.C., USA. He previously served as U.S. Deputy Assistant Secretary of State.



**“If you negotiate a deal and your society isn’t ready to embrace it, it’s all for naught.”**

Professor Daniel Hamilton

**“It’s true that bilateral negotiations allow you to be more focused, but these approaches have important limitations.”**

Karl Brauner, PhD

### Why do trade agreements cause controversy?

**Brauner:** The benefits of trade, just like any economic or technological change, affect different parts of the economy and different stakeholders in different ways. Certain industries come under completely new competitive pressure. It could make them more efficient or it could put them out of business. I think where we have failed in the past is that we have not acknowledged that there are losers. We have only looked at aggregated figures and shown that the national economy, if it’s open, benefits.

**Hamilton:** It used to be that negotiations took place in closed rooms. But if you negotiate a deal and your society isn’t ready to embrace it, it’s all for naught. Given that so many different parts of the economy are affected by these negotiations, there needs to be a way for citizens and various parts of the economy to have a voice in this, including critical voices.

### How are trade negotiation strategies evolving in the face of these challenges?

**Hamilton:** The new trade agenda is emerging more in bilateral and plurilateral agreements, such as the Trans-Pacific Partnership (TPP) between the United States and Asia and the Transatlantic Trade and Investment Partnership (TTIP) between the United States and European Union, with the sort of deep integration that goes beyond tariff reduction and finds ways to deal with non-tariff barriers: new kinds of rules to deal with concerns like the environment and climate change, labor, food scarcity, animal welfare and consumer pressures.

**Brauner:** It’s true that bilateral negotiations allow you to be more focused, but these approaches have important limitations. In the case of extended global value chains, for example, each agreement may have its own protocol on proof of origin, and managing all those protocols eventually becomes so burdensome that companies don’t attempt to make use of the deal. Nor must we forget that these big regional deals have not been concluded yet.

### Can regional trade agreements be a stepping stone to multilateral free trade, or are they a barrier to progress?

**Brauner:** I think they are both. When a regional or bilateral agreement is concluded, you generate freer trade among those partners. But during these negotiations, the countries involved cannot offer anything on the multilateral level because they must

make these offers exclusively to their partners. However, the way that these agreements encourage countries to remove certain obstacles in their trade may also make it easier to bring this level of liberalization to the multilateral scene. Once problems have been overcome in bilateral agreements, countries can negotiate the same subjects at a multilateral level more easily.

**Hamilton:** The political dynamic has changed fundamentally. Brexit has sparked a new debate about the United Kingdom’s future trading relations. Donald Trump wants to renegotiate NAFTA, kill the Trans-Pacific Partnership, raise tariffs on China, and strike bilateral trade deals. The United States and European Union need to reposition themselves to compete in the changing global economy, but the outlook for regional or multilateral trade agreements now looks cloudy. ■



#### Karl Brauner

Karl Brauner, PhD, has been Deputy Director-General of the WTO since 2013. Previously, he was Director General for external economic policy in the German Federal Ministry of Economics, and Germany’s member in the European Union’s Trade Policy Committee. He has attended all WTO ministerial conferences since 2001.



Stock prices on display in the financial district of Tokyo, Japan. Many industries are built on global trade, including the chemical sector.



# Why free trade matters

Teresa Szelest, President, Market and Business Development North America for BASF Corporation, believes that trade creates wealth and spurs innovation, leading to better products and lower prices. As a global exporter and importer, BASF supports comprehensive trade liberalization that goes beyond the removal of tariffs and addresses wider issues such as standards and regulation.

The chemicals sector is built on global trade. In 2015, international trade in chemical products was worth €1.6 trillion. Much of that trade is within the value chains that transform raw materials into consumer products. Around 80 percent of all chemical products are sold to other chemical companies, and much trade takes place between different units of the same company.

Encouraging trade through the reduction of tariffs and other barriers helps BASF, its customers and the chemicals industry. It reduces the cost of inputs and the price of end products, and opens access to new growth markets. At the same time, increased competition through trade accelerates the pace of innovation. That keeps us focused on finding new ways to manage our costs, improve our operations and deliver additional value to our customers.

The best route to achieve multi-lateral trade liberalization has traditionally been negotiations at the World Trade Organization (WTO).

But its latest round of negotiations has come to a halt. Furthermore, the challenges we face today are multi-dimensional, addressing not only the need to further reduce tariffs, but reaching greater international alignment on standards and regulations, and developing solutions to new non-tariff barriers. These complex issues are not currently covered by the WTO, so other answers have to be found. A pragmatic global solution can only be achieved through a “bottom up” process, beginning with bilateral or regional agreements.

To give an example for the importance of regulatory harmonization, take BASF’s pharmaceutical ingredients business. The production plants must comply with strict quality standards. This means the production plants are regularly inspected by both the European Medicines Agency and the U.S. Food and Drug Administration (FDA) using the same international standards.

This duplication of work and cost could be eliminated through an agreement between the two sides without affecting standards. The proposed bilateral trade agreement between the United States and the European Union – the Transatlantic Trade and Investment Partnership (TTIP) – would provide just such a framework for the authorities to recognize each other’s inspections.

Achieving this degree of trust and alignment between the two sides is a complex undertaking. That is why we need to think small first to achieve something big in the end.

Bilateral trade agreements may well prove the most feasible and pragmatic way to strengthen free trade and benefit society – serving as guardians against the recent rise in protectionist policies around the world. For such agreements to succeed, however, they must ultimately be open for countries to join and to shape the way the world does business. ■



**Teresa Szelest**

Teresa Szelest began her current role as President, Market and Business Development North America for BASF Corporation in 2015. She is responsible for BASF’s strategic business development and marketing across the region. She joined BASF in 1988 and held a variety of technical, management and business leadership roles throughout her career. Szelest holds a Bachelor of Science degree in chemical engineering from Rensselaer Polytechnic Institute in Troy, New York, USA.

**“Encouraging trade through the reduction of tariffs and other barriers helps BASF, its customers and the chemicals industry.”**

Teresa Szelest, President,  
Market and Business Development North America for BASF Corporation



 Peru  
Puente Continental

## Shuttling between the Atlantic and Pacific

In January 2016 the world's longest bus line, the Transoceánica, started offering service between Rio de Janeiro and Lima. It takes 102 hours to travel the 6,200 kilometer route between the two cities. Planning for the Transoceánica started in the 1980s. It was meant to serve as a connection between the Pacific and the Atlantic, via Peru and Brazil. The construction materials and bridges were purchased and streets were constructed. But when funds ran out in the middle of the 1980s, only 21 of the 22 planned bridges had been built, so crossing the Madre de Dios River near Puerto Maldonado in Peru required taking a ferry. The construction materials for the 22nd bridge, the final link, were put in storage until 2007 when work resumed. Many of the components required a complete overhaul: The supporting steel cables were replaced, any damage was repaired, and finally, the structure was also strengthened. The Puente Continental, the longest hanging bridge in Peru, was finally opened in 2011 and completed the connecting route between the Atlantic and the Pacific.



## Completely refurbished headquarters of the United Nations

It is the most expensive renovation of a public building ever: It cost \$2.15 billion to update the U.N. headquarters in New York, which opened in 1952. The building complex with the world-famous green-blue shining glass façade was designed by renowned architects such as Le Corbusier, Oscar Niemeyer and Wallace Harrison. The renovation was 30 times more expensive than the original cost of the building. The radical overhaul – including gutting the building, energy efficiency measures and technical updates – began in 2008. It was high time, since not only did the building have crumbling plaster, drafty windows and ancient heating systems, it also contained asbestos and outdated building protection and fire safety technology. The complex does not officially have protected building status because the supranational organization does not fall under the jurisdiction of any authority. Nevertheless, the historic identity of the iconic building had to be maintained. Instead of taking five years as planned, the work was only completed in 2016.



 United States  
U.N. headquarters



### Award-winning restoration

Like a castle adorned with battlements, towers, columns and little round arches, the JN Petit Institute with its library and reading room is a jewel in the historical center of Mumbai. The building was donated by the mother of Jamsetjee Nesserwanjee Petit and dedicated in memory of her only son. The restoration project lasted more than two years, meticulously eliminating all traces of the serious disintegration both inside and outside the building, using materials very similar to those it was originally built with. The plaster used for the decorative ceilings, for example, was imported especially from Paris. UNESCO granted the project an award of merit in its Asia-Pacific Awards for Cultural Heritage in 2015.

## Old buildings enter a new era

Not everyone ages equally well – this is also true for buildings and roads. But something can be done about the unwanted signs of aging and material fatigue, as these successful refurbishment projects from around the world demonstrate.

### Long-term treatment against aging

The clear, cubist forms of the gleaming white Fundació Joan Miró building soar into the blue skies over Barcelona. The idea for this museum came from the Catalan artist himself. It was completed in 1975 by his friend, the architect Josep Lluís Sert, a student of Le Corbusier. However, the quality of the concrete, compounded by its exposure to the salty sea climate, caused the building to age rapidly. It developed corrosion damage in many places, and this meant that repair work had to be started in May 2005. BASF tackled this with Master-Protect® 8000 CI. To this day, this silane-based corrosion inhibitor protects the steel reinforcement in the concrete of the restored building against new damage. At the same time, it forms a barrier to ensure that less water can penetrate into the concrete. This is also demonstrated by long-term measurements: In 2015, 10 years after its treatment, the building was still free of corrosion damage.





"I am the real one."

Identical only on the surface: Aktion Plagiarius e.V. annually awards an anti-prize to the most flagrant imitations. In 2013, a Dubai-based company received the award for its imitation of the "McEgg" egg cup. The original (on the left) is made by the German company WMF.

# Keeping it real

Fake goods are hugely profitable, increasingly sophisticated and often hard to tell apart from the genuine article. The economic impact, brand damage and even potential risk to human health are driving companies to come up with innovative ways to keep one step ahead of the counterfeiters.



"Hey egghead - too bad for you that I just don't care."

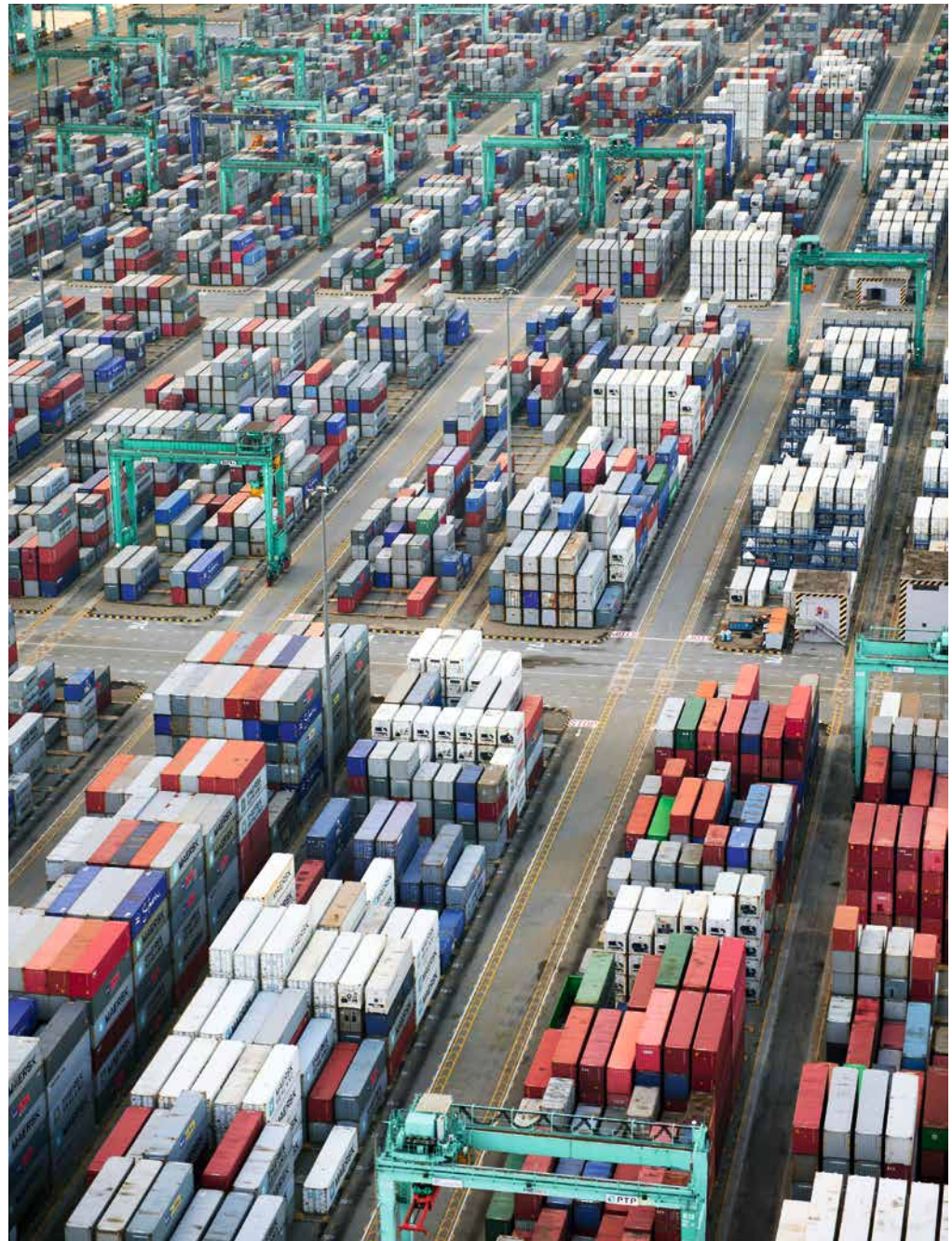
It's the real thing" may be one of the most famous advertising slogans ever, but how can consumers be sure that the products they buy are genuine, or companies ensure that the parts and materials they use really are what suppliers claim them to be? Whether it is imitation designer goods, or the dangerous trade in counterfeit pharmaceuticals or vehicle parts, fakes are big business.

Criminals are drawn by a tempting combination of big profit and small risk. "Almost every consumer item and most industrial components can and have been counterfeited," says Pottengal Mukundan, Director of the International Chamber of Commerce's Commercial Crime Services.

**Registering rights is key**

According to the European Union's law enforcement agency Europol, the most significant enabler for distributing counterfeit goods is the internet. Consumers are attracted by low prices and direct delivery, and some sites are hard to distinguish from those owned by the genuine rights holder. "It's easier today to close down sites selling or distributing counterfeit products, but on the other hand it's just as easy to immediately replace them," says Mukundan, and as it is an activity that transcends national jurisdictions, legal action can be difficult.

To protect their brand, companies should formally register trademarks and designs, stresses Paul Maier, Director of the European Observatory on Infringements of Intellectual Property Rights (IPR) at the European Union Intellectual Property Office (EUIPO). "It's vital for companies to have rights which they can prove belong to them, through certificates



issued by intellectual property offices. For trademarks, registration is a prerequisite to be protected in most jurisdictions, and an essential element of proof for designs." By registering their rights, companies can also use the EUIPO enforcement database, a secure tool providing direct communication between rights holders, customs and police to fight counterfeiting.

Businesses should also regularly monitor the internet for fake sites or products, and make sure that they are fully up to speed with the legal framework in all the territories where they operate. It helps to make regular test purchases and check

**Around 80 percent of global trade by volume is carried by sea. With the market for fake goods growing, new anti-counterfeiting technologies are constantly needed to tackle the problem.**

on sales networks and distribution channels as a matter of course. "In the process of market monitoring for any IPR infringements, customer feedback and information from business partners have been identified as the most reliable and relevant sources of information on infringements among small businesses notably," says Maier. Collaboration between public and private sectors on enforcement operations, and knowledge sharing with enforcers are also essential.

Pharmaceutical, crop protection, cosmetics and technical products like car parts and household appliances can all be counterfeited.

## The world's most counterfeited goods<sup>1</sup>

1

### Footwear



27,119

Leading sneaker brands are among the world's most infringed trademarks

2

### Knitted or crocheted clothing



17,995

Fake versions of designer items are becoming ever more sophisticated

3

### Leather goods



17,960

Luxury handbag designs can be one of the most lucrative products for counterfeiters

4

### Electrical machinery and equipment



15,907

Low-priced fakes frequently contain faulty parts that can over-heat or deliver electric shocks

5

### Watches



6,927

Premium brand names are among the counterfeiters' favorite targets

There are also fake versions of food and beverages. When even the materials used for production can be susceptible, tackling counterfeits is an issue for all kinds of manufacturers.

#### Smart anti-counterfeiting technologies

In the textile industry, for example, market surveys have revealed that some retail labels misrepresent the percentage and identity of cotton fiber, according to James Hayward, PhD and CEO of U.S. firm Applied DNA Sciences (ADNAS). Customers were not getting the quality they had paid for, so his company developed a clever solution to this problem, using markers based on plant genetic material deoxyribonucleic acid (DNA) to authenticate content. "We think of it as kind of diagnosis and then therapy," he says. "Our 'fibertyping' technology tells us what type of cotton you have in your product, and the therapeutic part is to DNA-mark the fiber during production." The raw cotton is marked at the cotton gin stage, and followed through the spinning and weaving processes right up to the point when it reaches the retailer or consumer.

The technology is able to withstand extreme temperatures, abrasion and even ultraviolet radiation. It has enabled companies that had difficulties controlling their off-

**"There is growing demand for laser marking. The possibilities it offers to tackle counterfeits are almost limitless."**

Steffen Ehrenmann, PhD, Product Manager at TRUMPF

shore supply chains – with products coming back with 20 percent compliance or below – to achieve 100 percent compliance, based on more than 1,000 DNA tests. Furthermore, the amount of DNA required is only one part to a trillion parts of cotton fiber. "It is so miniscule that there's no impact on any fiber, whether it's synthetic or natural," says Hayward.

Laser marking is another technology helping companies prove that their products and parts are genuine. TRUMPF, a global high-tech company headquartered in Ditzingen, Germany, produces lasers that can mark many materials quickly and durably, including metals, plastics and organic materials like leather. A mobile phone or hand scanner linked to a database reads the encoded information. The marking itself might be hidden within the product or so tiny as to be almost invisible. Lasers can even mark under the surface or make a local change to the material composition of the top layer.

"There is growing demand for this technology," says Steffen Ehrenmann, PhD, Product Manager at TRUMPF. "We have customers in automotive, aerospace, medical devices and the food industry, among others. The possibilities it offers to tackle counterfeits are almost limitless."

TRUMPF's lasers can be used to mark a wide range of products, such as medical devices, to show they are genuine.



<sup>1</sup> By number of customs seizures. Quantity of product per seizure varies. Source: Organization for Economic Co-operation and Development (OECD) and European Union Intellectual Property Office (EUIPO)



**The Grand Egyptian Museum in Giza is the largest archaeological museum in the world. BASF provided the special concrete mix that contributes to its stunning appearance – a look that could not have been achieved with an inferior product.**

In China, the impact of counterfeits on the crop protection market is estimated to be between 10 and 15 percent. “A pretty substantial slice,” says Mark Shillingford, BASF’s Head of Marketing Crop Protection in China. What is harder to estimate is damage to crop production, farmers’ yields, their land and, potentially, to human health and product reputation.

#### **Anti-fake labels and invisible tracers**

To address this, BASF has developed a color additive labeling process, launched in late 2014. Genuine products feature a watermark that is invisible indoors but displays Chinese characters when exposed to sunlight. Within six months of launching, however, the technology was being copied. “We were already planning for obsolescence,” Shillingford explains. “This year we launched a new counterfeit technology, involving different codes, which we hope will keep us one step ahead of the counterfeiters. This new technology is on the inside and outside of the packages and you need special equipment to read it.”

**“Imagine you have a bridge that’s collapsed and you want to trace whose cement it was – you can do that, as well as find out if the company used a sufficient quantity of premium cement in the concrete.”**

Lorenzo Ambrosini,  
Segment Manager at BASF  
Construction Chemicals  
Zurich, Switzerland

Even the cement production industry has attracted counterfeiters. “A producer can open cement bags, take out 10 percent, and put in sand instead, or not use the right amount of cement needed in concrete, for example,” explains Lorenzo Ambrosini, Segment Manager at BASF Construction Chemicals in Zurich, Switzerland.

Cement production is highly complex and, once the product has left the plant, it can be difficult to track. However, BASF has developed a tracer that uses a dispersion of acrylic co-polymer particles dyed with fluorescent material that stick to the cement particles. “The combination of colors means we can create a code for the cement, like a barcode. But it’s hidden, so you need the right equipment to see it,” says Ambrosini. It allows the cement to be measured after years in hardened concrete. “Imagine you have a bridge that’s collapsed and you want to trace whose cement it was – you can do that, as well as find out if the company used a sufficient quantity of premium cement in the concrete,” he says.

The technology for measuring the particles is not yet automated,

according to Ambrosini. “It’s still manual work, but one day you’ll be able to take simple equipment to your building site, point it at your concrete wall and scan.” He believes similar labeling technology could also be used for other premium, high-performance products such as paints or cosmetics.

In the world of counterfeits, one thing is sure: Fast-changing technologies and disruptive developments such as 3D printing are likely to mean that the threat will require ever more ingenious responses. Businesses are likely to find that investing in doing all they can to protect themselves, and choosing trustworthy partners, will pay for itself many times over. In the meantime, there’s a very simple rule for all to bear in mind, says Mukundan. “Be wary of products that appear cheaper than they should. There’s usually a reason why they are.” ■

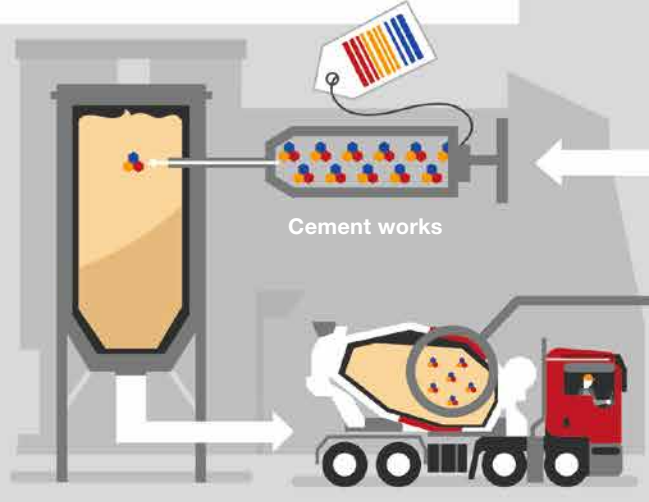
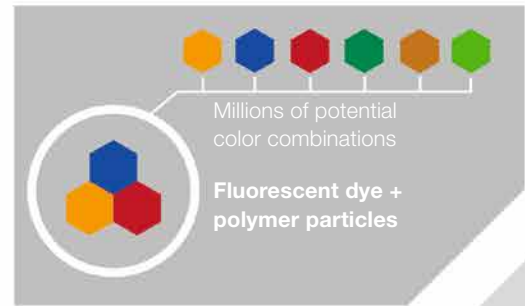


# A barcode for cement

For some jobs only a premium cement will do. That's why BASF has developed a way to label cement with an invisible chemical tracer. Like a barcode, it stays with the cement throughout the distribution chain, helping protect customers from counterfeit products.

A chemical tracer is a milky liquid dispersion of polymer particles dyed with a fluorescent material invisible to the naked eye. The chemical tracer particles can be dyed with a single color or a number of colors, creating millions of potential combinations.

## Chemical tracer

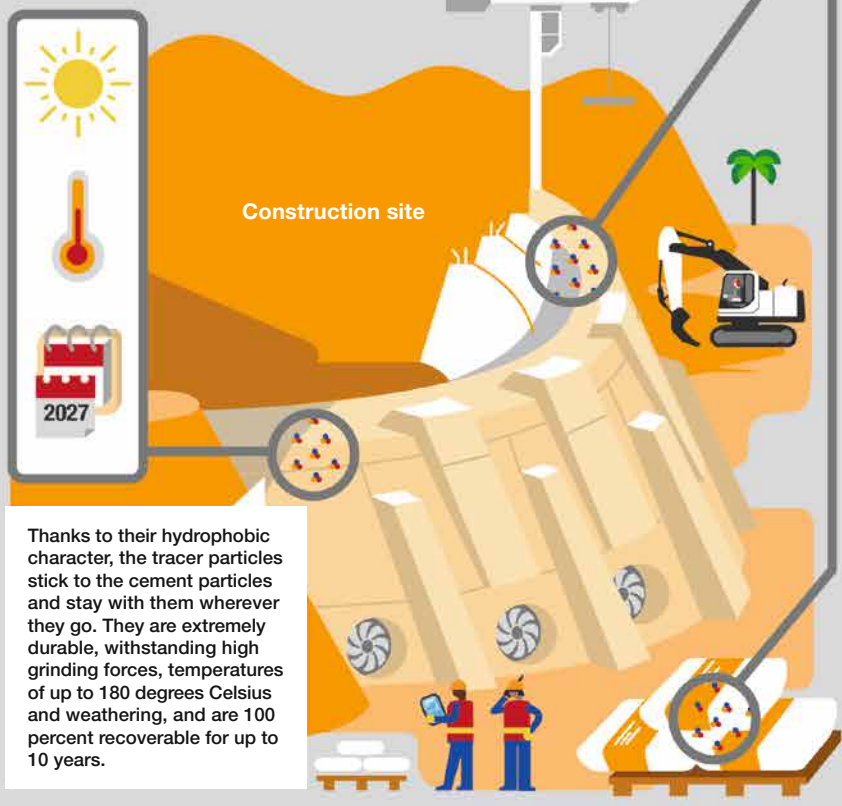


At the cement works, the dispersion with the tracer is dosed onto the cement clinker through a screw pump. The clinker is milled, producing an even distribution of the tracer particles.

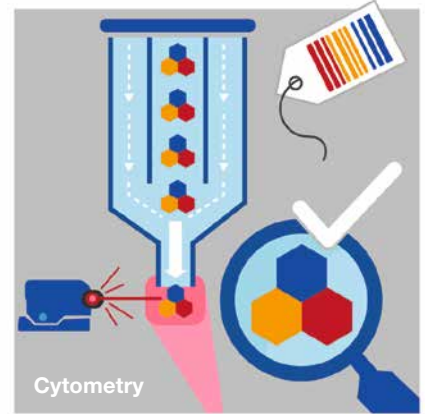


## Laboratory

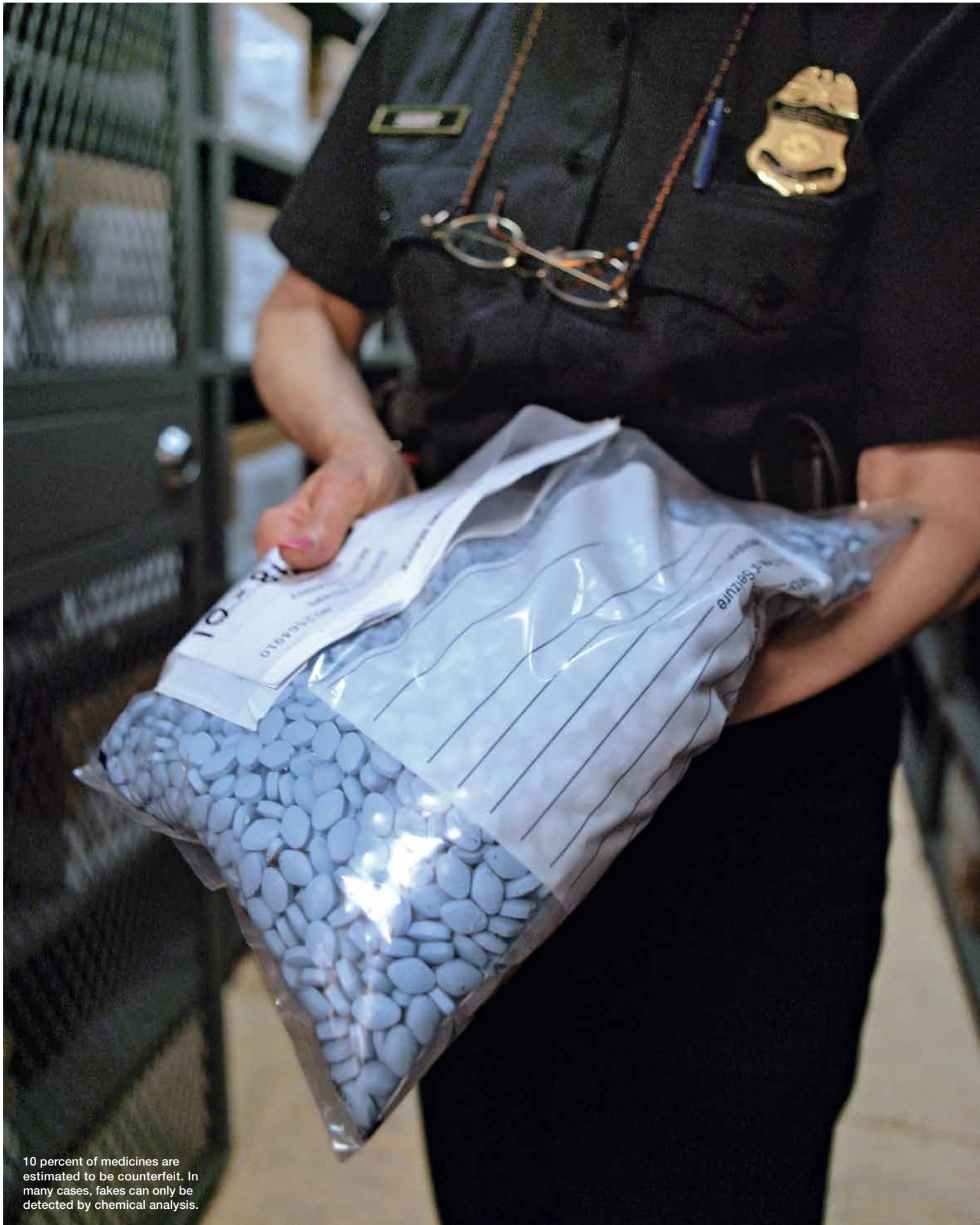
Samples can be collected at any point in the distribution chain and sent to a lab for analysis.



Thanks to their hydrophobic character, the tracer particles stick to the cement particles and stay with them wherever they go. They are extremely durable, withstanding high grinding forces, temperatures of up to 180 degrees Celsius and weathering, and are 100 percent recoverable for up to 10 years.



The tracer particles are analyzed by flow cytometry, a process more often used in medical diagnosis, such as counting human cells. They are passed through a narrow stream of flowing liquid and then excited by a laser beam which causes them to emit their fluorescent light. The fluorescence ranges of the emitted light are visualized in a cytogram, enabling the different particles to be identified and counted. If the concrete has been watered down with a lower quality of cement, it will become obvious at this stage.



10 percent of medicines are estimated to be counterfeit. In many cases, fakes can only be detected by chemical analysis.

# “A significant threat to our economy, health and safety”

U. S. Customs and Border Protection is on the frontline in the battle against the counterfeiters. Based in Washington, D. C., USA, the department’s Director of Intellectual Property, Michael Walsh, heads up a staff of international trade specialists and oversees the Los Angeles-based National Targeting and Analysis Group for intellectual property rights. In an interview, he describes some of the job’s main challenges.

## Creating Chemistry: How big a problem is counterfeiting?

**Michael Walsh:** It’s a significant threat to our economy, as well as health and safety. We’re very dedicated in terms of enforcement actions to try to stop as many of the counterfeit goods coming in as we can.

## Which goods tend to be the most counterfeited?

Over the past five years we’ve seen a continued trend where fashion, consumer electronics, footwear, watches, handbags and optical media have been among the most seized items.

## On a day-to-day basis, what are the main challenges?

It’s the ever-increasing flow of goods into the country, and trying to use our resources as effectively as we can. The counterfeiters have become very sophisticated, and trying to determine if goods are counterfeit becomes quite a challenge.

## What is a typical day for a customs officer?

Officers have their primary responsibility at the border working with passengers, but if they’re working with trade then it’s looking for all the different potential violations. That means ensuring all our trade and intellectual property agreements are complied with, or looking out for concerns with regard to safety. All of that’s part of their day-to-day work. The part relating to intellectual property rights is important because many of the goods that violate these rights have the potential to do harm to the American public.

## How are officers being trained and do they specialize in specific market sectors or goods?

That’s an ongoing issue. We work very closely with the rights holders to provide continuous training to frontline personnel. Our frontline officers make the initial determination and work with industry specialists at our Centers of Excellence and Expertise to make further determinations. It is a combination between making the initial determination and specialists making the final determination, working closely with the rights holders themselves. We try to expedite that as quickly as possible to make sure we’re not holding up legitimate goods.

## What are the department’s most effective tools?

I think it’s the coordination and cooperation with the private sector, letting us know about areas of concern, providing good product identification guides, and making sure we can rely on them when we have questions. We have a lot of sophisticated tools in our laboratory and scientific services, but the work with the private sector is critical. We’re looking to continue to evolve as counterfeiting techniques evolve, and we’re continuously giving new instructions to our folks on what to look for, how to look for it, and what to do about it.

## Will you reveal to us some of the more unusual measures counterfeiters take to import their goods?

People will go to great lengths. We’ve seen outer shells on handbags that, when taken off, have brand names underneath, or labels sewed over the tags on sneakers that can be removed to show the counterfeit label afterwards. People can be very creative. ■



Michael Walsh

As Director of IPR Policy and Programs at U.S. Customs and Border Protection’s Office of Trade, Michael Walsh is national coordinator of efforts to stop counterfeits entering the United States. A 25-year customs veteran, he is a graduate of Harvard’s John F. Kennedy School’s Senior Executive Fellows program. In 2015 his department seized more than 28,000 counterfeit items with a value of over \$1.3 billion.

**“The counterfeiters have become very sophisticated, and trying to determine if goods are counterfeit becomes quite a challenge.”**

Michael Walsh, Director of IPR Policy and Programs at U.S. Customs and Border Protection’s Office of Trade

# The chemistry of apples

The water molecule  $H_2O$  is one of around 300 substances contained in an apple.

Water  
Glucose  
Fructose  
Sucrose  
Lignin  
Pro vitamin A  
Thiamine (vitamin B1)  
Riboflavin (vitamin B2)  
Niacin (vitamin B3)  
Pyridoxine (vitamin B6)  
Cobalamin (vitamin B12)  
Ascorbic acid (vitamin C)  
Folic acid (vitamin B9)  
Tocopherol (vitamin E)  
Vitamin K  
Chlorine  
Iron  
Potassium  
Calcium  
Copper

Magnesium  
Manganese  
Sodium  
Pectin  
Phosphorus  
Sulfur  
Zinc  
Aspartic acid  
Cysteine  
Glutamic acid  
Uric acid  
Leucine  
Lysine  
Cumaroylquinic acid  
Caffeoylquinic acid  
Phloretin  
Procyanidin  
Quercetin (flavonol)  
Formaldehyde

**Wild apples have been growing for millions of years and there is evidence that they were cultivated in Asia as early as 4,000 years ago. From there, apples spread across the world and gained a reputation as a healthy food – and for good reason: A “fruit pharmacy” is lurking in and just below the peel.**

**I**t is said that a falling apple inspired Isaac Newton circa 1660 to come up with his revolutionary idea of gravity. Today, apples are the world's most cultivated fruit – and still a source of inspiration for scientists, for example, because of the wealth of substances they contain.

An apple contains nearly all of the vitamins that humans need for their metabolic processes, including E101 and E300. Riboflavin (E101), also known as vitamin B2, is a natural dye and is important for protein and energy metabolism. Ascorbic acid (E300) is better known as vitamin C and is one of the most effective antioxidants. On average, 100 grams of apple contain 12 percent of the recommended daily intake of Vitamin C.

As well, minerals and trace elements based on calcium, magnesium, sulfur, phosphorus and chlorine are found in apples. Even just one small apple provides around one-tenth of your daily potassium requirement – this is good for fitness and concentration and helps to improve muscle tone. Munching on an apple also seems to help people lose weight. This slimming effect is attributed in part to the pectin contained in the apple – due to its water-binding properties, it makes you feel full faster.

But what exactly is in and under the peel? Which chemical building

blocks are contained in apples and what effects do they have? “The apple cells’ molecules are distinguished from each other by many factors, depending on variety, harvesting time and method. All apples have almost identical DNA sequences, but they differ from one variety to another,” says Luca Sebastiani, Professor of Horticultural Science at the Istituto di Scienze della Vita in Pisa, Italy. But one thing they have in common is that every apple is mostly (85 percent) made up of water and contains roughly 11–14 percent sugar, primarily fructose. Various other substances in the apple account for the remaining few percentage points. These include polyphenols as antioxidants, which are important for the apple. They are responsible for the color and aroma of the fruit, regulate the metabolic activities of the apple and protect it from damage, such as damage caused by intense solar radiation.

#### **Rich in nutrients**

People benefit from the same properties: The positive effect of antioxidants appears to help prevent illnesses such as asthma and cancer. More than 200 milligrams of these polyphenols can be contained in 100 grams of apple. One of these is the plant pigment quercetin, which is “being researched as a natural therapeutic agent against high blood pressure,” says Sebastiani’s colleague, Professor Rossella di Stefano, who is investigating therapies for cardiovascular illness at the University of Pisa. “Various studies

**Three-quarters of the valuable substances contained in an apple are found in or directly under the peel.**

**An apple contains nearly all of the vitamins that humans need for their metabolic processes and it provides around one-tenth of our daily requirement of potassium.**

on humans and animals have provided indications,” di Stefano adds, “that quercetin has a possible therapeutic role in the treatment of hypertension.”

Two-thirds of the effective antioxidants in an apple are contained in and just below the skin, so eating it unpeeled is a good idea. “All apple varieties are healthy and their consumption is important for humans’ well-being,” says Sebastiani. Apples are a great source of nutrients – even though the seeds contain amygdalin, which human metabolism turns into hydrocyanic acid. There is no risk of poisoning if you eat every part of the apple, but eating only the seeds is not advisable. Even just a small volume – around 10 grams of chewed apple seeds – can be harmful to the human body. One kilogram of apples can also contain as much as 20 milligrams of formaldehyde, the common name for the chemical compound methanal. Formaldehyde, like many other substances, is a necessary component for the metabolism of organisms – and not just of apples.

A great deal of research has been done, but the complex contents of the apple, their interaction and their effects still leave some scope for scientific activity. “More large-scale, randomized and well-controlled human intervention studies are required to explore the potential mechanisms,” di Stefano says. For now, the fruit still holds some secrets under its red and green skin. ■



# Storing sunshine

Solar thermal power plants turn the sun's energy into electrical energy. Their major advantage: With heat storage systems, they are also able to supply electricity when the sun isn't shining. Discover more about this environmentally friendly technology which experts predict has a bright future.

The largest solar thermal power plant in the world is being built on the edge of the Sahara: By 2018 it should supply electricity to more than 1.3 million people. The first plant, Noor I, is already up and running – day and night.



**H**undreds of thousands of mirrors – arranged in 800 rows, each hundreds of meters long – glisten in the desert sun on the red earth of Ouarzazate in southern Morocco. What looks like a mirage in the shimmering light of the desolate plains is a power generating station worthy of superlatives. The solar thermal power plant in Ouarzazate will become the largest in the world, roughly as big as 4,000 soccer fields. Since it started up in February 2016, the first phase Noor I (“noor” means “light” in Arabic) has been operating with a nominal output of 160 megawatts (MW) of electricity. This is enough to supply 350,000 Moroccan households. “Solar thermal power plants concentrate the sun’s light to generate high temperatures. In sunny regions, they can generate environmentally friendly electricity from a renewable source on a large scale,” explains Professor Robert Pitz-Paal, Director of the Institute for Solar Research at the German Aerospace Center (DLR) which has been conducting research into solar thermal power plants for nearly 40 years.

Concentrating solar power (CSP) is most suitable for countries with high solar intensity, according to solar experts. Sites with high energy yield where solar thermal power plants are being built or already operating can be found in southern Europe, North Africa and the Middle East, South Africa, China, the southern United States and Australia. The Moroccan solar park has a perfect location: The solar radiation intensity in the area around Ouarzazate reaches more than 2,500 kilowatt hours (kWh) per square meter and per year – one of the highest levels worldwide.

#### **Sun as a source of energy**

Just like sunflowers, the 537,000 computer-controlled parabolic mirrors rotate to always follow the sun. At the

Noor I plant, they act like a magnifying glass, concentrating the sun's rays and turning them into heat energy. Each of these slightly bent mirrors is more than 10 meters high and has pipes running through its middle that contain a circulating thermal oil. The synthetic liquid, which can be heated up to 393 degrees Celsius, is sent to the power plant at the center of this giant field of mirrors. Here, steam is generated which is used to drive the enormous turbines of the power plant and generate electricity.

To make electricity available even after the sun goes down, large heat storage units were installed. Solar thermal power plants thus have a decisive advantage in the renewable energy mix: Electricity can be used around the clock. "Energy can be saved here in the form of heat at a relatively low cost. With thermal storage units, such as large salt tanks, these power plants can therefore also provide a reliable source of electricity even in the evening and at night when the sun is no longer shining," explains Pitz-Paal.

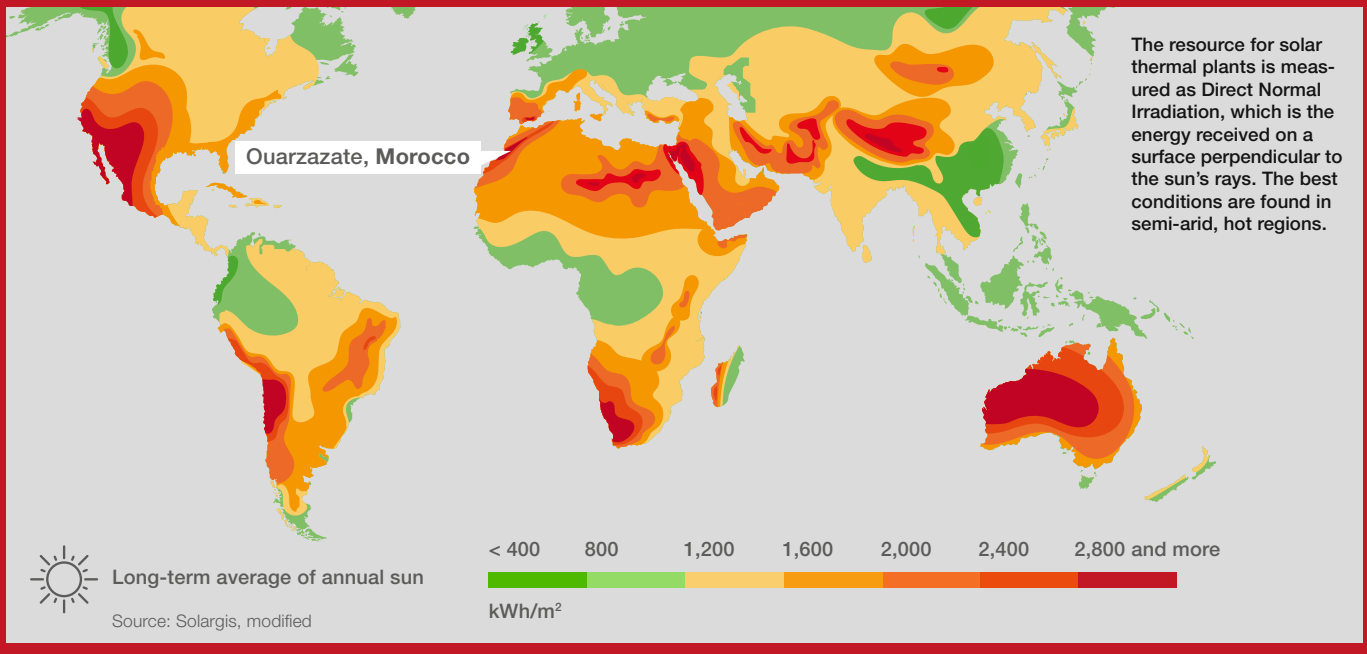
**Solar mecca**

The heat storage units at Noor I are made up of two giant steel tanks: "These contain a special salt mixture made with potassium and sodium nitrate, which liquefies at tem-



The sun reaches temperatures of up to 15 million degrees Celsius. Only a mere fraction of this radiant power reaches the earth – yet it would still be enough to meet the energy demand of everyone on the planet.

**Global Direct Normal Irradiation**



The resource for solar thermal plants is measured as Direct Normal Irradiation, which is the energy received on a surface perpendicular to the sun's rays. The best conditions are found in semi-arid, hot regions.



peratures of around 240 degrees Celsius,” says Matthias Hinrichs, PhD, Manager Solar Business and New Business Development Inorganics at BASF. For more than 90 years, the chemical company has been producing storage salts, focusing on ultrapure synthetic sodium salts. By releasing the heat from the stored salt, the CSP power plant can maintain its full performance overnight. One advantage of the synthetic sodium salts made by BASF: “Thanks to their high purity and quality, these can be used to make salt mixtures that can be heated up to a temperature of 565 degrees Celsius with minimal corrosion. And if there are careful controls of the chemical conditions in the CSP power plants, the mixtures can even get hotter,” Hinrichs explains. Enormous volumes are required for the salt mixtures in the storage tanks: BASF produced around 27,000 metric tons of sodium nitrate in Ludwigshafen just for this plant in Morocco.

Noor I is only the beginning: The model project is designed to have four power plants and a capacity of around 500 MW by the end of 2017. According to the study “Solar Thermal Electricity – Global Outlook 2016,” countries such as Morocco are thus making an important contribution to reducing emissions of greenhouse gases. By 2020 the countries in the “sun-belt” – those located between 40° north and south of the equator – could avoid 32 million metric tons of CO<sub>2</sub> by using CSP. The study, which was commissioned by SolarPACES, a technology program of the International Energy Agency (IEA), Greenpeace and the European Solar Thermal Electricity Association (ESTELA), also found that the use of this climate-neutral energy source in these countries would create investments worth €16 billion by 2020 and 70,000 new jobs in the future.

#### Modest start, promising outlook

The principle is not new. According to a legend from ancient Greece, Archimedes concentrated sunlight using burning lenses in order to fend off a Roman invasion. But, over time, the technology has been refined (see infographic on page 51).

## China's Solar Valley

The various ways the sun's energy can be used are demonstrated by the city of Dezhou in China, where the sun heats water in households and photovoltaic installations generate electricity. Dezhou, a model city for solar power, is just one of the numerous eco-cities that are being built in China right now, prompted by the law on renewable energies that entered into force in 2006.

Dezhou takes advantage of its location: This sunny city in the east of China is the world's largest production site for solar water heaters. The many solar heating systems are another hallmark of Dezhou's “Solar Valley”: Around 90 percent of all of the residential buildings in the newly built district have their hot water heated by the sun. Dezhou is the headquarters of Himin Solar Corporation, a pioneer in the solar thermal field which makes the eco-friendly water heaters affordable for poor households, too. The cheapest model costs around €200. Company founder Huang Ming has been harnessing the power of the sun since 1995. For his solar innovations, “China's Sun King” received the alternative Nobel Prize, the Right Livelihood Award, in 2011.

The Solar Valley project was initiated by Dezhou's local government in 2005. It has largely been planned and built by Himin Solar. This solar model city shows that solar energy can be an alternative to conventional energy when the weather conditions are right. The sun's rays power the stoplights that direct traffic and the streetlights that illuminate the city, while visitors can ride on solar-powered buses and boats. Solar collectors have been mounted on factories, rooftops and façades and are even an eye-catching architectural feature: The low-emission high-rise development Utopia Gardens is crowned by giant floating sun sails made of solar modules. The landmark of Solar Valley is the Sun-Moon Mansion, the world's largest solar-operated building with an area of 75,000 square meters.



China harnesses the power of the sun: The Sun-Moon Mansion in Dezhou is the world's largest solar-operated building (top picture). Collectors are inexpensive and in the cities many residents use warm water that has been heated by the sun (bottom picture).

Just prior to the First World War, a pilot plant was built in North Africa that concentrated the sun's rays. After the Second World War, the green technology experienced a revival, more pilot power stations were built, and in the mid-1980s the first commercial solar thermal power plant went online in southern California. Spain and the United States are the world leaders in terms of CSP capacity right now, but other countries are catching up. By 2020, China wants to start up solar thermal power plants with a total capacity of 10 gigawatts (GW) and Saudi Arabia is planning to have 25 GW of CSP capacity by 2032.

In order to successfully create a future energy system based on renewable sources, the technology shift will have to be accelerated, asserts the IEA in its technology roadmap. Solar thermal power plants will play an important role, according to the IEA. But for now, the reality is different. At the end of 2015, there were solar thermal power plants with a capacity of 4.9 GW operating worldwide. To put this in perspective: The electricity generated from renewable energies at that point was 1,985 GW. One reason for the slow growth is increased cost pressure. The specific investment costs per installed kilowatt of solar thermal power plants were initially cheaper than photovoltaic systems. But this advantage has reversed as a result of the sharp price decline for solar modules since 2011. This downward price trend was made possible in part by high subsidies.

Luis Crespo, PhD, president of ESTELA, thinks it is pointless to do a pure cost comparison of photovoltaic and CSP: “Renewable energies can complement each other. The fact that solar thermal power plants allow energy to be stored is what makes the further expansion of renewable energies possible.” New hybrid projects, for example, combine photovoltaic and CSP technologies. And although growth has lagged the projections made in the past, the above-mentioned study on the future of solar thermal electricity, which was co-authored by Crespo, foresees a bright future for solar thermal power (see infographic on page 50).

**The higher the temperature, the more efficient the plant**

In the view of solar experts, one major prerequisite for making solar thermal power plants more competitive is higher operating temperatures: As the process temperature increases, the plants can generate proportionately more power from the heat provided. “A very promising solution is the power tower where tracking mirrors, known as heliostats, direct the sun’s rays very precisely to a high-temperature receiver at the top of the tower,” says Mark S. Mehos, head of the research and development department for solar thermal power plants at the National Renewable Energy Laboratory (NREL) in Colorado, USA. The strong concentration of solar radiation results in operating temperatures of more than 550 degrees Celsius. An NREL study on the future development of solar thermal power plant technology shows that this can improve the efficiency of today’s plants, resulting in lower costs for delivered energy.

**Higher operating temperatures with salt**

BASF researchers are also working on increasing the operating temperatures. They are investigating the chemical behavior of the salts at high temperatures in order to identify measures that would enable the storage salts also to be used directly as a heat transfer medium. The thermal oils that are usually used



Solar towers achieve the highest thermal efficiency. The PS20 power plant belonging to the company Abengoa Solar in Seville, Spain, has an output of 20 megawatts.

**From solar cannons to Olympic torches – a look back at the beginnings of solar thermal power**

The history of solar thermal energy is almost as old as human history. By around 800 BC, the Egyptians had created basic solar mirrors which they used to light up dark rooms. The mirrors could also focus the sun’s rays so that they warmed up a container with water. An even more spectacular application is the device that the solar pioneer and famous mathematician Archimedes reputedly designed in 212 BC. According to legend, during the siege of Syracuse he used the sun’s rays and a highly polished bronze shield as a mirror to set fire to the entire Roman fleet, causing it to sink. Students at the Massachusetts Institute of Technology (MIT) rebuilt Archimedes’ apparatus in 2005 to test whether the legend was true. They found that it works in principle, but they were only able to start a small fire at a very short distance of 25 meters away. But one ancient sun-related ritual is still carried out: To this day, every four years the Olympic torch is lit with the help of the sun using a parabolic mirror.

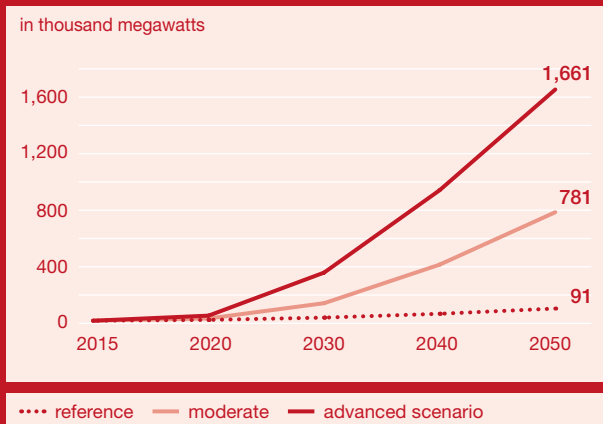
break down at temperatures of more than 400 degrees Celsius. And if salts could replace oils as heat transfer media, the power plants would be able to operate at even higher temperatures and therefore more efficiently.

To ensure that the salt chemistry is taken into consideration from the initial planning stage for a CSP power plant, BASF not only offers the storage salt, it also provides consulting services for the planning, construction and operation of the plant. Another boost to the competitiveness of CSP has been the decline in costs for components such as mirrors and pipes in recent years. And the more solar thermal power plants go online, the more this trend will intensify, says ESTELA president Crespo. However, he feels there are not enough new CSP projects in the pipeline right now: “The obstacles are political, not technology-related.”

The association is therefore calling for stable political framework conditions and reliable planning processes for investments in the expansion of solar thermal electricity. Crespo asserts: “If everyone involved acts in concert, concentrating solar power could be the most important form of climate-neutral energy in the 21st century.” ■

**Amount of energy from solar plants will grow – Forecasts under three scenarios**

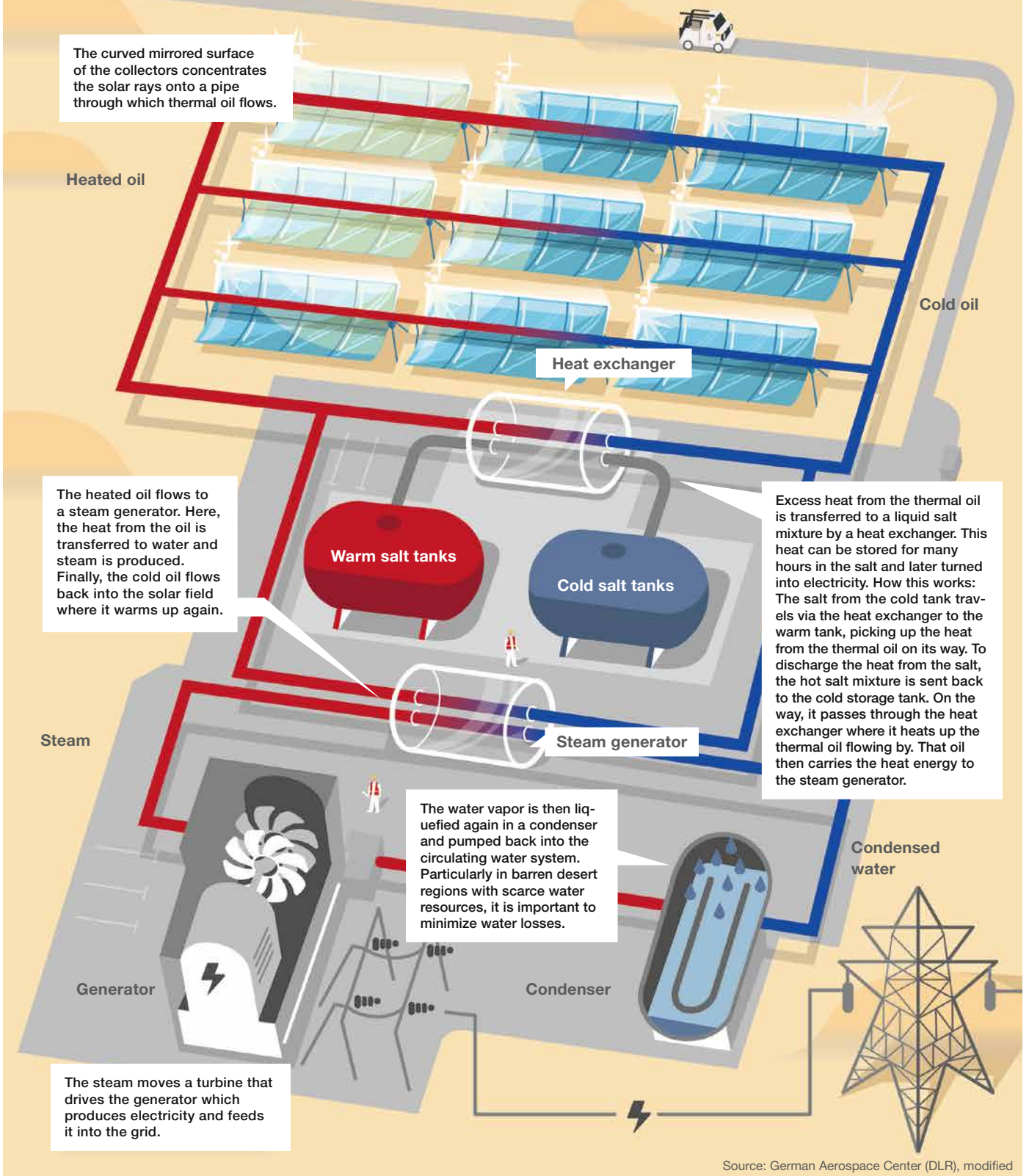
The amount of solar thermal electricity from concentrated solar power plants is expected to grow over the coming years.



Source: International Energy Agency (IEA)

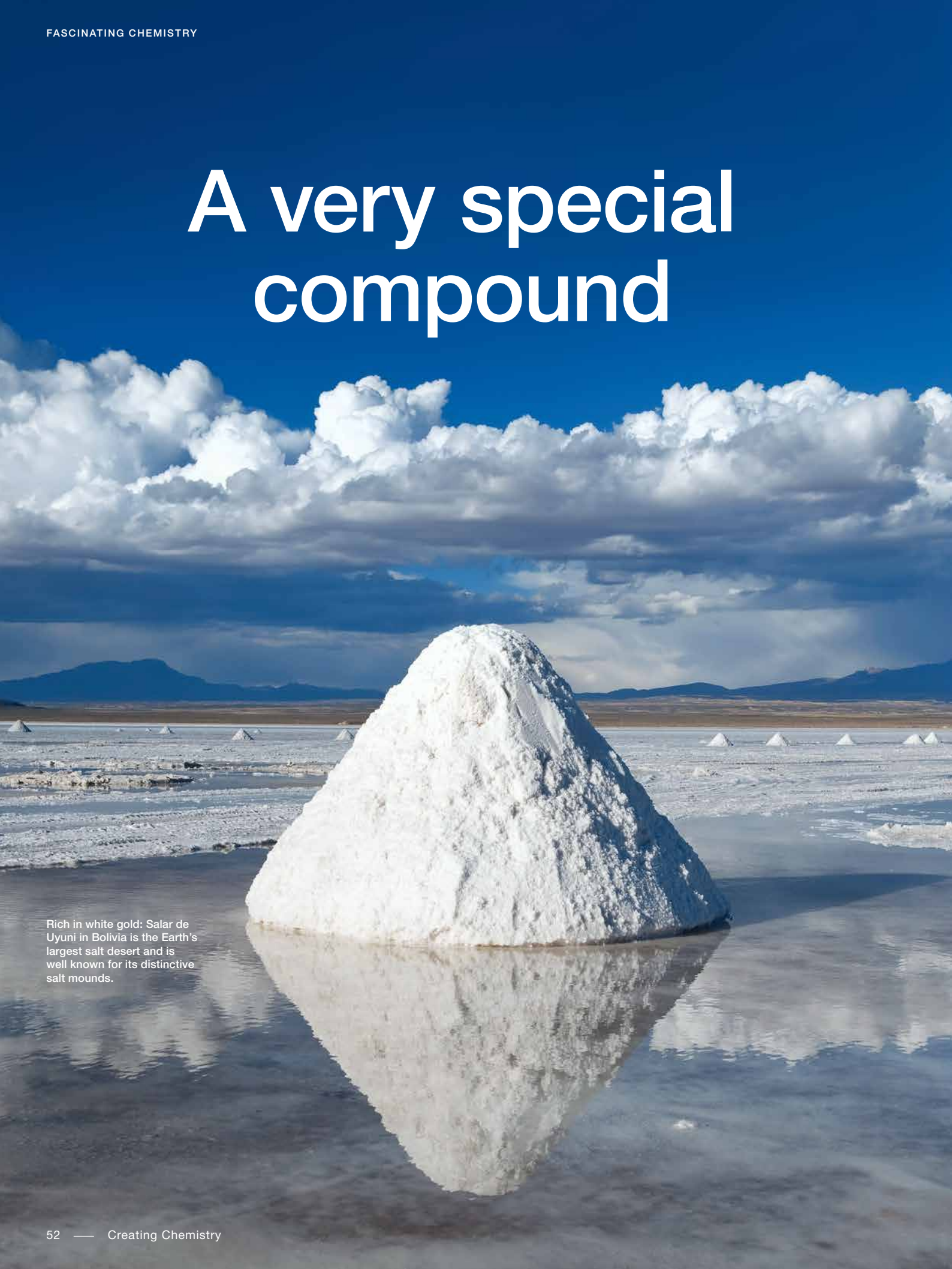
## Sun in the mirror

A concentrating solar power (CSP) plant is a thermal power plant that uses the sun's energy to produce electricity. Mirrors concentrate the sun's rays in order to warm up a heat transfer medium to high temperatures. One difference between the various types of solar thermal power plants is the shape of the collectors that capture the sun's energy. Using the example of the popular parabolic trough technology, we will show you how it works.



Source: German Aerospace Center (DLR), modified

# A very special compound



Rich in white gold: Salar de Uyuni in Bolivia is the Earth's largest salt desert and is well known for its distinctive salt mounds.

Salt is much more than just a condiment. And food is not the only thing that needs a pinch of salt: It is also found in soap, glass and plastic containers.

**C**areful – it's

easy to get confused. Have you ever had to spit out your first sip of coffee in the morning because you accidentally added salt instead of sugar? But aside from taste, what does salt have that sugar doesn't, even though the two look so similar? Salt's electrostatic forces are what make it a very special raw material in all its forms and facets. When we talk about salt in an everyday context, we mean sodium chloride, also known as table salt. But from a chemistry perspective, it is just one of many salts, since "salt" covers all of the ionic solid compounds. They often form stunning crystal shapes, but not every crystal is a salt.

Each salt has a positive and a negative charge and thus the desire to bond. This property is what makes salt so multi-talented. For example, in the bathroom, where salt in the form of soap (in chemistry terms, the sodium and potassium salts of fatty acids) is waiting to bind with the fats on our skin and the particles of dirt they contain. It is also practical that some plant pigments are just as eager as salt to make electrostatic bonds – the red wine stain on the flokati rug becomes invisible when rubbed with salt because the salt and the pigment are attracted to each other.

#### Not all salt is the same

Salts can be white or colorful, like the purple-colored potassium permanganate which is used in deo-

dorants because of its disinfectant properties. Salts can taste spicy, such as ammonium chloride, a component of salty licorice. Or salts can also taste sweet, like lead acetate (also known as lead sugar) which is poisonous but was nevertheless used as a sweetener until the 19th century. Some salts are even highly toxic, such as potassium cyanide, which is used in gold extraction.

The best-known salt is sodium chloride. But around 95 percent of global table salt production does

**On average, our bodies contain 150–300 grams of sodium chloride. Without salt we would be unable to live.**

not end up on our table – instead, it is used as an industrial raw material for numerous products, ranging from aluminum to pulp.

Salt has very special properties when it is moving, i.e., in liquid form. "Ionic liquids are made up of electrically charged molecules," explains Professor Barbara Kirchner from the Mulliken Center for Theoretical Chemistry at the University of Bonn, Germany. Surprising reactions are possible in these kinds of liquids. "From the various combinations of molecule ions, you can get an endless variety of new liquids," the researcher explains. "Right now, research is being done into their energy storage properties in the field of lithium-air batteries." And in solar thermal energy, ionic liquids play an important role as heat storage media.

#### Enjoy in moderation

No living creature is able to survive without the physiological functions of salt. On average, our bodies contain 150–300 grams of sodium chloride. Whatever salt we lose by flushing out or by sweating, we have to replace through our food consumption – as a rule, up to 6 grams per day. This is because sodium ions act as a sort of universal regulator in our bodies: They are vital for nerve and muscle function and for regulating our hydration and blood pressure. Without salt we simply would be unable to live. The astounding thing is that only a factor of 20 separates the amount that is physiologically necessary and a fatal dose. If a person consumes around one gram of salt per kilogram of body weight in a day, depending on his or her physical condition there is a 50 percent chance that the person will die. An adult weighing 60 kilograms can therefore die by consuming around 60 grams of salt within 24 hours; for a small child weighing 15 kilograms, a deadly dose could be just a large tablespoon with 15 grams. ■



**Ibexes lick at rocks containing minerals, including sodium which is also essential for animals to survive (top picture). Salt is also found in soap (bottom picture).**

# A big supporter of little scientists

Seizing opportunities is something Dietmar Hopp does a lot – and he wants to give others the chance to do the same. The SAP founder has been a philanthropist for more than 20 years, supporting educational projects among other things. One of these projects is the “Little Scientists’ House” which fosters children’s natural inquisitiveness.

“I was a ‘little scientist’ when I was a child,” says Dietmar Hopp. “Since there were hardly any toys 70 years ago, nature was our playground and we used natural materials to make things, build and experiment.” This curiosity and flexibility had a lasting impact on the communications engineer Hopp, particularly in the formative stage of his career. “Later, as we built SAP, I also thought of myself as a scientist in some ways. I was open to new ideas and wanted to try things out, understand them and move them forward,” adds Hopp, who was one of the co-founders in 1972 of what is still today the youngest German global conglomerate. The SAP founder is proud that this attitude made him so successful, but he is certainly not cocky. Quite the opposite: The businessman and biotech startup investor has remained humble, and this humility combined with his incredible drive has also made him a successful philanthropist and patron. Founded in 1995, the Dietmar Hopp Foundation has already distributed more than €500 million. Originally it was started to help children suffering from cancer as well as their families, but today the foundation also supports projects in the areas of medicine, sports, education and social programs. Hopp says this corresponds with his own “personal understanding of a holistic approach,” adding: “As a child in the postwar period, the things I

**“I immediately tried out the ‘tornado in a bottle’ at home with my grandchildren.”**

experienced shaped my life. But every era has its own special challenges. How one addresses them ultimately depends on the individual and the opportunities that one takes advantage of.” That is why it is important to him to improve the chances of disadvantaged people as well as support youth.

#### Awakening curiosity

This is the reason why Hopp also played a role in establishing the Berlin-based foundation Little Scientists’ House 10 years ago. Throughout Germany, the foundation aims to foster children’s natural

#### ■ BASF project “Curiosity Plus Pipette”

##### Childcare center as laboratory

The BASF project “Curiosity Plus Pipette” takes children between the ages of four and six on a journey of discovery into the world of science. Under the supervision of BASF apprentices, the children dissolve salt or chalk in water. They screen, filter and pipette to build a real magnetic stirrer. The apprentices regularly visit the childcare centers over a period of several weeks. They provide exciting inspiration to awaken scientific curiosity among children, parents and educators. At the same time, the apprentices strengthen their social skills and increase their own technical knowledge by conveying information in a child-friendly way. The project is part of the education initiative “Offensive Bildung,” in which BASF and partners have been actively promoting diverse early childhood education in the Rhine-Neckar metropolitan region, Germany, since 2005. Besides scientific education, the 17 projects also focus on areas such as language skills, inclusion and strengthening emotional resilience.

The offerings of the Little Scientists’ House are also available to daycare centers. The “tornado in a bottle” is fun way to teach children how to best empty a bottle.



“I was open to new ideas and wanted to try things out, understand them and move them forward.”

#### Dietmar Hopp

Born in Heidelberg, Germany, in 1940, Dietmar Hopp started his career 26 years later at the IT corporation IBM in Mannheim. Together with four former colleagues, he founded the company Systemanalyse und Programmentwicklung, now known as SAP, in 1972. The company listed on the stock market in 1988. Hopp established the Dietmar Hopp Foundation in 1995. So far it has distributed around €500 million to charitable causes, mainly in the Rhine-Neckar metropolitan region. Furthermore, Hopp is an investor. Soccer fans will know the 76-year-old as a backer of the club TSG 1899 Hoffenheim. Having played for the team in his youth, he later helped it rise up into the Bundesliga, the top German league.

inquisitiveness in the areas of science, mathematics and technology. McKinsey and the Helmholtz Association approached the Dietmar Hopp Foundation with this idea, where it fell on sympathetic ears. Together with the Siemens Foundation, Hopp provided the seed capital for the educational initiative and has been supporting the Little Scientists' House as a foundation partner ever since. So far, the Dietmar Hopp Foundation has directed around €4.1 million to the project, which is now also receiving significant support from the German Federal Ministry for Education and Research. The foundation currently has 136 employees. The Little Scientists' House has built up a network with more than 225 partners

all across Germany, including museums, organizations, childcare center operators, youth welfare offices and companies. One cooperation partner is Wissensfabrik – Unternehmen für Deutschland e.V. (Knowledge Factory), in which BASF and around 120 other companies and foundations are active.

#### Discover, research and learn

The Little Scientists' House supports educators and teachers to guide children as they discover, research and learn. It provides suggestions for child-friendly experiments in 15 subject areas – ranging from astronomy to magnetism and time. For example, children can make rockets out of straws, magnets out of spoons and clocks out

of cakes. And 76-year-old Hopp is not immune to joining in the fun. “At the 20th anniversary of my foundation, the Little Scientists' House demonstrated the ‘tornado in a bottle.’ I immediately tried that out at home with my grandchildren,” Hopp says. Using two plastic bottles, an adaptor and tap water, the experiment shows how to best empty a bottle – by rotating it when it is upside down.

Educators from more than 26,500 childcare centers, after-school programs and elementary schools have already taken advantage of the continuing education offerings of the Little Scientists' House. This makes it the largest initiative offering early childhood education training in Germany. ■

# Pioneering thinker—then

## Alessandro Volta

Electricity from chemistry: The Italian physicist described the voltaic pile, the first-ever functioning battery, to the Royal Society in London in 1800.

In Europe at the end of the 18th century, the generation of electricity was a mystery, even considered magical. Carnival entertainers created a fascinating spectacle with simple electrostatic generators. But it was Alessandro Volta who achieved the breakthrough that ushered in the electric age. The scientist and inventor developed the first apparatus which enabled electricity to flow for a longer period.

Volta knew from an early age what he wanted. As a teenager he taught himself the fundamentals of electricity. At the age of 18 he decided to study experimental science, against the wishes of his uncle and guardian. It was the right decision. He later carried out groundbreaking work, especially in the area of electrical science. Volta developed a usable electrophorus, a simple device to generate an electrostatic charge from static electricity. As a physics teacher at the local high school in Como, Italy, in 1776 he discovered the combustible gas methane and used it to construct a device known as Volta's pistol. The pistol creates an electric spark which causes the methane to combust – a predecessor of the gas lighter. Two years later, Volta became a professor for experimental physics at the University of Pavia in Italy.



### The voltaic pile

Alessandro Volta discovered metals as a source of electricity. This finding enabled him to develop the voltaic pile, which was made of zinc and copper discs layered over each other and separated by cardboard soaked in brine. This “galvanic cell” produces electrical voltage as the zinc discs give off electrons, creating an excess of electrons and thus a negative charge. The copper, on the other hand, absorbs the zinc electrons, creating a shortage of electrons and a positive charge. When the plus and minus poles (the two ends of the voltaic pile) are connected, an electrical current flows. Even today many batteries still work on this principle, such as small-scale hearing aid batteries.

The Italian scientist Alessandro Volta (1745–1827) is the inventor of the battery and the namesake of the electrical unit of measurement the volt.

It was here in 1787 that his career reached its zenith. Alessandro Volta combined various metals and realized that when they come into contact with one another, the metals become charged to differing degrees – and this creates electric potential. He put this knowledge into practice with his voltaic pile (see box).

Volta's invention was the first practical, usable source of electrical current. Our entire electrified world – including the lightbulb, electricity generators and electric motors – is based on it. His work formed the foundation for the first mass-produced battery in 1802. Alessandro Volta became famous: The London-based Royal Society awarded him the Copley Medal, the highest scientific honor of that time. Napoleon also admired the scientist and appointed him as a senator and later also made him a count. But Volta did not live to experience his highest honor. In 1881 – 54 years after his death – the first International Exposition of Electricity in Paris named the unit of electric potential after him: the volt. ■



# Pioneering thinker—now

## Michael Thackeray

The South African-born chemist is a leading scientist in the development of lithium batteries – a key technology in harnessing clean energy.

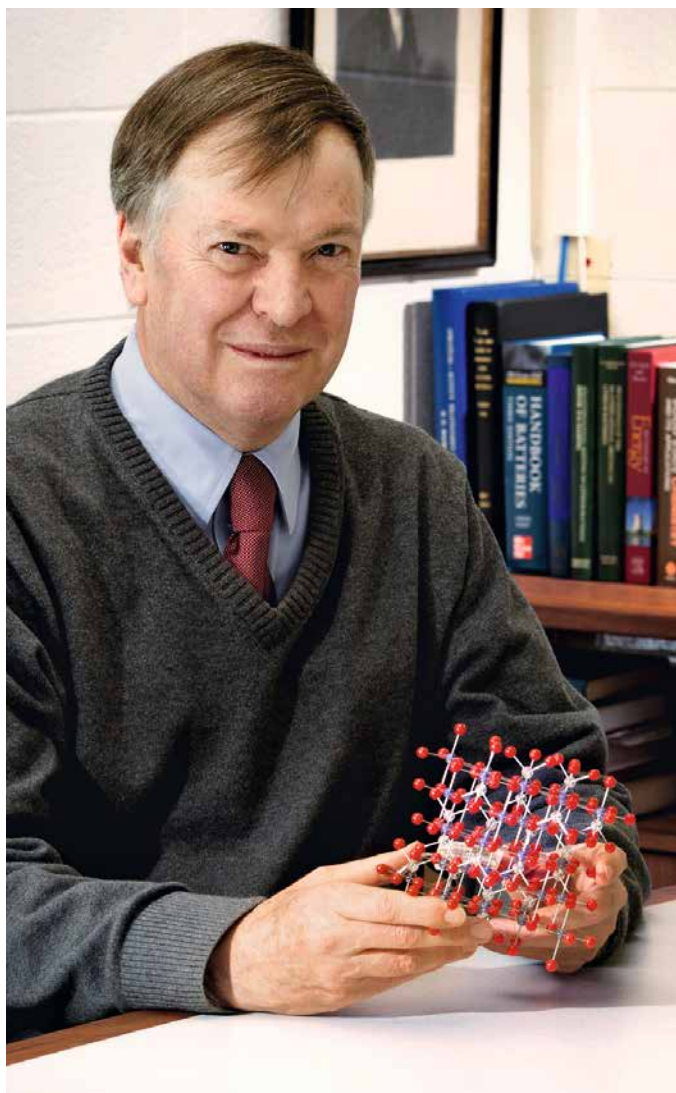
**G**rowing up in Pretoria, South Africa, Michael Thackeray, PhD, was interested in science from an early age. He first caught the chemistry bug in his second year at the University of Cape Town after discovering the beauty of crystals. “A light went on,” says Thackeray. “I remember saying, I can see myself working in this field.”

After graduating with a Master of Science in chemistry in 1973, the thought of a career in “messy batteries” was farthest from his mind. However, when he joined the Council for Scientific and Industrial Research (CSIR) in Pretoria, the Middle East oil crisis had erupted, triggering a worldwide race to develop rechargeable batteries. Johan Coetzer, Thackeray’s mentor at CSIR, had begun researching crystalline silver-ion-conducting solid electrolytes, giving Thackeray his first insight into relationships between crystal structures and electrical energy. Together, they worked to create new high-temperature sodium and lithium battery technologies.

Michael Thackeray, PhD, is a Distinguished Fellow in the Electrochemical Energy Storage Department at Argonne National Laboratory in Illinois, USA.

### Spinels explained

Spinels are crystals that have a cubic structure, through which lithium ions can move in three dimensions. This structure considerably speeds up the charging and discharging process in a battery as the ions shuttle back and forth between the two electrodes. At the University of Oxford in England, Michael Thackeray, PhD, discovered that lithium could be inserted into iron oxide and manganese oxide spinels at room temperature, a finding that has resulted in inexpensive and safer electrodes.



Thackeray found himself fascinated by the possibilities that lithium offered and applied to work with Professor John Goodenough, a world authority on metal oxides, at the University of Oxford in England. In 1981, he moved with his family to Oxford and began investigating the behavior of spinel oxide electrodes at room temperature (see box). His research on lithium insertion reactions led to the use of a variety of spinel electrode materials in lithium-ion batteries – today’s dominant rechargeable technology in electronic devices and electric cars.

Since 1994, Thackeray has headed a team at the non-profit Argonne National Laboratory in the United States. They have developed materials for a solid-state lithium-polymer battery for stationary energy storage and designed composite electrode structures that improve the performance and safety of lithiumion batteries.

At 67, Thackeray is still working on advancing composite electrodes by including a spinel component in the structure. “This approach looks promising indeed,” he says. “We’re also seeking to exploit the energy from the oxygen in metal oxide structures – a more formidable task.” ■

Ozone exposure can lead to discomfort and adverse health effects in airplane passengers and crew. Removing it from the cabin air makes air travel more comfortable.

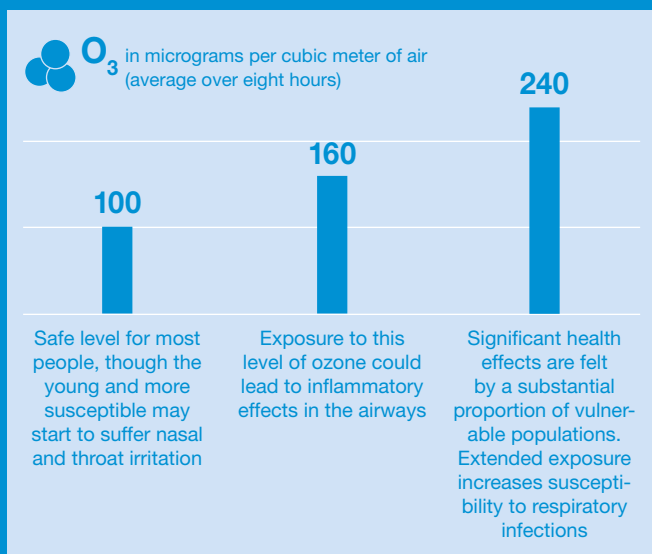
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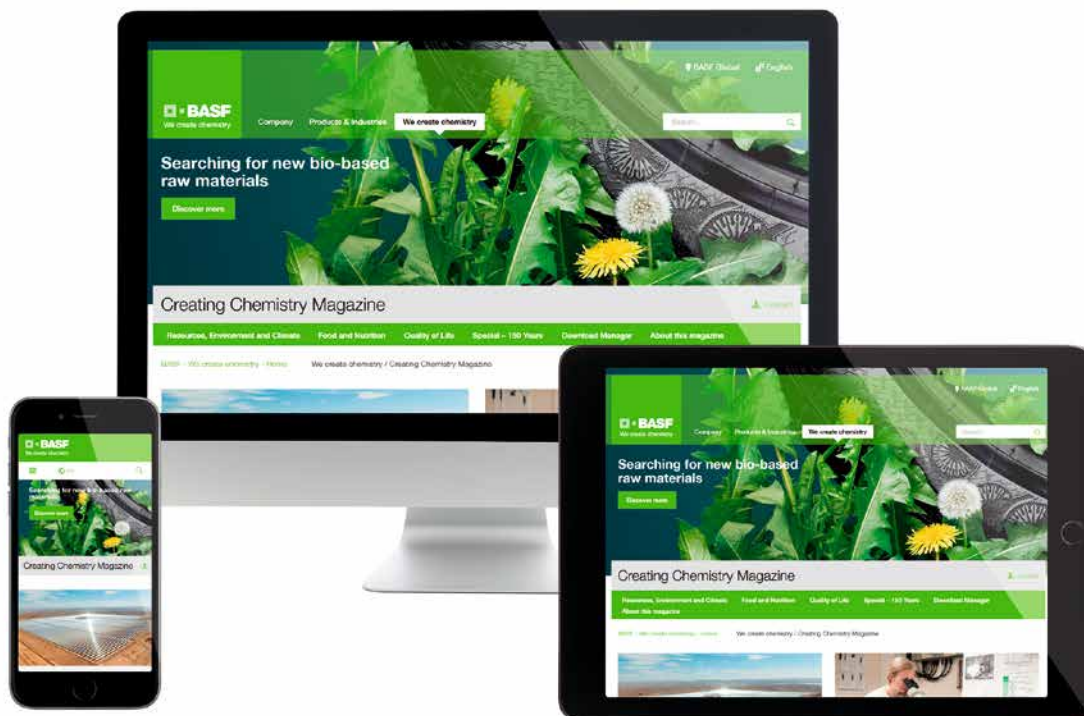
Sources: WHO, U.S. EPA, BASF

You cannot see ozone, but even small quantities can be hazardous to your health. Atmospheric ozone is caused by the photochemical conversion of oxygen by solar ultraviolet radiation. Ozone levels vary with season, altitude, latitude and weather systems. On the ground, ozone concentrations as low as 120 micrograms per cubic meter can be the cause of upper respiratory symptoms, dry eyes and headaches. At altitudes where commercial airplanes regularly cruise, ozone reaches significantly higher concentrations. When this enters the aircraft through air conditioning ducts, passengers and crew can feel quite uncomfortable.

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### Publisher:

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Communications &  
Government Relations  
BASF Group  
Anke Schmidt

### Editorial content:

BASF SE, Editorial Office  
Holger Kapp  
Julia Durstewitz  
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Axel Springer SE  
Heike Dettmar  
Janet Anderson

### Design:

BASF SE, Channel Management  
Charlotte Miller

Anzinger und Rasp, Munich  
Olaf Zimmermann  
Maria Freundorfer

### Printing:

johnen-druck GmbH & Co. KG

### Cover photograph:

Gabriel Gauffre

### Illustrations:

Florian Sänger (page 14–15, 41, 48, 51)

### Photography credits:

Wolf-Dieter Böttcher (page 2, 6, 7, 8, 44)  
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## Contact

BASF SE  
Corporate Communications  
Joseph Jones  
Phone: +49 621 60-99223  
Email: [joseph.m.jones@basf.com](mailto:joseph.m.jones@basf.com)

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