

150 years

 **BASF**

We create chemistry

Creating Chemistry

For a sustainable future

The future of mobility

Gridlock, smog and fuel are some of the challenges created by a growing number of cars. See how innovative concepts will move people in the future.

Focus from page 6

How will we feed ourselves in the future?

Burgers from a lab or insects on the menu? Explore how the way we eat could change.


Food trends feature from page 36

The source of progress

Innovation is the key to progress. Discover how innovative spirit can be fostered.

Innovation feature from page 48

Issue five 2015



Mary Crass from the International Transport Forum on strategies to improve mobility worldwide.

Interview from page 18

Focus:
The future of mobility



THE ISSUE

6 The future of mobility – Time to change direction

An increasing population, climate change and urbanization – the world is changing rapidly with new demands arising. How innovative concepts are changing the future of mobility.

THE GRAPHIC

16 Mobility in the city of tomorrow

Autonomous vehicles, road signs on demand, self-driving capsules and cars that can be folded up for parking: A vision of how we could move around in the city of tomorrow.

THE EXPERT

18 Keeping the world moving

Mary Crass, Head of Policy and Summit Preparation at the International Transport Forum (ITF), talks about how to improve mobility on a global basis.

THE SCIENCE

22 Developing the batteries that will drive the future

Improving the performance of batteries is what drives researchers at BASF's Battery Materials Lab in Amagasaki, Japan.

Content

INFORMATION

4 The world in figures

During evening rush hour, a driver in Istanbul spends an average of 125 hours in traffic jams each year – facts about the topics covered in this issue.

A GLIMPSE AROUND THE GLOBE

34 Innovative uses for 3D printing

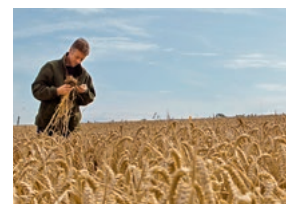
3D printing is evolving rapidly. Innovative applications around the world appear almost every day.

INNOVATION

26 New discoveries

New ideas and astonishing inventions that enrich our everyday lives.

FEATURE: FOOD TRENDS



36 How will we feed ourselves in the future?

Global food production needs to rise to provide a nutritious diet for everyone. Ideas from around the world could change the way we eat.

FROM TWO PERSPECTIVES



28 Plastics under discussion

Plastic: A victim of its own success? Two experts share their views on plastics.

42 The chemistry of cooking

Writer Harold McGee on popular food myths and the science behind them.

VIEWPOINT BASF

32 Innovative everyday companion

Melanie Maas-Brunner, Head of Performance Materials Europe at BASF, explains how plastics make day-to-day life easier and will help solve challenges of the future.

FASCINATION OF CHEMISTRY



44 Bubbles with great potential

Foams provide a wide variety of products, from mattresses to car bodies and chocolate mousse, with special properties.

INSPIRATION

46 Frustration can be the mother of invention

Inventor and industrial designer Sir James Dyson wants to inspire the next generation of engineers with his foundation.

FEATURE: INNOVATION

**48 The source of progress**

Without innovation, progress is impossible. What is the essence of innovation and how can it be fostered?

INVENTION

56 Pioneering thinker – then and now

In 1823, Johann Wolfgang Döbereiner discovered platinum catalysis. Ferdi Schüth later paved the way for high throughput technology to be used in catalysis.

CHEMISTRY AROUND US

58 Steady voltage for smartphone, tablets and more

A powder made from iron scrap protects our electronic devices.

READER SURVEY

What do you think of our magazine?

We are interested in your opinion and would appreciate your response to our short reader questionnaire. Further information can be found at the end of the magazine.

Editorial

**Everything in motion**

Motion fascinated Leonardo da Vinci, in his words it was “the cause of all life.” It is motion that ensures that door hinges don’t rust, water doesn’t stagnate and athletes build muscles. More than 500 years ago, the universal genius da Vinci imagined new forms of motive power beyond human muscle: He designed a helicopter-like machine, a flying device with an airscrew.

Motion has been inspiring researchers for centuries. They have developed a huge variety of – sometimes futuristic – modes of transportation. BASF’s labs and factories create materials for cars, bicycles, airplanes and trains. We develop chemicals for batteries and are pioneers in catalysts. Our plastics make vehicles and planes lighter so they need less energy.

Life without motion is inconceivable. And yet our desire for individuality, freedom and mobility represents one of the greatest challenges of the 21st century. This is particularly true for cities, which are now already home to half of humanity. The number of cars on the road and the size of traffic jams continue to break records. Urban planners face the challenge of how to move all kinds of different traffic through the city as smoothly as possible.

Mobility connects when people are able to travel safely to work, to leisure activities, to visit friends and back home to their families. In Latin America, cable cars are taking on this role as more and more cities build these “aerial subways” to connect outlying suburbs with the center of town – changing in some way the lives of those living there.

Life is all about motion, today even more so than in da Vinci’s time. In 2015 – our anniversary year – BASF is looking at new, challenging questions. We therefore decided to make mobility the focus of our magazine Creating Chemistry. I hope you enjoy this latest issue.

Yours,

Dr. Kurt Bock

**Chairman of the Board of Executive Directors
BASF SE**

The world in figures



After driving

16,000 kilometers

on a test circuit, the first **autonomous truck** from the Daimler subsidiary **Freightliner** received a license from the state of Nevada to operate on public roads. The truck uses two radar units to monitor the road – a long-range sensor that covers a narrow strip 250 meters in front of the vehicle and a short-range sensor that covers a wider area 70 meters ahead.¹

► “The future of mobility” from page 6 onward.

Employees at the technology company W. L. Gore & Associates can use up to

10%

of their working time to pursue their own ideas and initiatives. This “dabble time” has led to many innovations, including the **development of Gore’s ELIXIR® guitar strings** which opened up a whole new market for the company.²

► “The source of progress” from page 48 onward.

Aerogels can hold up to **2,000** times

their own weight. These highly porous solids, which contain up to 99% air, weigh just one-third as much as cork.³

► “Bubbles with great potential” from page 44 onward.



In less than

6 months



from the drawing board to the streets: The Strati electric car from Local Motors is the first car to be produced using a **3D printing process**. The two-seater is made of plastic and can travel up to 40 kilometers per hour.⁴

► “A glimpse around the globe” from page 34 onward.
 ► “The source of progress” from page 48 onward.

1 Freightliner Inspiration Truck, Daimler AG, *Press release*, May 5, 2015.
 2 Management Innovation Exchange, *Innovation Democracy: W.L. Gore’s Original Management Model*, September 23, 2010.
 3 Zeit Online, *Wissen, Luft und Gelee dämmen Kleider und Kühlschränke*, November 15, 2012.
 4 Local Motors Inc., *Press release*, September 8, 2014.
 5 Popular Science, *Can artificial meat save the world?* November 18, 2013.
 6 Statista – Das Statistik-Portal, *Verteilung der weltweiten Kunststoffproduktion nach Ländern und Regionen im Jahr 2013*, 2015.
 7 Vegetarierbund Deutschland, *Press release*, June 9, 2015.
 8 Zeit Online, *Japans Magnetbahn fährt Rekordgeschwindigkeit*, JR Central Japan Railway Company, April 21, 2015.
 9 TomTom International BV, *Press release*, March 31, 2015.



Around
80%

of the world's farmland is used to support the **meat and poultry industry**, with much of this area dedicated to growing animal feed.⁵

► "How will we feed ourselves in the future?" from page 36 onward.



Germans spent around

€ **213** million

on **meat alternatives** and **vegetarian sandwich spreads** in 2014. Sales of these products have risen by 73% there in the past five years.⁷

► "How will we feed ourselves in the future?" from page 36 onward.



Drivers in **Istanbul** wasted an average of

125 hours

stuck in **traffic jams** during evening rush hour in 2014. This makes the city on the Bosphorus the most congested, followed by Mexico City with 102 hours and Rio de Janeiro with 93 hours.⁹

► "The future of mobility" from page 6 onward.

China accounted for

24.8%

of **global plastic production** in 2013, making it the world leader. Europe ranked second with 20% and the NAFTA region (United States, Canada and Mexico) was third with 19.4%.⁶

► "Plastics under discussion" from page 28 onward.

Traveling at

603 kilometers per hour

the **Maglev magnetic levitation train** set a world speed record on a test track in Japan. By 2027, the train should travel from Tokyo to Nagoya in just 40 minutes.⁸

► "The future of mobility" from page 6 onward.





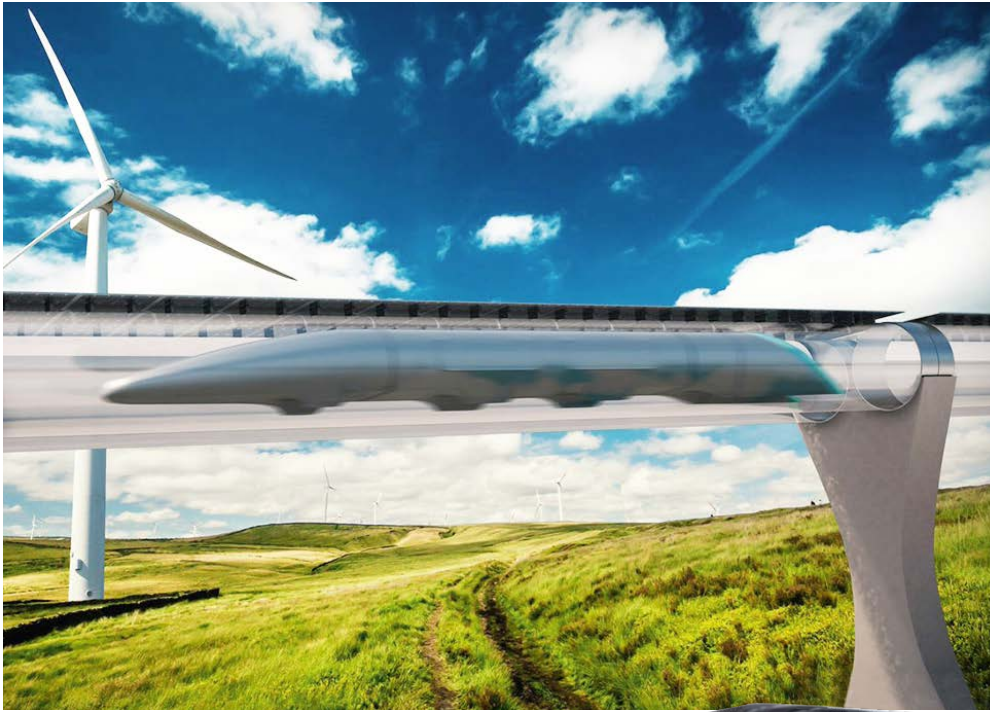
The future of mobility

Cars were once the ultimate symbol of progress and independence. But today, a century later, what once stood for freedom is quite often stuck in traffic jams, contributing to air pollution in the world's megacities. Mobility in the 21st century requires innovation. Discover cities and technologies that demonstrate how it's possible to overcome the challenge of the century.



Cars take flight

Want to take off and fly over a traffic jam? Now you can, with the AeroMobil, a hybrid between a sports car and an ultralight plane that has collapsible wings. The flying car can reach top speeds of around 200 kilometers per hour in the air and 160 kilometers per hour on the ground. Its flight range is around 700 kilometers. The Slovakian firm AeroMobil plans to launch this innovative flying vehicle on the market in 2017. Other organizations are also working on flying cars, including Terrafugia – a spin-off company from the Massachusetts Institute of Technology (MIT) – and the E.U. research project myCopter.

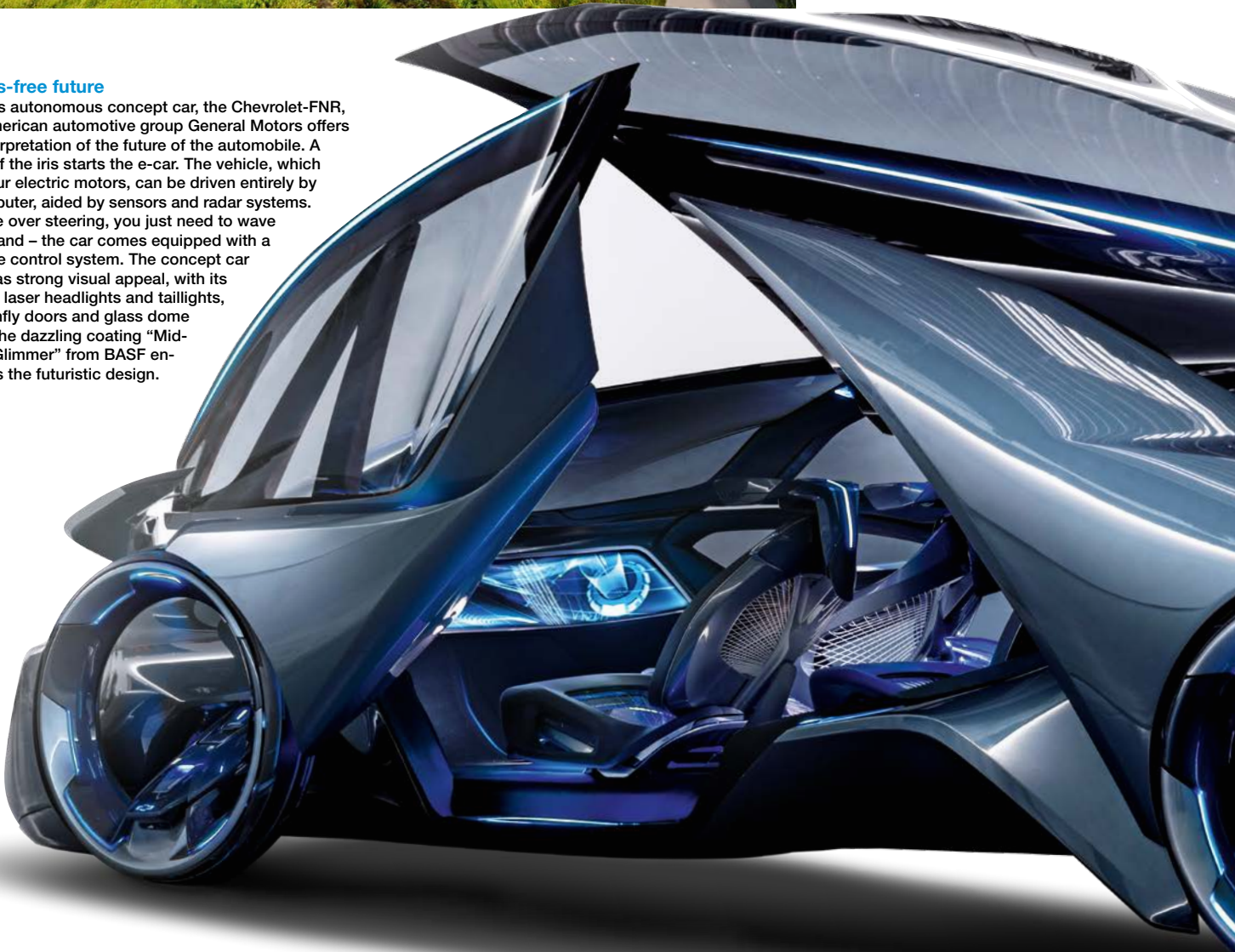


Turbo travel in a tube

Entrepreneur Elon Musk is known for making the seemingly impossible possible. The founder of the aerospace company SpaceX and Tesla Motors has now embraced the idea of a super-fast train, the Hyperloop. It should transport passengers in a pod through a tube nearly void of air at speeds of up to 1,200 kilometers per hour, making it competitive with flying. A test track is being built in Quay Valley, California. In addition to Musk, two start-ups and more than 150 developers – including some from the U.S. networking equipment manufacturer Cisco, aircraft manufacturer Boeing and Harvard University – are now working on the project to turn this vision of a train-in-a-tube into reality.

Hands-free future

With its autonomous concept car, the Chevrolet-FNR, the American automotive group General Motors offers its interpretation of the future of the automobile. A scan of the iris starts the e-car. The vehicle, which has four electric motors, can be driven entirely by a computer, aided by sensors and radar systems. To take over steering, you just need to wave your hand – the car comes equipped with a gesture control system. The concept car also has strong visual appeal, with its crystal laser headlights and taillights, dragonfly doors and glass dome roof. The dazzling coating “Midnight Glimmer” from BASF enhances the futuristic design.





Flowing freely

This double-layer traffic circle keeps everything moving smoothly: Shanghai's elevated pedestrian bridge over a roundabout diffuses the flow of urban traffic, meaning pedestrians and drivers no longer have to fight for limited space. On ground level, five multi-lane streets lead into the orderly roundabout with no need to stop for red lights. On the top level, rising above the traffic, pedestrians can cross the intersection safely, also without having to wait.



Powered by the sun

A comfortable and sustainable mobility solution for short distances: The e-floater, an extremely lightweight yet stable solar-powered scooter, will enable you to quickly get from your home to the city center or the nearest public transport stop. The e-floater consists of more than 80% composite and plastic materials from BASF and weighs less than 12 kilograms.

www.floatility.com

Time to change direction

Smog, congestion, lack of parking – cities around the world are suffering more every day from the swarms of vehicles on their streets. The car, once celebrated as a symbol of freedom, is now increasingly subject to limitations. On days with high air pollution, cities such as Paris, Beijing or São Paulo restrict access to cars by alternating between license plates ending with either odd or even numbers. In Shanghai, a license plate now costs as much as a small car. And the logistics company UPS has invested millions in a proprietary GPS system that ensures its vehicles almost entirely avoid left turns in order to save time and fuel.

There are numerous ideas because one thing is clear: Mobility will have to be very different, especially in the world's metropolises. Today's traffic systems are no longer sufficient to handle the masses of

people surging into megacities. In the United States, United Kingdom, France and Germany alone, gridlock costs the economies around €180 billion (\$200 billion) and each person about 111 hours of their time every year, according to a study conducted by the Centre for Economics and Business Research (CEBR) on behalf of the traffic information specialist INRIX. And by the year 2030, the economic costs will rise by nearly 50% due to growing traffic volumes.

Mobility rethink required for energy shift

People are unlikely to abandon cars completely, but they will play a different role in our lives. “For many generations, the car was the ultimate status symbol,” says Peter Newman, PhD and Professor of Sustainability at Curtin University in Australia and a former member of the Intergovernmental Panel on Climate Change (IPCC). “But in numerous countries, ‘peak car’ is

“For many generations, the car was the ultimate status symbol. But in numerous countries, ‘peak car’ is already over.”

Peter Newman, PhD and Professor of Sustainability at Curtin University in Australia

already over.” Although the term ‘peak car’ is not as well known as ‘peak oil’ (the time when maximum global oil production is reached), the reign of the automobile is approaching its end, according to Newman. Whether in Perth, New York or Berlin, young people in a growing number of Western cities are losing interest in owning a car. The number of cars sold to this target group is sinking even though economies are expanding. Although this phenomenon is only being seen in metropolitan areas of a few industrialized countries, it represents a small revolution. For example, in 2013 around 30% of households in major German cities owned neither a car nor a motorcycle, according to the Federal Statistical Office. Within ten years, this figure has risen considerably from the level of 22% recorded in 2003.

This societal transformation is the reason Newman has hope that the IPCC's famous two-degree target may yet be achievable. He now believes in green cities, which will not be dominated by cars but instead will depend on the intelligent linking of diverse modes of transport, including cars, trains, buses, bicycles and motorcycles. The future of transportation will be intermodal. The key thing will be the most efficient way of getting from point A to point B, not the form of transportation.

Newman is particularly interested in the changes taking place in the megacities of China and the United States, the two largest emitters of greenhouse gases.



Shanghai has been building a modern metro network since 2000. Covering more than 500 kilometers, it is one of the world's longest networks of subways and elevated trains.

Gridlock in São Paulo. The South American metropolis suffers from severe congestion, especially in evening rush hour when traffic jams can stretch more than 300 kilometers. Not only does this cost time and money, it also contributes to heavy air pollution in the city.



And there is a lot happening. In the 1990s Shanghai was still following the American model: Building high-ways, replacing bicycles with cars – and heading towards gridlock.

However, since the start of the new millennium, this metropolis of 24 million residents has been trying to turn the tide by investing in subways and elevated trains. Within ten years Shanghai built the largest metro system in the world, with more than 500 kilometers of lines carrying eight million people every day. Across China, a total of 86 new subway lines have been built.

Even in the United States, which has the reputation of having the worst public transportation in the industrialized world, more and more cities are following the example of Portland. That city has not built any new freeways in the past 30 years and has instead invested in a revival of its streetcar system. In 2013, the U.S. news agency AP counted 30 streetcar projects throughout the

country – and noted that today’s tracks are being laid exactly along the routes where they were torn up in the 1950s and 1960s.

Airborne alternative

Latin America, on the other hand, is discovering the allure of cable cars. La Paz, Bolivia’s high-altitude metropolis, is currently building the world’s largest urban cable car network. Nine lines stretching 30 kilometers could account for around 15% of public transportation once they are completed. Commuters who until recently spent an hour traveling up or down curvy mountainside roads in cars or buses can now reach the neighboring city of El Alto in just 17 minutes. The electric cable car systems are so inexpensive to operate and low in maintenance that they are even affordable for cash-strapped governments.

Meanwhile in Europe, urban buses – previously a source of exhaust emissions – are going electric. The

Sharing hits the fast lane

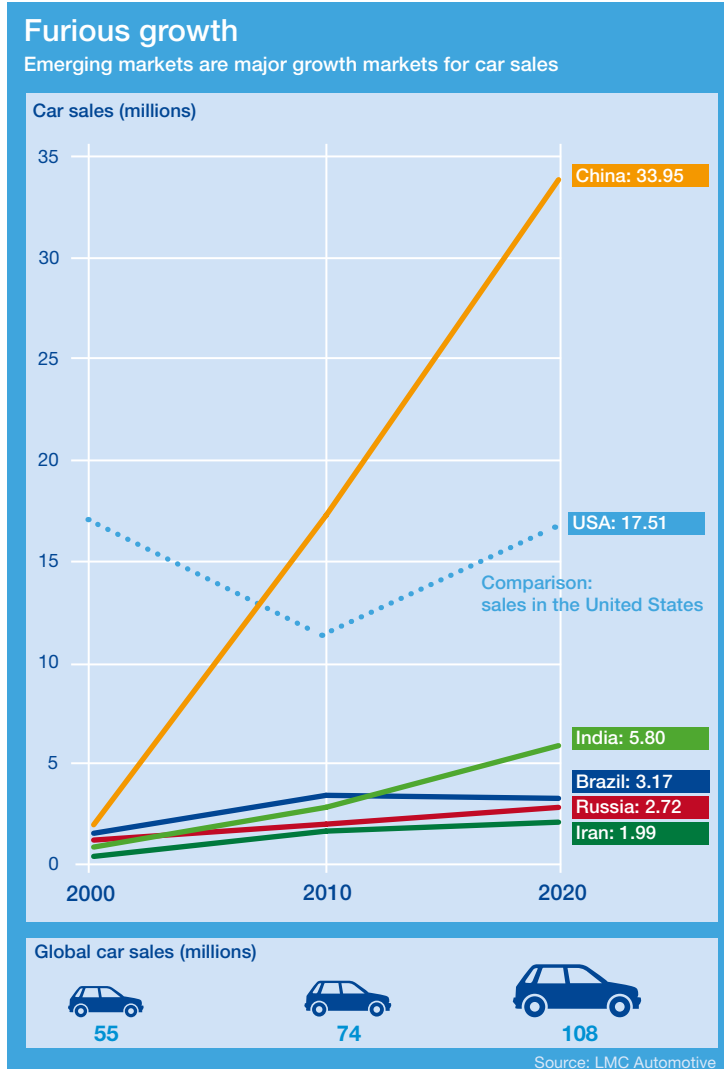
Car sharing is booming: Between 2014 and 2018 the market will grow by around 40% worldwide, forecast analysts from Frost & Sullivan. Alone the German firm car2go, which is competing with the U.S. company Zipcar to become the world market leader, had a million users in eight countries at the end of 2014. Simultaneously, a growing number of companies are giving private individuals the opportunity to share their own cars and make some money. After launching two years ago, the Hong Kong-based peer-to-peer platform Carshare.hk now has more than 2,000 cars and 20,000 members registered. These ingenious start-ups are tapping an enormous growth market: According to the consultancy Roland Berger, half of all car owners in the industrialized world can imagine sharing their vehicles. This is good news for those looking for parking as well as for the environment because each shared car can replace up to ten private cars, according to a study conducted in Bremen, Germany, a pioneering city for car sharing.

cities of Mannheim, Germany, and Milton Keynes, England, are testing the first e-buses that wirelessly self-charge at bus stops. On a small scale, the principle is similar to that of electric toothbrushes. Now the system has to be scaled up as efficiently as possible and installed under the street. If this is successful, researchers hope the next step may be buses that can be recharged in dedicated charging lanes as they travel along their routes.

The expansion and electrification of public transit vehicles is only the first step; in the long run, significantly more vehicles will have to be powered by electricity, Newman believes. In the United States alone, around 20 million barrels of oil are consumed every day, of which 72% are used in the transportation sector, according to the U.S. Energy Information Administration (EIA). Globally, transportation accounts for 51% of the more than 90 million barrels of oil consumed daily. In a “business as usual” scenario, the concentration of CO₂ will increase so much by the end of this century that temperatures are expected to rise by between 3.7 and 4.8 degrees Celsius, according to reports by the U.N.’s IPCC.

But, for now, electromobility and hybrid vehicles are still just niche markets. The first step in reducing emissions, a process that has been underway for years, is to increase the efficiency of combustion engines and their catalyst technologies. After all, gasoline-powered vehicles are not going to be phased out any time soon. The latest Shell study forecasts that in Germany cars with combustion engines will continue to dominate the market over the next 25 years. Vehicles with hybrid engines are predicted to have a 27% share of the market in 2040. The authors believe cars with electric or fuel cell motors will account for around 5% of vehicles.

The reasons why electric cars have not yet gained mass-market appeal are their limited range and the lack of charging infrastructure, coupled with the fact that they still cost about one-third more than comparable cars with combustion engines, says Dr. Axel Thielmann, Deputy Head of the Competence Center Emerging Technologies at the Fraunhofer Institute for Systems and Innovation Research (ISI).



The search for tomorrow's batteries

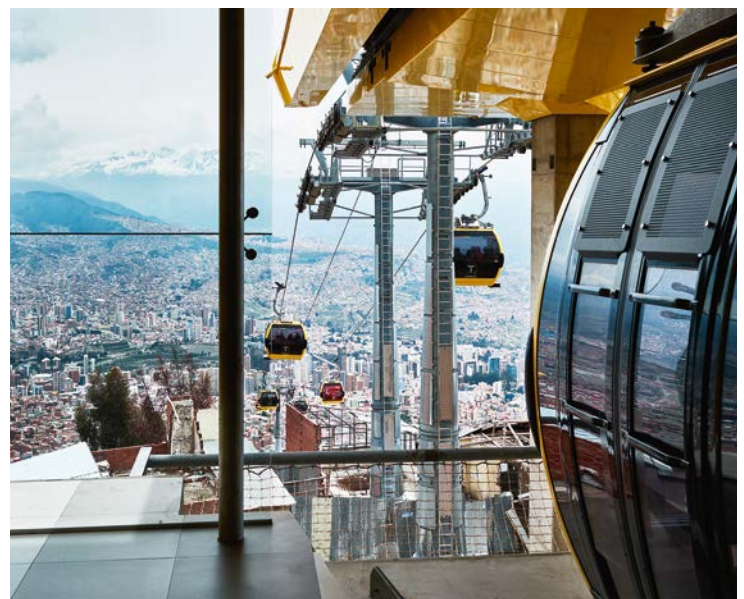
Researchers are working very hard on the next big breakthrough that will make rechargeable batteries cheaper and more durable, with higher energy density and thus less weight. But the problem is that achieving one desired property often comes at the expense of another: A long range and large battery capacity mean higher costs and weight, while low cost and weight mean limited battery capacity. High energy NCM, an optimized special mixture of nickel, cobalt and manganese, is a promising material that may hold the solution. This cathode material, which is also licensed to BASF, should take lithium-ion batteries to a new level of performance. In a survey conducted by Fraunhofer ISI among 91 international battery experts, respondents said NCM technology had an excellent chance of becoming the "third generation" of lithium-ion batteries that would make e-cars more affordable and give them longer ranges in the coming years. But this will not be the end of the story: Over the next 10 to 20 years, revolutionary technologies such as lithium-sulfur could become ready for the market. BASF is also very involved in this field: Between 2011 and 2016, the company is investing several hundred million euros in research, development and the production of leading edge battery materials (see Battery Materials Lab report on page 22).

But batteries are not the only things that need to become lighter and more powerful: Vehicles themselves have to shed some weight because more power is required to propel every extra kilogram. The BMW i3, a compact city car, is the first electric automobile from a German premium manufacturer to use carbon fibers rather than metal in the passenger compartment. Previously, this difficult-to-manufacture material was mainly used in custom-made Formula 1 racing cars and aerospace engineering. "The novelty for mass-production vehicles is the combination of carbon fibers with a polyurethane matrix," says Dr. Guiscard Glück, Vice President New Markets and Products in BASF's Performance Materials division. "The self-supporting rear seat shell is made from the BASF foam Elastolit® and meets the high safety standards even though

New life for old batteries

At the end of its life cycle in an electric vehicle, a rechargeable battery usually still has 80% of its storage capacity – too much to scrap it but too little for electromobility. The Second Life Batteries alliance now wants to demonstrate that these batteries can be used to build a large-scale storage system for electricity from renewable sources which will provide power when the wind is not blowing and the sun is not shining. BMW is supplying this pilot project with 416 rechargeable batteries from its i3 e-car and its ActiveE research vehicle. Bosch is in charge of integrating the batteries and managing the system. Vattenfall will be starting up the two-megawatt storage unit, located at the cruise ship terminal at Hamburg's port, in December 2015. Using stored wind energy, the system should be able to supply 30 four-person households with power for seven days.

➔ To find out more, visit: www.bit.ly/1Szzh5H



The future is electric: European cities, in particular, are increasingly using e-buses in their public transit networks, such as here in Hamburg, Germany (top).

Latin America, on the other hand, has discovered the allure of the cable car. In La Paz, Bolivia's largest city, they will soon account for around 15% of public transit (middle).

The sporty BMW i3 not only boasts an innovative electric motor, it is also lightweight thanks to the carbon fibers in the body which compensate for the weight of the battery (bottom).

it has a wall thickness of just 1.4 millimeters. In addition, more than two dozen components made of engineering plastics are used to strengthen the vehicle's carbon body, thus considerably reducing the weight of this sporty e-car." The BMW i3 weighs 1,195 kilograms, roughly the same as its fellow BMW sub-brand, the gasoline-powered MINI. But the MINI is shorter and does not carry a 230 kilogram lithium-ion battery on board.

The love affair with four-wheeled vehicles – whether powered by electricity or gasoline – also brings other challenges for the world's big cities. If half a city's residents travel by car and the other half take public transportation, the car passengers take up more than 90% of the driving surface, which leads to congestion.

Robotaxis to fight traffic jams

If cars were self-driving, however, the roads could be as empty as they were in the 19th century, believes Dr. Raúl Rojas, Professor of Artificial Intelligence at the Free University of Berlin. With intelligent route planning, these tireless chauffeurs could easily transport four or more people at once, turning the car into a share taxi. And this will pay off: An analysis of 150 million taxi trips through Manhattan by the Massachusetts Institute of Technology (MIT) found that the number of trips could have been reduced by 40% if each taxi had taken another passenger. Google co-founder Sergey Brin has often said in interviews that he believes individual car ownership will decline. The large numbers of private cars are putting an enormous strain on communities. At peak times, one third of driving in a city can be due to people looking for parking, Brin says, which wouldn't be necessary if self-driving cars could simply drop off passengers at their destination and then pick up the next ones.

Self-driving robotaxis can drop passengers off at their destination and then collect the next ones, thus eliminating the time-consuming search for parking.

■ **BASF's PremAir® NXT**

Protecting the air we breathe

Most automobiles today are fitted with catalytic converters that convert exhaust emissions into less harmful gases, making a significant contribution toward improved air quality. BASF's PremAir® NXT is a catalytic radiator coating technology that converts ground level ozone – the main component of smog – into oxygen. As air flows over a vehicle's radiator, it catalyzes this reaction. Compared to previous technologies PremAir® NXT provides higher ozone conversion performance over the lifetime of a vehicle. It also allows car manufacturers to meet strict emission requirements.

➤ To find out more, visit: www.basf.com/premair-nxt

Earlier this year, an Audi A7 named Jack showed just how close the automotive companies are getting to their vision of a driverless car. Fitted with radar sensors, laser scanners and 3D cameras for a 360-degree panorama view, Jack was able to drive on autopilot the approximately 900 kilometers from Silicon Valley to Las Vegas. Reaching speeds of up to 110 kilometers per hour, the research vehicle from the Volkswagen subsidiary is able to change lanes and pass other cars without any human assistance. However, the driver is asked to take the wheel again in urban areas because the spontaneous movements of cyclists, pedestrians and children are too unpredictable.

By the end of the decade, the technology from the test car should be available in a series-production Audi. "We are getting close to the self-driving car," says Professor Dr. Jürgen Lehold, Executive Director of Research at Volkswagen Group. However, it will be another 10 to 15 years before we reach fully automated driving – which allows the driver to take a nap or read the newspaper. Before then, it will be necessary to ensure that the car can recognize any unexpected incidents. But intelligent vehicles will be a reality soon, Lehold is convinced. "We need them to meet the needs of modern society. They will reduce accidents and traffic jams, and let

drivers relax more during the ride." It is not only car manufacturers working on autonomous vehicles; technology companies like Apple and Google that previously had little to do with the automotive sector are also forging into this market.

Technology is not the only issue on the mind of Volkswagen's research chief. Finding new business areas is just as exciting, he believes. "We know our way around cars, now we are learning IT," says Lehold. Traffic reports, gasoline prices, parking spot reservations – which services does a driver really need for better mobility? And the competition never sleeps, either. BMW, for example, has developed a route planner especially for its e-cars which includes public transportation and even rental bikes. As soon as the car approaches a major city, the software recommends switching to a bike, commuter train or subway, if it helps the driver get to his or her destination faster.

"We are getting close to the self-driving car."

Professor Dr. Jürgen Lehold, Executive Director of Research at Volkswagen Group





Even though there are high hopes that digitalization and the continuous exchange of data between vehicles, smart infrastructure, traffic lights and construction sites will offer tremendous opportunities to make driving safer and traffic flow better, high tech alone will not be sufficient to solve the challenges facing cities.

Increasing quality of life

There are more aspects to consider. “For a city to be livable, the pace should be that of a pedestrian or a cyclist, not of a car,” believes Jan Gehl, PhD. For more than 40 years, Gehl, a Professor Emeritus of Architecture and one of the world’s most influential urban planners, has been studying how mobility and architecture in cities relate to quality of life. The fact that his hometown Copenhagen has been named the world’s most livable city three times testifies to his success. The movement that has seen pedestrians and cyclists slowly taking over the city was sparked in 1962, when the first inner-city street was closed for car traffic. At the time, shop owners

Pedestrians and cyclists have priority here: Copenhagen serves as an example for many cities such as New York.

“For a city to be livable, the pace should be that of a pedestrian or a cyclist, not of a car.”

Jan Gehl, PhD and Professor Emeritus of Architecture, Royal Danish Academy of Fine Arts, School of Architecture

protested out of fear that their sales would collapse, but in fact the businesses have flourished. Over the subsequent years, more and more streets in Copenhagen were pedestrianized with scientific support from Gehl and his research team, sidewalks were widened and a complete citywide network of bike lanes was built. Today all 18 public squares in the inner city are car-free, 45% of Copenhagen residents cycle to work and taxi drivers are required to have a bike rack on their vehicle in order to get a license.

Gehl’s ideas have also inspired New York City’s planning. In May 2009, Broadway was closed to vehicles around Times Square. Although some believed this would result in a disaster, the flow of traffic actually improved by 7%, according to calculations by the Department of Transportation. Taxi rides were suddenly 17% faster. The city widened sidewalks again and started building an extensive network of bike lanes throughout the city. Within two years, the number of people cycling to work doubled.

Since then, Madison Square and 11 other squares have also been made car-free.

This kind of rethinking is taking place in a growing number of cities worldwide. But Copenhagen, the model metropolis, is now grappling with the consequences of its success. These days, cycle lanes are often congested. During rush hour, cyclists sometimes need to wait for traffic lights to change three times before they can cross the street. In the popular pedestrianized shopping areas, residents and shopkeepers face skyrocketing rents. Jan Gehl has a simple answer: “We just need to build more cycle paths and pedestrian zones.” ■

➤ To find out more, visit:
www.bmw.com/i3
www.volkswagenag.com/innovation
www.audi.com/com/brand/en/vorsprung_durch_technik/content/2014/10/piloted-driving.html
www.basf.com/creator-space/urban-living
www.automotive.basf.com
www.gehlarchitects.com

Mobility in the city of tomorrow

As urban areas struggle with smog and impending gridlock, sustainable thinking is required to make mobility cleaner, more flexible and space-saving. Our graphic shows how we might be getting around cities in the future.

Autonomous cars

The car of the future will drive itself, leaving people free to read the newspaper or work during the trip. It can also find the next available parking spot all on its own and come back when it is summoned. At the same time, networked cars will communicate with each other and be able to give warning about potential hazards.

Energy for carbon-free travel

Charging cables are a thing of the past. Instead, electric cars of the future are able to get power from charging points built into the asphalt. The car just needs to drive over a slab in order to start the inductive charging. The energy is transmitted to the car's battery by a magnetic field between two coils, one located in the floor of the car and a second one in the asphalt slab under the car. In addition, lampposts can function as charging stations.

Self-driving capsules

Public, self-driving capsules operate like a taxi on rails, allowing for personalized routes on public transportation. There are no fixed stops or schedules. The capsules are just ordered via smartphone when needed. Without having to lift a finger, passengers will be whisked to their desired destination by these innovative vehicles.



Cars take flight

Simply by extending their wings, the helicopter-like high fliers can conquer the skies.

Intelligent traffic management

Instead of fixed traffic lights and painted-on pedestrian crossings, the intelligent city automatically analyzes sensors located in places such as cars and public transit vehicles. It can tell, for instance, where a pedestrian wants to cross the street and then project the necessary signals. There can also be variable speed limits and detour suggestions that appear on the road in order to help keep traffic flowing. The facades of buildings are turned into digital projection surfaces to communicate with road users, for example, to warn them about an accident around the next corner.

Travel through tubes

Future mobility is also heading underground. Turbo pods will automatically carry passengers at enormous speeds through a system of tubes that minimize friction and aerodynamic drag. These systems use their propulsion energy extremely efficiently: Once accelerated to its peak speed, the pod just continues rolling along without any additional energy inputs.

Using land for parks, not parking

Cars are turning modular: They can be expanded to fit the number of passengers, or folded up like a baby carriage when parked. This allows three to four vehicles to be parked in the space taken up by a conventional car. Additionally, automated parking systems ensure optimum use of vertical space, thus freeing up parking spots to become green recreational areas instead. And disused elevated railway lines are being turned into public parks.

Keeping the world moving

Making transport work better for all is a global priority. Which ideas are emerging and what concrete ideas already exist? Mary Crass of the International Transport Forum (ITF) discusses multi-modal systems, solutions for rural public transport, and designing towns for walkability.

Creating Chemistry: The ITF 2015 Summit took as its theme the three Ts – Transport, Trade and Tourism. What are your key areas of focus this year?

Mary Crass: Governments and actors throughout the transport sector must start treating the three Ts as interlinked sectors. Too often tourism is seen as something separate from trade, but it accounts for 21% of exported services and therefore plays a major role in trade. Transport enables both trade and tourism and is being challenged by growing demands in each of these areas. Annual global tourist arrivals are expected to reach 1.8 billion by 2030! We need more accessible tourist infrastructure and information for all visitors – notably the growing numbers of older travelers. On trade, governments must work together to cut documentary and procedural barriers as well as physical barriers. Overall, we need better policy coordination of all three Ts to deliver global economic development and social cohesion.

The ITF headquarters are in Paris, where air pollution was recently so bad that half the cars were banned from the roads and public transport made free for a day. Do you see your travelling conditions improving?

Overall, Paris has made huge strides in discouraging car use, without

introducing congestion charging along the lines of London's very powerful model. Dedicated bus lanes, for example, have cut the amount of road space available. Car and bike sharing is spreading. Challenges remain in outer areas, but the Grand Paris scheme is being presented as a model for other cities with plans for new automatic metro lines, stations and ring routes, and improved train service. Political commitment will be key in its realization.

A recent study sees fleets of self-driving shared cars replacing 90% of conventional cars in mid-sized cities. Given people's attachment to the convenience of their own cars, is this realistic?

The car's convenience lies in the predictability with which people feel they can get where they want, door-

to-door. But congestion affects predictability, while car ownership has its costs, including those associated with vehicle purchase and maintenance, fuel and parking, and time spent finding parking. Mobility alternatives need to tackle the challenge of being on demand and covering the last journey kilometer, by offering connected travel across modes. Larger cities need different solutions. If they can extend their public transport to offer some of the qualities of private car travel, for example by bringing in car and ride sharing as well as bike sharing, that's all to the good. People want comfort, accessibility and reliability; with these offered by other mobility solutions they stand a better chance of leaving their cars behind.

Your recent study of rural transport highlights the importance of better coordinated services. What do you see as the key issues for ensuring mobility for people who don't live in towns?

Rural public transport costs more than public transport in dense urban areas. There is a role for government subsidies, but we also have evidence of rural dwellers' willingness to pay more for services that are efficient even if they don't offer the frequency available in towns. One example is demand responsive buses, which could be an option in low-density or rural areas. It's impor-

Mary Crass

Mary Crass has been Head of Policy and Summit Preparation at the International Transport Forum (ITF) for six years. Prior to that, she was a transport policy analyst and principal administrator at the ITF and its predecessor, the European Conference of Ministers of Transport, both housed at the Organisation for Economic Co-operation and Development (OECD) in Paris. Previously she worked in the private sector and consultancy. Crass has a Master of Arts degree in international economics and energy and environment policy from Johns Hopkins University School of Advanced International Studies in Washington, D.C., USA.

“Transport enables both trade and tourism and is being challenged by growing demands in each of these areas.”

Mary Crass, Head of Policy and Summit Preparation at the International Transport Forum

Mary Crass at the Trocadéro in Paris where transport, tourism and trade go hand in hand: Known as place with the best view of the Eiffel Tower, it is a popular tourist spot. At the same time, it hosts a metro station as well as restaurants, hotels and shops.





Mary Crass lives and works in Paris where the ITF is headquartered. According to her, the French capital has recently made huge efforts towards better mobility – building on a variety of transport modes and measures such as dedicated bus lanes (left), metro lines and new stations. As in other parts of the world car and bike sharing are spreading (bottom).

tant that such services don't operate in isolation, but as parts of larger, connected multimodal networks. Smartphone-accessible travel information is a key enabler.

What role will networked travel information and transport infrastructure play?

A crucial one, not least in deploying automated vehicles that can operate safely. The support of the entire intelligent transport systems industry will be needed, including electronic travel information, traffic and public transport management, driver assistance and automated safety systems. A recent example is the European eCall regulation that requires new cars to be equipped with eCall technology from April 2018. In the event of a serious accident, eCall automatically communicates relevant information such as the vehicle's location to emergency rescue services.

Car ownership is soaring in developing economies, generating rising congestion. When we compare this with Western experience, what lessons can be learned?

As average income increases, more and more people want their own car. While not necessarily denying opportunities for private vehicle ownership, decision-makers need to distinguish between car ownership and use, and ease people away from over-dependence on cars through policies that shape and manage use and through careful early planning based on access to services and amenities instead of strictly promoting mobility. Bus and rail corridors need to be planned with transit-oriented development in mind. Policy-driven parking restriction and charging can be effective. Where public transport infrastructure and services are not yet well developed, policies that promote car and ride sharing can be pursued. And walking and cycling can be promoted as an integral part of transport policy.

Encouraging such alternatives depends on road users being attracted to the idea and feeling safe. What needs to be done?

In too many countries, non-motorized transport remains on the margins of policy making. It needs to be brought forward with positive 'keep the car at bay' strategies for traffic





calming, urban 30 kilometers per hour maximum zones, and car free areas.

Walkability is emerging as a residential or business locational criterion in the United States.

Do you see this spreading?

Yes, provided that local governments are prepared to flip the urban planning process on its back, by considering access to amenities and services first as well as proximity to public transport. The idea is well accepted in North America, for example, in the form of transit-oriented development. This provides for new homes, shops and workplaces to be clustered within easy walking distance of transit stops and stations.

The environmental agenda sees electric vehicles playing increasingly important roles. How can public policy encourage e-mobility?

E-mobility is an important issue for governments. They can encourage it by giving grants and purchase subsidies, legislating for electric vehicle uptake in public sector fleets, and supporting research and develop-

The car's main convenience, according to Mary Crass, is its predictability – an aspect that is also crucial in her daily work-life. However, she states, other mobility solutions can catch up.

“People want comfort, accessibility and reliability; with these offered by other mobility solutions they stand a better chance of leaving their cars behind.”

Mary Crass, Head of Policy and Summit Preparation at the International Transport Forum

ment in new battery and charging technologies. But although electric cars have environmental benefits, they also face hurdles. ITF research shows that their cost is still often higher than equivalent internal combustion vehicles. The gap may narrow with higher volumes of production, but internal combustion vehicles may still provide higher range at lower cost in many scenarios. Also, when evaluating their environmental benefit, it's necessary to consider the carbon-intensity of the electricity production. Generally, future mobility solutions will be powered by different sources of energy – electricity, certainly, but also hydrogen, solar, and biofuels. Until new technologies reach scale, improvements in fuel efficiency of existing engine technologies will be essential.

What are the next big issues you are addressing in the run up to your 2016 Summit?

Next year's theme is 'Green and Inclusive Transport'. Transport is a major enabler of economic growth and development: Cheaper, safer, more reliable and frequent transport facilitates trade and the movement

of people and enables people to access employment, goods and services. The transport model that facilitates this economic exchange is, however, not currently environmentally sustainable. Our research shows that, globally, transport remains 97% dependent on fossil fuels, and contributes up to 25% of CO₂ emissions. Without action, its output will rise by 170% by 2050. We believe green transport can be a driver of green economic growth. But some segments of society are impeded from accessing opportunities as a result of their income level, mobility, location, or prohibitive transport costs. Inclusive transport implies that everyone has access to the labor market, education and public amenities, as well as social and leisure activities. ■

▶ To find out more, visit: www.internationaltransportforum.org



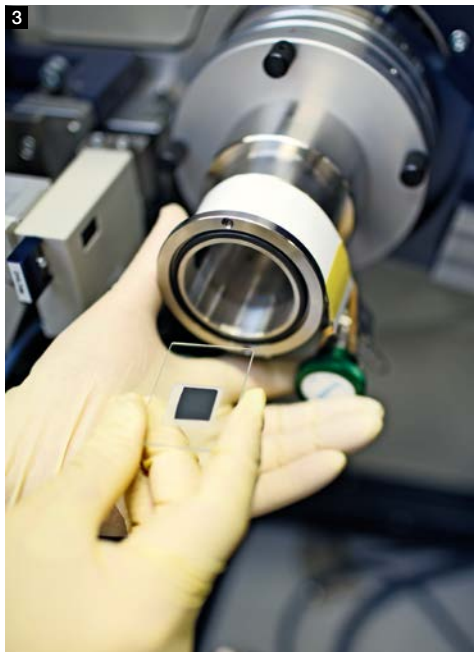
1

(1) Lab manager Dr. Martin Schulz-Dobrick and a colleague check the quality of an electrode.

(2) The electrodes are pressed out and then combined into a test battery.

(3) To examine the crystalline structure of the cathode materials, a sample is placed in the X-ray diffractometer.

(4) Chemist Dr. Masaki Sekine creates new additives for electrolytes that are tailor-made for each customer.



3



4

Developing the batteries that will drive the future

At the Amagasaki Battery Materials Lab in Japan, BASF researchers are developing innovative materials that will improve lithium-ion battery performance and increase the driving range of electric vehicles.



Monday morning 9 a.m., Dr. Masaki Sekine, an organic chemist, sits down at his computer to read the e-mails he has received from colleagues he is collaborating with in Germany and elsewhere in BASF's international network of R&D battery materials facilities. Sekine works in the newest addition to this network, the Battery Materials Lab in Amagasaki, Japan, inaugurated in early 2014. He is expecting feedback from colleagues on his efforts to create "a totally new molecule that has never existed before."

Sekine is part of the team that synthesizes innovative substances for use as additives in electrolytes, the chemical medium that allows the flow of lithium ions between a battery's positive electrode, the cathode, and its negative electrode, the anode. The new additives influence the electrochemical reactions in the battery and can therefore affect the battery's performance.

The kinds of additives Sekine creates depend on which aspect customers want to enhance in their batteries. Many of the lab's customers are Japanese manufacturers of lithium-ion batteries who are developing new batteries for electric

vehicles. They are looking for improvements such as higher power density, greater high temperature stability or an increase in cycle performance, meaning the number of possible discharges and charges.

To create a new additive he uses a process of organic synthesis. The synthesis of the additive takes place in a solvent. This solvent must be separated after the successful reaction.

"Purification of the additive is a challenging part of the process," says Sekine. "In many cases it doesn't go as planned. And in most cases a single purification round doesn't provide enough purity to satisfy the strict specifications for a battery additive. Even tiny impurities can lead to uncontrolled reactions and could damage the battery performance significantly, such as increasing the risk that the battery discharges when not in use."

Working in a global network is stimulating and helps teams to find solutions quickly. "I was once stuck with a synthesis," Sekine recalls. "Theoretically, several synthetic routes were available, but I couldn't make it work. Then a colleague in Germany contacted me and suggested an alternative catalytic route which was much more efficient."

“Our expertise in cathode and electrolyte materials development and our ability to work together as one team differentiate us.”

Dr. Martin Schulz-Dobrick,
Head of Amagasaki
Battery Materials Lab, Japan

Such feedback and open collaboration are key. That is why the next step for Sekine is to discuss his results with the lab's electrochemical testing group.

Testing 1, 2, 3, 4 ...

One member of the testing group is Dr. Zhen-Ji Han, who hails from Yanji in China and joined the team in 2013. She helps develop electrolyte formulations and conducts electrochemical testing for batteries using next-generation anode materials. It is her job to test the latest synthesized additives.

She takes the new additive to the Cell Assembly room where, donned in coveralls, protective gloves and safety goggles, she mixes it into a prepared base electrolyte and then injects the solution into a test cell. This enables her to examine the cell's electrochemical properties. Battery performance deteriorates with usage but also over time. Each of these aspects, performance, calendar life and cycle longevity, has to be tested. To test the latter one, the cell is placed in a cyclor machine, where it is repeatedly charged and discharged over a period of weeks or months.

Han discusses her findings with the synthesis group. “Because we know more about the battery's chemical interactions, we can advise the synthesizers which parts of the additives are functioning well or not, and how best to redesign their molecular structures,” she says.

Meeting different needs

A lot of the work carried out at the lab is tailored to individual customers' requirements. This is where Hiromu Sugiyama enters the stage. The senior researcher in cathode development works directly with customers helping them to achieve performance targets. This involves checking cathode materials' test data to see that the transition metal content is suitable for the targeted performance tasks, or looking at whether a material's particle size and shape will enhance or hinder a performance goal.

“We always have to consider how the cathode interfaces with the other components in the battery,” explains Sugiyama, who joined the team in 2014. “So testing and analysis is done working closely with the other research teams.”

■ BASF TODA Battery Materials LLC

The right chemistry for e-mobility

Delivering on the potential of e-mobility will require batteries that can provide higher energy density, greater power and longer lifetime, safely and at a lower cost. In order to meet this challenge, BASF has joined forces with TODA KOGYO CORP., a leader in developing and manufacturing cathode active materials for lithium-ion batteries.

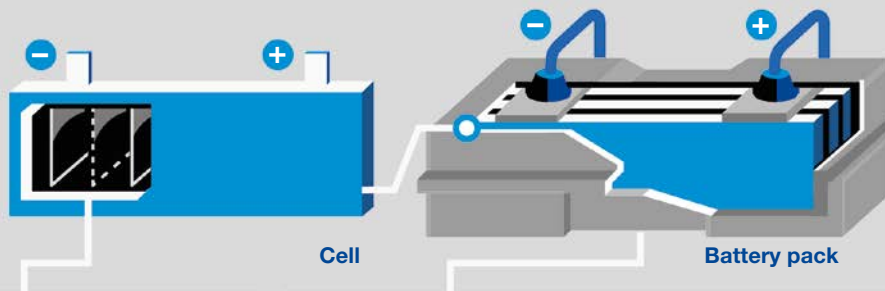
Combining BASF's R&D expertise with TODA's cathode material portfolio, the new joint venture, BASF TODA Battery Materials LLC, will develop and manufacture a range of advanced cathode materials to meet different requirements. Cathodes consist of tiny particles whose shape and size impact performance. Controlling these two factors is key to achieving an optimal result – something TODA excels at.

Along with electric vehicles, the new cathode materials will also bring improvements in performance for lithium-ion batteries in consumer electronics and stationary storage devices.

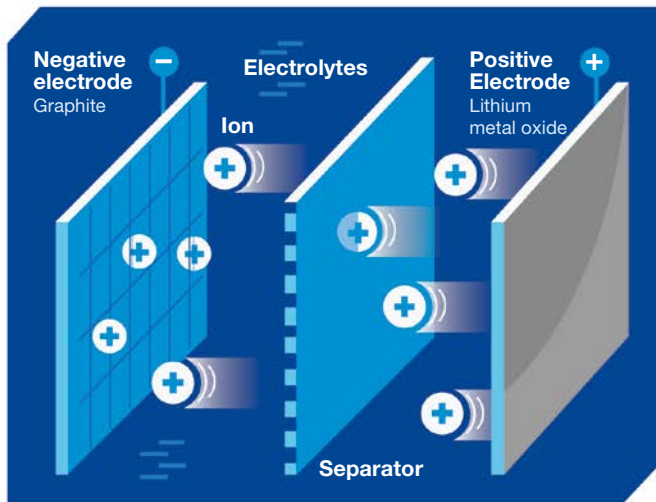
➤ To find out more, visit:
www.basf.com/basf-toda-battery-materials

Tomorrow's batteries

Affordable, high-performance batteries suitable for everyday use are necessary for the expansion of electromobility and the integration of renewable energy. BASF is researching and developing materials to improve existing battery systems as well as materials and components for future generations of batteries with high storage capacity.



Lithium-ion battery: cell structure and charging process



Applications and research objectives

- Automotive industry**
Increasing the range of electric cars from 150 to 200 kilometers to as much as 400 to 500 kilometers
- Consumer devices**
Reducing weight, increasing number of charging cycles and thus product lifetime
- Energy storage**
Lowering storage costs and increasing lifespan



5

All under one roof

“The Amagasaki lab is special in a number of ways,” says Dr. Martin Schulz-Dobrick, head of the facility. “It’s BASF’s first facility in Asia Pacific to combine development of cathode materials, electrode and electrolyte materials with application technologies. We not only conduct basic research on these materials starting from scratch, but also support our customers in prototyping batteries.” One example of the application work on a customer’s specific needs is the joint development of an electrolyte recipe. “We are jointly designing and building test batteries, which allow us to test our materials under conditions close to our customers’ needs and therefore speed up the whole development,” the lab head explains.

And, significantly, the facility brings the different areas of research together under one roof. “This is the big advantage of our lab,” says Schulz-Dobrick, who transferred from BASF’s headquarters in Germany to Japan in 2013. “Our expertise in cathode and electrolyte materials development and our ability to work together as one team differentiate us from other material suppliers, who can generally provide battery makers with either electrolyte or cathode materials. We specialize in both.” ■

(5) Dr. Zhen-Ji Han discusses the results of the new electrolyte additives with a colleague.

(6) Once mounted in a climatic chamber, the finished batteries are then connected to the power supply and tested.

(7) Hiromu Sugiyama with the X-ray diffractometer, which is used to test the cathode material.

(8) The electrode paste is carefully applied to the backing film and spread into a thin layer. The electrode must be uniformly thick.



6



7



8

New discoveries

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



Solar-powered tent keeps food fresh

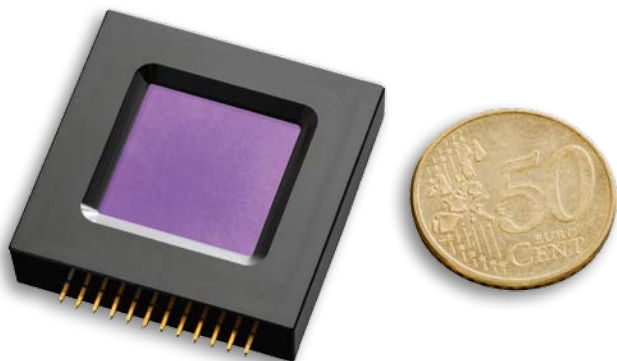
Belgian designer Arne Pauwels has invented a tent-like structure for food to help smallholder farmers in hot, dry regions reduce spoilage of their harvests. A small, three-watt solar panel operates a fan inside the tent that evaporates water, creating a humid and warm microclimate which can keep up to 150 kilograms of fruit and vegetables fresh for as long as 10 days. This requires around half a liter of water per week and less than 1% of the energy a refrigerator would need. More than 170 of these microclimate tents had already been delivered to Afghanistan, Haiti and Uganda before mass production started in August 2015.

www.wakati.org

3D in real time

An interdisciplinary team of BASF researchers has invented a new technology that enables especially efficient measurement of spatial data. The XperYenZ™ sensor system is the first that, in real time, can measure the distance to an object using the light reflected by it. And it works both in the micro range and up to hundreds of meters away. This eliminates the need for the geometric calculations that currently have to be carried out. With its novel combination of precision and speed, this imaging 3D sensor system can be used in many areas, such as consumer electronics, traffic safety and production monitoring. The first products based on XperYenZ™ should come on the market in 2017.

www.trinamix.de



Floating air purifiers

Inspired by the Chinese Lantern Festival, Polish designer Michał Pośpiech came up with a visionary and elegant idea: A flying air purifier that helps create a healthy microclimate outdoors. The wings of these machines have solar panels on the top and exchangeable filters underneath. Every movement they make circulates and cleans the air. The UrbanCONE can be steered using a smartphone. For now, it is still just in the design stage.

www.behance.net/gallery/24171731/UrbanCONE



Safety in a spray can

Invisible during the day, the safety spray LifePaint starts to work when the sun goes down: Its ultrafine glass spheres, when sprayed onto clothing or a bicycle, are reflective in the glare of car headlights. Volvo and the Swedish producer Albedo 100 have teamed up to improve safety for cyclists. If testing in the London area proves successful, the spray will be sold across Europe.

www.volvolfepaint.com



Energy grows on trees

The Arbre à Vent® (“wind tree” in English) – the brainchild of Jérôme Michaud-Larivière, founder of the French start-up NewWind – stretches several meters into the sky. Its 72 microturbines look like leaves and can generate energy even at wind speeds of just two meters per second – nearly without making any noise. With an annual output of 2,400 kilowatt hours, according to the company, one tree generates enough electricity to power a four-person household for almost a year. The first prototype of this biomorphic wind turbine was installed in August 2013 on the western coast of France. Further installations are planned in 2015, including at the Place de la Concorde in Paris. Series production of the Arbre à Vent® is scheduled for summer 2016.

www.arbre-a-vent.fr



When the sun is your greatest enemy

In Tanzania, one in every 2,500 inhabitants is born with albinism. Here, near the equator, the extreme solar radiation can be life threatening to people with light-colored skin, hair and eyes. They have a high risk of getting skin cancer and their average life expectancy is just 30 years. The “KiliSun” sunscreen is produced locally and distributed free of charge by the Regional Dermatology Training Centre (RDTC) to people with albinism in the region. BASF is supporting the Centre by providing high-quality UV filters to add to “KiliSun” and helping with the development of an improved sunscreen.

www.kcmc.ac.tz

Plastic: A victim of its own success?



The success of plastic is undisputed, at the same time its downsides such as waste disposal are the subject of much debate. Prof. Dr. Helmut Maurer and Patricia Vangheluwe, PhD, two experts in the field of plastics, discuss their ideas on how to tackle this global challenge.



Plastics touch nearly every area of our lives, bringing improvements, convenience and cost savings. These highly versatile materials have helped shape our world for over 100 years and new plastics are being developed all the time. But as plastic waste builds up in landfills and the oceans, its disposal is now a major environmental issue. Patricia Vangheluwe, PhD, from PlasticsEurope and Professor Dr. Helmut Maurer from the European Commission's Waste Management and Recycling Unit discuss the dilemma this poses.

Creating Chemistry: For some the word “plastic” has become synonymous with a disposable culture, yet the material makes a huge contribution to our daily lives. Do you think plastic has an image problem?

Helmut Maurer: Plastic is a victim of its versatility and great success. What do we not make out of plastics? We even have it in our bodies as part of medical applications. There is no reason to demonize plastic. The trouble from my point of view is that it is widely overused. We market it and produce as much as we possibly can, and then the instruments are not in place to properly handle it. Planned obsolescence has become an industrial principle.

Patricia Vangheluwe: I agree that plastic has an image problem and we need to change this. For instance, we have to do a lot more to use post-consumer plastic waste as a resource and make people understand that plastic is a valuable material. As a society we have to tackle that issue, because plastic offers such tremendous opportunities to address societal challenges and it is one of the most resource-efficient materials around.

Rising consumption has led to problems as countries struggle to deal with a vast amount of plastic material being thrown away. According to the United Nations Environment Programme (UNEP), between 22% and 43% of plastic waste ends up in landfills worldwide rather than being reused or recycled. How can we tackle this problem?

Patricia Vangheluwe

Patricia Vangheluwe, PhD, is director of consumer and environmental affairs at PlasticsEurope, the European association of plastics manufacturers. She has a PhD in organic chemistry from the University of Leuven, Belgium, and did a post-doctorate at the University of Pretoria, South Africa, as well as a Master in Controllershship at the Belgian Vlerick Management School. Previously she worked at LyondellBasell and predecessor companies in marketing, strategy, communications and human resources.

Maurer: In developing countries plastic is practically always thrown away, either in landfill or in nature. Even in Europe around 50% goes to landfill. It is clear we have to act urgently. What we need is a global landfill ban. And we have millions of tons of plastic broken down to microparticles floating around in our oceans – an influx of another 10 to 15 million tons reaches the marine environment every year. We need to talk globally – the oceans don't have borders. We also need to work on the chemistry of the material. You have to make products with materials that are designed to be recycled and avoid toxic additives that make recycling difficult. That is a big challenge for the plastic industry.

Vangheluwe: I share Helmut's view that we need to encourage a landfill ban globally. When it comes to post-consumer waste, the whole of the value chain – from plastics producing companies to product producers, retailers and end-consumers – can do better. We have to design products for resource efficiency, which is not quite the same as design for recycling, and in doing so we have to take into account what will happen with the product at the end of its life. Producer companies have always taken waste very seriously, because it makes economic sense to use resources within production in the most efficient way. All the product and application development they are doing is to make products lighter, more durable, more functional. This helps save resources, which has similar positive effects as preventing waste.



“We have to do a lot more to use post-consumer plastic waste as a resource and make people understand that plastic is a valuable material.”

Patricia Vangheluwe, PhD, Director of Consumer and Environmental Affairs at PlasticsEurope

It is often cheaper for industrially advanced countries to send plastic thousands of miles by ship than to reprocess it where it was used. Shouldn't recycling be made more economically desirable closer to home?

Vangheluwe: Quality recyclates should be considered as products, the same as any other product on the market. In a free market products can be traded; supply and demand dictate the market. But it is good that recyclers work hand-in-hand with the value chain close to home to extract more value from these recycled materials. Plastics producers can help recyclers because they have knowledge of the material itself. This information can

help determine which markets those products can serve and how to do the quality control.

Maurer: As Patricia rightly says, producers know their material best and for recyclers it is extremely important to have that same knowledge. There's still a lot to do to facilitate this knowledge transfer. In order to enhance domestic plastic recycling, there are plenty of things we can do. First, we can set targets to define a goal to recycle a lot more. Then we also have to facilitate markets. We can set up end-of-waste criteria and create a market pull for high-quality recycling.

Burning waste plastic to generate energy is an industry in itself. As worldwide plastic recycling rates are low many people argue it is an essential part of the energy mix. Do you see a long-term role for energy-from-waste schemes using plastic?

Maurer: Generally speaking, burning plastic should be avoided because in burning we lose the process energy necessary for making the plastic. Burning will slow down as recycling becomes more attractive. But the reality is, much post-consumer plastic is unsuitable for recycling – partly because of hazardous materials put in by producers, like certain flame retardants or phthalates. But we are talking about a moving target because the plastic of tomorrow – the better recyclable plastic – will naturally lead to more recycling. Another important argument against burning plastic is climate change. Until 2050 we have a maximum budget of 1,000 billion tons of CO₂ emissions to respect if we want to limit global warming to 2 degrees Celcius. But already known global fossil fuel reserves equal 2,900 billion tons of CO₂. If we had to leave them in the ground, this would force us to do more recycling.

Vangheluwe: Energy recovery is sometimes the most eco-efficient solution, especially for mixed waste. When this is the case from a life cycle perspective, energy recovery makes sense as one of the waste management options. Hopefully one day the innovation will be there that allows us to break down mixed plastics that cannot be sustainably recycled into raw materials which can be reused to produce plastics in an economical and environmentally sustainable way – that would be a breakthrough that would help to increase recycling of plastics.

How do you see plastic products developing over the next 50 years? Where do you see the biggest opportunities and challenges?

Maurer: I would like to see plastic getting rid of its negative image as an omnipresent, cheap and easily breakable material. But I would warn about looking to the way forward as depending only on more technology. We have to face the fact that an annual 5% global growth rate in plastic production would mean doubling production every 14 years, so that by 2043 we would be producing 1,200 million tons a year. This would obviously not be sustainable. Already today, plastic in the marine environment is totally out of hand. I think we are producing too many things that aren't really needed.

Vangheluwe: We will see continuous developments in intelligent and barrier packaging, medical applications

such as prosthetics, and even lighter composite materials that can be used in structural applications for the automotive and construction markets. Bio-based plastics will continue to be developed and I believe we will have mixed plastic that will be used as a raw material stream for plastics in the coming 50 years. We will also have increasing use of CO₂ as a feedstock and as such closing the full carbon cycle. It's already taking place now to produce polyurethanes. If plastic is to continue to deliver all the benefits it has delivered so far, we will all have to continue working on the challenge of waste management, litter and plastics in the environment. I've always believed that technology and innovation can make a difference. With ongoing education on proper waste management and innovation, plastics will continue to provide solutions to many of the societal challenges ahead of us. ■

Prof. Dr. Helmut Maurer

Professor Dr. Helmut Maurer is principal lawyer at the European Commission's Waste Management and Recycling Unit in the Directorate General for the Environment. He is responsible for questions regarding a future strategy for plastic waste, circular economy and coherence of waste legislation. He completed his doctorate in comparative employment law at Trier University, Germany, and has held two tenures at different universities.*

“Even in Europe around 50% of the plastic goes to landfill. It is clear we have to act urgently. What we need is a global landfill ban.”

Prof. Dr. Helmut Maurer, Principal Lawyer at the European Commission's Waste Management and Recycling Unit, Directorate General for the Environment



Innovative everyday companion

Plastic plays a role in our lives like no other material. Whether at home, on the road, at work or while shopping, we are surrounded by plastics – keeping buildings warm, providing soundproofing, making vehicles lighter and keeping food fresh longer. Although some people see plastic as being in conflict with nature, plastics actually help to conserve resources and reduce emissions.

The story of the development of plastics goes back to the Stone Age, when Homo sapiens used birch tar from birchbark to produce tools. In the 19th century, increasing industrialization led to the development of several groundbreaking plastics, such as vulcanized rubber as well as celluloid, which was used as a see-through backing for photographic film. In 1950, BASF filed for a patent for its foam plastic Styropor®, which is still one of the most commonly installed insulation materials today. And in 1957 the “Age of Plastic” was ushered in with the start of large-scale production of polyethylene, which is mainly used in pipes, cable insulation and packaging.

The key features of plastics are their technical properties which can be varied significantly according to their molecular composition or by the addition of additives: They can be malleable, elastic, hard or unbreakable.

Plastic-based insulation installed in the walls, floors and roofs of houses makes a major contribution

to reducing energy consumption. After all, buildings are responsible for 40% of energy consumption and CO₂ emissions in Europe. The plastic insulation used in a typical house can save as much energy in one year as was originally used to produce the plastic.

The amount of plastic used in aircraft construction has grown considerably since the 1970s. For example, the structure of a Boeing 787 is made up of 50% plastic composite materials. This is mainly because of the weight savings resulting from the use of plastics, which also boast good technical properties and great stability. Likewise, plastics are becoming more and more popular in the automotive sector. A plastic-based component is only around half as heavy as a component from conventional metallic materials, so it helps save fuel.

The largest field of application for plastics, however, is packaging: These days, 50% of all European goods are packed in plastic. Nevertheless, plastics make up just 17% of all packaging waste.

And one major advantage of plastics is the avoidance of food waste: Each year, 1.3 billion tons of food go to waste, equivalent to one-third of all food produced for human consumption. When packed in plastic, food remains fresh for much longer. For example, that way a piece of Parmesan cheese can remain fresh for 50 days rather than 20 days. At the same time, because it weighs less than conventional materials like glass and metal, plastic packaging saves fuel and CO₂.

Plastic is therefore much too valuable to end up in landfill. The best option for used plastics is to find a new application to reuse them. When this is not a sustainable option, plastics can be used as a source of energy. In terms of energy recovery, plastic has the same calorific value as the crude oil from which it was once made so it can be thought of in this context as “solid crude”. For this reason, BASF and companies in the European plastics industry support a landfill ban for plastics from the year 2025 on. ■



Dr. Melanie Maas-Brunner

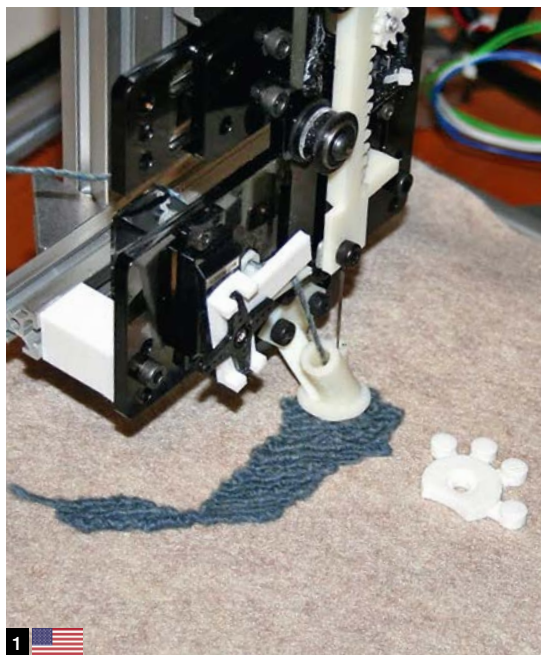
Dr. Melanie Maas-Brunner has been head of the unit Performance Materials Europe at BASF since 2014. After receiving her doctorate in chemistry, she joined BASF as a researcher in process development in 1997. She was later responsible for global product strategy for dispersions and paper chemicals. From 2008 until 2012, she worked for BASF in Asia, where her roles included head of the business unit Polyurethanes Asia Pacific. Maas-Brunner studied and received her doctorate in technical chemistry at RWTH Aachen University in Germany and the University of Ottawa, Canada.

“Plastic is much too valuable to end up in landfill. The best option for used plastics is to find a new application to reuse them.”

Dr. Melanie Maas-Brunner, Head of BASF's Performance Materials Europe Unit



Production of the Boeing 787 Dreamliner in South Carolina, USA. The structure of the plane is made from 50% plastic composite materials. This considerably reduces weight and helps to save fuel.



1 



2 



3 

1 **United States**
Soft and cuddly

Cuddly teddy bears straight off the printer? The Disney Research Team in the United States has found a way to print in wool, meaning that alongside hard, precise objects, this new technology can now also be used to create things that are soft and squeezable. The printer builds up the yarn in layers, producing a unified mass that looks and feels like felt. In collaboration with a team from Carnegie Mellon University's Human-Computer Interaction Institute in Pennsylvania, USA, they even printed a moveable teddy bear arm.

2 **China**
Printed homes

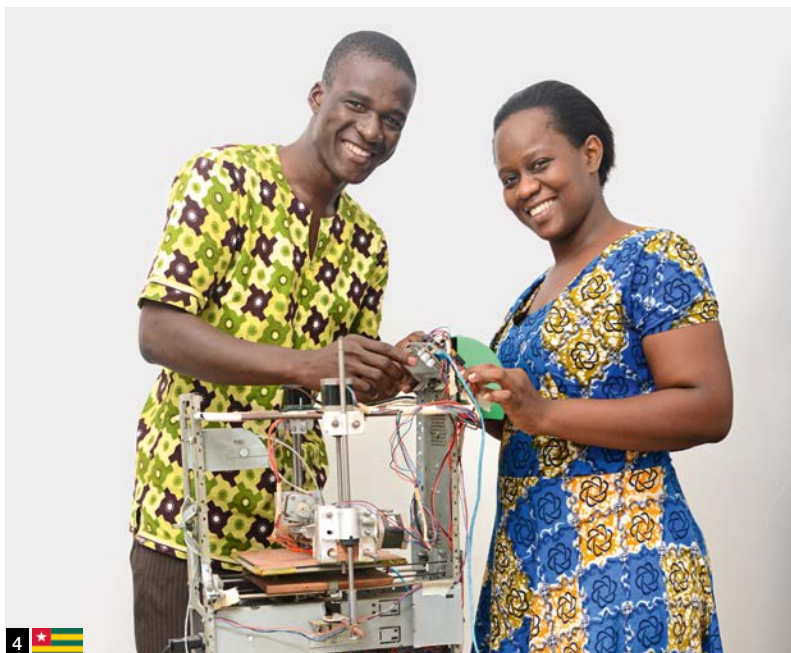
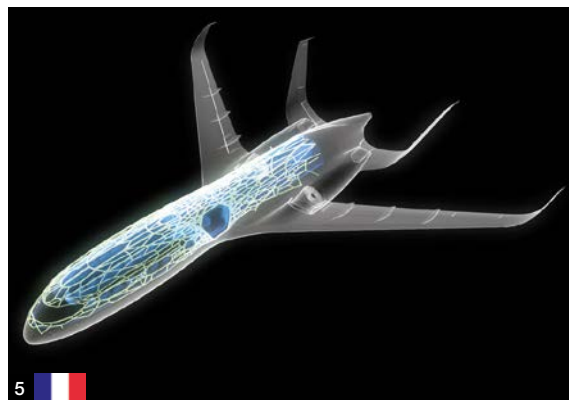
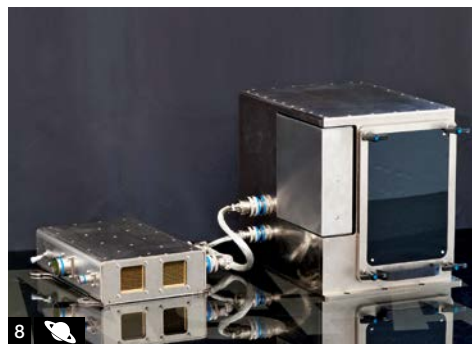
The Chinese construction company WinSun Decoration Design Engineering has not only shown it can quickly and cheaply produce houses using a 3D printer and recycled concrete material – printing 10 houses in one day – it has now gone on to print an entire 5-story apartment building and a standalone villa. The aim is to be able to construct homes at affordable prices for the Chinese market. The smaller houses cost just around €4,500 (\$5,000) to produce.

3 **United Kingdom**
Replacement body parts

While 3D printing is already widely used in dentistry to print teeth and parts of jawbones, U.K. scientists have developed a process for printing ears out of synthetic material for children with severe disfigurements. Replacement ears are normally made manually. 3D printing simplifies the process. In the first clinical trial of its kind, a team at University College London has been carrying out tests and is months away from implanting the printed ears into patients. The team is also working on printed noses, tracheae, tear ducts or blood vessels.

Innovative uses for 3D printing

Although 3D printing is not a completely new phenomenon – the first patent was awarded in 1986 – it is evolving rapidly: New applications appear almost daily, from all around the world, in fields as diverse as medicine, consumer products and construction.

4 5 7 6 8 

4 Togo Recycled electronic waste

If 3D printing is set to revolutionize manufacturing, Afaté Gnikou from Togo is making sure that no one needs to be left out for lack of resources. Together with a team at the Woelab Fab Lab in Lomé, he has developed the first 3D printer made entirely of electronic waste. Tailored for the African market, the W.AFATE printer is now in series production and won first prize at the international Fab Lab Conference in Barcelona in 2014.

5 France The future of flight

Aircraft manufacturer Airbus wants to use 3D printing to create new airplane structures that mimic the design of bone or skeleton – strong, flexible forms that weigh significantly less than those built with traditional manufacturing processes. Starting with tiny carbon nanotubes that “grow” inside the printer, huge complex structures can be created quickly with very little material waste. The weight reduction from the lighter materials would lead to huge fuel savings.

6 Australia An unfolding story

With 4D printing, Australia has gone one step further and added a new dimension: time. Researchers at the University of Wollongong have succeeded in printing a valve that opens and contracts over time in reaction to surrounding water temperature. The achievement opens up myriad possibilities in areas like medicine, construction and robotics, for fully functioning devices that come straight off the printer – no assembly required.

7 Argentina It needn't cost a mint

3D printing in metal is pricey. But Argentinian engineer Gastón Accardi has come up with a prototype of a metal printer that cost him less than €2 to make. Essentially a marker filled with a copper acid solution, it uses the concept of electroplating to build up 3D objects layer by layer in different types of metal. Although still a little slow, the machine could one day be a boost to small businesses.

8 Space Zero gravity printing

With visions of life on Mars firing our imaginations, 3D printing is seen as an off-world solution to everything the human needs, from food to shelter. But without gravity, how do you prevent the material you are printing from just floating away? Working with NASA, U.S. company Made In Space has developed Zero G, the first 3D printer designed to operate in zero gravity. Launched into orbit in 2014, it is serving as a test bed for space manufacturing technology.



How will we feed ourselves in the future?

The United Nations (U.N.) predict that by 2050 we will need to increase food production by 70% to feed the world. There is no single solution to this challenge, but it is prompting some innovative ideas that could profoundly change the way we eat.

In 1931, Winston Churchill predicted in an article for *The Strand Magazine* that the time would come when scientists would use microbes to grow meat in laboratories, much as bakers use yeast to make bread.

Eighty-two years later Churchill's prediction became a reality: In 2013, Mark Post, PhD and Professor of Physiology at the University of Maastricht, made scientific and culinary history by presenting and then eating a burger that he had grown in his laboratory in Maastricht. Even today, for many, the idea of lab-grown meat is outlandish. But as a perfect storm of events gathers to threaten global food security, there are a growing number of reasons to believe it is an idea whose time has come.

Last year the global population reached 7.2 billion and is set to reach over 9 billion by 2050. While one in nine still does not have enough food for a healthy life, there has been a significant rise in the middle classes, who are predicted to reach 4.9 billion by 2030. With this newfound wealth comes an appetite for meat, eggs and dairy products – the kind of high-value, high-protein diet so long associated with the West – and rising obesity rates. Obesity is already the fifth most common cause of death worldwide. Meanwhile, the way we grow livestock has a huge impact on the environment as one of the greatest sources of greenhouse gases.

With all these challenges, how can we improve food production, supply and nutrition while preparing for a world population of more than 9 billion? We have to start thinking urgently about how to meet this additional demand in a sustainable way.



“I entered into this to address the problems I find most pressing, which are threats to food security and the environmental cost of beef production.”

Professor Mark Post, PhD,
University of Maastricht



Professor Mark Post, PhD, taking a bite of his burger made of lab-grown meat (top). Another promising solution are insects – a highly nutritious and ecologically more sustainable protein source than meat (right).

A good starting point is meat. Global meat consumption is on the rise, despite it being one of the most inefficient sources of protein in terms of production. According to a recent study in *Nature Climate Change*, meat and dairy products contain only 2.6% of the feed and pasture biomass fed to animals; the remaining 97.4% is lost. Climate change scientists have been warning for over a decade of the need to cut meat consumption. It takes between 5 and 20 kilograms of grain and some 15,000 liters of water to produce 1 kilogram of beef, while methane from cows is 25 times more effective as a global warming agent than CO₂. Yet, by 2050, consumption of meat worldwide is expected to rise by 76%.

Many see an alternative in the world of insects. They cause fewer greenhouse gas emissions, they require significantly less land and water than cattle rearing, and insects such as crickets only need 2 kilograms of feed for every 1 kilogram of bodyweight gain. In 2013, the U.N. Food and Agriculture Organization (FAO) carried out a major study into edible insects and their prospects as an alternative food. Insects already form part of the traditional diet of 2 billion people and

■ BASF's international Kitchen Labs

Food is culture, culture is local

Not only regional distinctions in taste or mouth-feel play a role in the production of food. Weather conditions also influence the appearance of products like cakes, whipped toppings and bread. Do customers in Turkey like their cakes light and fluffy or moist and dense? How can we improve the stability of a cake topping in regions with high humidity? These are the questions being answered in BASF's international Kitchen Labs, where experts from BASF and customers are working together to improve or develop new recipes. The goal is to hit exactly the right note for each market – for example, a cake mixture especially suited to Middle Eastern needs.

➔ To find out more, visit: www.newtrition.basf.com

1,900 species are used as food. They score high by practically every criterion you wish to judge them on – they are a highly nutritious food source of good types of fat.

Yet, despite their merits, insects have failed to catch on in the West. In countries where animals have always been an abundant and cheap source of protein, eating insects is not culturally acceptable and transitioning to a meat-free diet is a challenge. Which is one reason why Post, in his Maastricht laboratory, has committed himself to finding a way to meet the global demand for meat without impacting the environment or even harming animals. Hence the lab burger.

The process he has developed requires taking a small biopsy from a living cow. Around a hundred skeletal muscle stem cells are harvested and then cultivated to the point where it is theoretically possible to produce a hundred metric tons of meat from a single sample.

Post and his team believe it will take up to seven years for the product to get through Europe's strict food regulatory process. But he is unequivocal about his motivation. "I did not enter into this to become an entrepreneur but to address the problems I find most pressing,

which are threats to food security and the environmental cost of beef production," he says.

Post himself admits that it will be a while before lab-grown meat is generally acceptable. But a recent survey of German customers by the food company Nestlé may give Post hope. It asked people about their attitudes to alternative sources of protein and revealed that, in 15 years, lab-grown meat could well be as acceptable to consumers in Germany as sushi is today.

In the meantime, other ideas are emerging that may be more easily achievable. Brent Taylor is the co-founder of Beyond Meat, a company that has broken the mould of traditional plant-based meat substitutes by producing an alternative using pea and soy protein that is so close to meat and chicken that it is targeted at meat eaters as well as vegetarians.

According to Taylor, the company's ambitious aim is to cut global meat consumption by 25% by 2020: "We want to be the next great global meat company. We want to speak to meat reducers who are looking for different solutions. Past efforts were for a vegan or vegetarian market, so these products did not fulfill the experiences of somebody who enjoys

The company Beyond Meat has ambitious aims: By 2020, it wants to cut global meat consumption by offering a meat alternative made of plant protein that matches the experience of eating real meat.

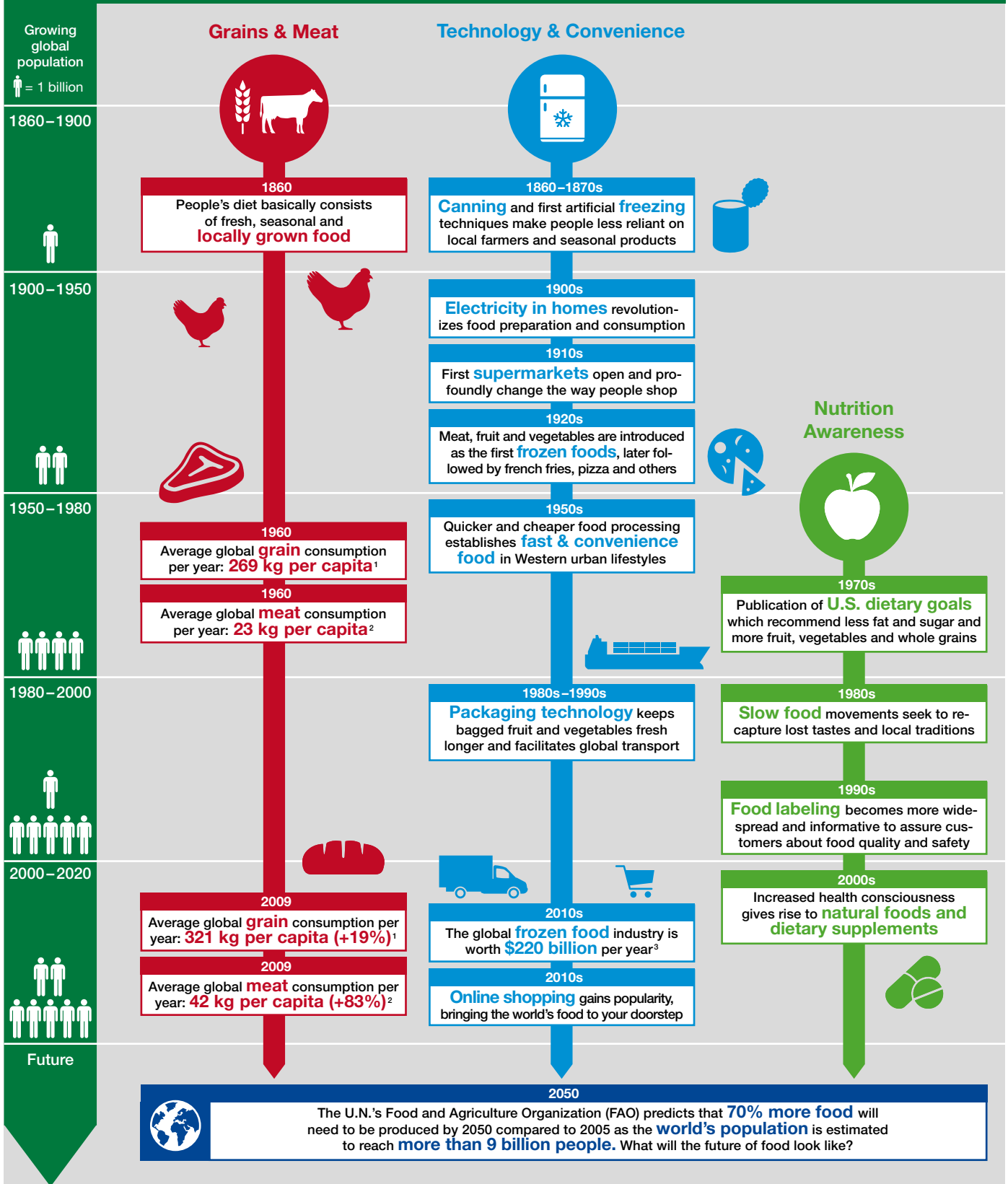
"We want to be the next great global meat company. We want to speak to meat reducers who are looking for different solutions."

Brent Taylor, co-founder of Beyond Meat



150 years of food – How the way we eat has changed

In 1865, the majority of the world’s population lived on the land, consuming homegrown crops and livestock. But population growth and urbanization were creating challenges, thus changing the way food was grown, processed and distributed. An overview of certain developments.



1 Earth Policy Institute, U.S. Department of Agriculture, 2011.
 2 FAOSTAT, Food and Agriculture Organization of the United Nations (FAO), 2014.
 3 Markets and Markets, Frozen Food Market Analysis, 2011.



BASF grows genetically optimized canola. The aim is to develop plants with elevated levels of healthy, long-chained Omega-3 fatty acids (left). Fish is naturally rich in Omega-3. Tasteless fish oils can enrich dishes without changing their flavor (right).



“Consumers understand that their health is their new wealth. They seek holistic solutions which establish, develop and support long, healthy and active lives.”

François Scheffler,
Vice President Human
Nutrition at BASF

the experience of meat. For us, it is always, how do we create not only the structure of meat but the fantastic sensory experience of meat,” explains Taylor.

Taste, texture and smell – all these sensory elements play a critical role in our experience of eating and, along with cultural norms, define our attitudes toward food. The problem is that, in spite of increasing awareness, these forces often draw us to foods that are not sustainable or healthy. So how can we make a healthy, sustainable diet more appealing?

This is a conundrum that the multinational agricultural, food and feed company Cargill recognizes. “The consumer wants less of the bad – things like eliminating trans fat, lowering saturated fat – and the addition of the good – things like Omega-3,” explains Kyle Marinkovich, Assistant Vice President Marketing at Cargill.

Omega-3 is a good example. Awareness of the benefits of eating fatty fish – a rich source of Omega-3 – is on the rise. Omega-3 fatty acids can help in the prevention of diseases, such as metabolic diseases, cognitive decline and cardiovascular disease. Yet surveys show most people around the world still fail to eat enough of it. One of the reasons often cited is that the taste and smell is off-putting.

Solutions to this problem are tasteless fish oils that can be added to foods without changing the flavor – thus providing the healthy ingredient without altering customer expectation or taste – and highly concentrated Omega-3 capsules.

Working with new impulses, scientists are discovering new ways to improve our health by finding even better ways to increase the nutritional content of our diets. BASF, for example, provides pure and highly concentrated Omega-3 fatty acids for use in consumer health, clinical nutrition and pharmaceutical products. “A hard line between food for energy and pharmaceuticals to correct disease is no longer relevant. Consumers understand that their health is their new wealth. They seek holistic solutions which establish, develop and support long, healthy and active lives,” says François Scheffler, Vice President Human Nutrition at BASF, who confirms that nutritious foods and special nutrition, including dietary supplements, are a growing market.

Our concerns about population growth, health and the environment are leading us to look for new ways of feeding ourselves. They have spawned a whole new movement of so-called “food hackers”, who have adopted the Silicon Valley approach of using technology to make life


better and have applied it to food. At a recent Food Hackathon in San Francisco, California, food innovators, entrepreneurs, scientists and technologists came together to explore how emerging technologies and sciences can reshape the “global food web,” and provide affordable nutrition for all.

Much of this is still visionary and some of the ideas might take some time getting used to. Because food is more than nutrition. It binds us to family and culture and is a source of great pleasure for many. We are protective about our relationship with food and are reluctant to change our eating patterns.

Which is why there is no single alternative solution emerging as to how we will sustainably feed ourselves in the future. Whether it is lab-grown meat, insects or vegetable protein, the transition will be slow, but the possibilities are diverse and ideas are out there. Who knows what we will be eating in 30 years, but one thing is certain: The journey has clearly begun. ■

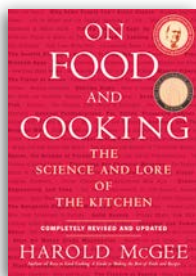
➤ To find out more, visit:
www.culturedbeef.net
www.beyondmeat.com
www.basf.com/creator-space/food
www.omega3.basf.com

The chemistry of cooking

A close-up portrait of science writer Harold McGee. He is a middle-aged man with a receding hairline, wearing glasses and has a grey beard and mustache. He is looking directly at the camera with a slight smile. He is wearing a blue and white striped collared shirt under a dark blue sweater. The background is a plain, dark grey-blue wall.

Science writer Harold McGee has revealed many secrets about the chemistry of cooking and food. In his garden in California (upper right corner) he also grows his own fruit and vegetables for cooking.

Science writer Harold McGee, PhD, has dedicated his life to finding out what really happens to bread when it bakes, to meat when it hangs or to egg proteins when we whisk them. His journey has led to surprising discoveries and a body of work that has inspired some of the world's greatest chefs.



Harold McGee

Harold McGee, PhD, writes about the chemistry of food and cooking. His first book “On Food and Cooking: The Science and Lore of the Kitchen”, published in 1984 and updated in 2004, uses science to explore why food behaves and tastes the way it does. His most recent book “Keys To Good Cooking: A Guide To Making The Best of Foods and Recipes” was published in 2010. He has also written the regular column “The Curious Cook” for The New York Times, and has been a visiting lecturer at Harvard University. Currently he is working on a new book on the science of taste.

www.curiouscook.com

Creating Chemistry: Which food myth are you most proud of debunking?

Harold McGee: Recently I put to the test the idea that you have to cook pasta in a large amount of water. I live in California where there is a water shortage and where we are worried about using more energy than we need to. It turns out that you can cook pasta in minimal amounts of water – around 1.5 quarts (1.4 liters) instead of 4 to 6 quarts (3.8 to 5.7 liters) – starting with cold rather than boiling water and it tastes the same. It works because noodles absorb water only very slowly at temperatures much below the boil, so little happens in the few minutes it takes for the water to heat up. And no matter how starchy the cooking water is, the solid noodle surfaces themselves are starchier, and will be sticky until they’re lubricated by sauce or oil. Given how much pasta is cooked a year, this would save lots of water and hundreds of thousands of barrels of oil a year, too.

Why did food science in the 20th century get so side tracked into the food industry?

It’s not that science got side tracked, it just got absorbed into modern movements that were more pressing and larger scale than what happens in homes and restaurants. Around the turn of the 19th to 20th century there were problems with canning – understanding why some cans exploded on store shelves was urgent. Then there was the Spanish American War and World War One, and the need to supply food to troops. Laws were introduced to monitor food safety. It meant scientific talent was drawn into manufacturing. A more relaxed view of what scientific understanding could contribute to domestic and restaurant cooking had to wait.

What made molecular cuisine so attractive in the last decade?

With the opening up of the world, national cuisines have become much less important than they used to be. These days, if you are an ambitious chef who wants to make a name for yourself you need to be inventive. That is where science has been particularly interesting to chefs at the cutting edge – they realize it is a wonderful partner in the search for new ways of doing things. If you under-

stand the basic principles then you can come up with variations on dishes and even completely new ideas that you would not even think of if you were just following recipes from generations ago. For example, chefs have worked with liquid sauces and solid gels like aspic for centuries, but Heston Blumenthal learned about “fluid gels” that flow when poured but become solid at rest. He used that idea to create a cup of tea in which one portion of the tea is hot and a second portion is iced – with no barrier between them.

How important to you is the exploration of different cultural approaches to food?

My focus is on what is possible to do with natural ingredients and their transformation by physical and chemical manipulation. The laws of physics and chemistry are the same no matter what country you live in. That is not to diminish the importance or interest of cultural differences, but I try to find commonalities that all cultures depend on and make use of in their own ways. For example,

the sodium and chloride ions in salt bind water molecules to themselves when salt dissolves, and cultures all over the world have used that property to preserve foods by removing their moisture and the moisture of microbes that would spoil them.

What advice do you have for novice cooks and what is the scientific explanation for that advice?

My top tip is to buy a good digital thermometer and be sure to use it when you cook meats, fish, and eggs, all protein-rich foods whose texture is determined by the extent to which the proteins are unfolded and bonded together by heat. In the critical range between 50 and 70 degrees Celsius, every degree or two can make a difference.

Has your scientific approach to food changed your enjoyment of food?

I don’t chew food with a frown but I do appreciate the complexity of the raw materials and the skill it takes to transform them into delicious food with every bite. ■





Bubbles with great potential

What do mattresses, metallic car bodies and chocolate mousse have in common? They can all be made from foam. But what exactly makes this bubble-filled material a product of the future?

It is not easy for Dr. Björn Braunschweig to relax at the end of the day: Even when he tries to enjoy an after-work beer, the researcher from the Cluster of Excellence Engineering of Advanced Materials at the Friedrich-Alexander University (FAU) in Erlangen-Nuremberg, Germany, can't help but notice the foam at the top of his glass. Why does the local beer from Bavaria have larger bubbles that pop faster than the Guinness® on the next table? "The head on the Irish stout is much more stable because the nitrogen gas used in the carbonation process is less soluble in liquid than the carbon dioxide used for draft German beer," Braunschweig explains. The 30-something scientist knows a thing or two about foam: In 2014, he received a €1.5 million starting grant for up-and-coming research leaders from the European Research Council for a five-year project to conduct basic research on foams.

Fabulously functional foams

It might seem odd that funding is being channeled into research on foams, of all things, but foam is a very versatile material with a bright future. Layers of Styrodur®, for

The cell surface of foams makes them flexible to use. Styrofoam spheres coated with carbonyl iron powder make this metal foam light as a feather, but at the same time as stable as solid metal. Installed in cars or planes it helps to cut fuel consumption and CO₂ emissions (left).

example, are not only used for insulation, they also reduce the stresses that earthquakes put on buildings, thus giving planners the confidence they need to build in seismically active areas. And joggers need to use less energy when they wear running shoes made with foam beads from BASF because the shoe's dynamic sole springs back into its original shape immediately after impact. Even as we sleep we can reap the benefits of polyurethane foams because they provide the same high elasticity in mattresses and pillows that was previously only possible with latex, and at the same time they are breathable and long-lasting.

"Foams are a booming market," says Braunschweig. "The air bubbles make the material very light and foams have the huge advantage of extreme plasticity." In lightweight vehicle construction, foams ensure an optimal balance between robustness and weight. At first glance, a vehicle body made of metallic foam seems just as hard as a traditional one. But if there is a crash, the foam body doesn't break and split. Instead, it undergoes plastic deformation and – similarly to an airbag – can absorb the impact.

To create foams with particular properties, researchers will need to understand every aspect of the foam, from the smallest molecules to the bubbles themselves. The interface – the place where the gas and liquid or the gas and the solid meet in the individual bubbles – is especially important. Which molecular components stabilize this surface? What interactions take place with the molecules there? The better researchers can answer these questions, the closer they will get to achieving their goal of creating a "molecular toolbox" that can control and predict the properties of foams.

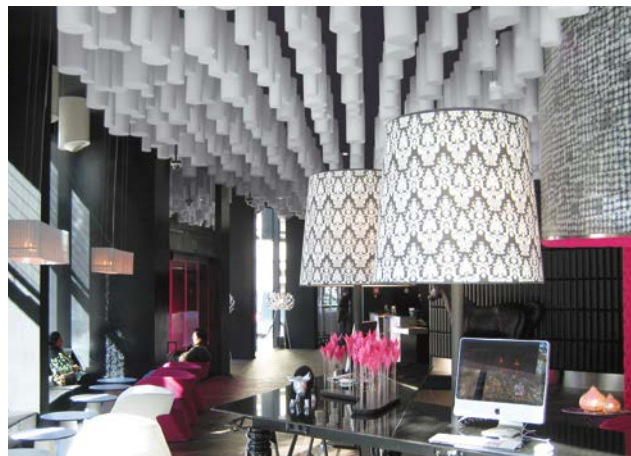
"Intelligent foams" demonstrate what the future may hold. These foams can change their properties in response to external stimuli such as light. Braunschweig believes this could play an important role in self-healing foams whose moveable molecules on the bubble's surface enable the bubble to expand under negative pressure and temporarily close any "injured" cells in the foam structure. Intelligent foams could also be beneficial for the recycling of insulation materials: "When a foam is no longer needed, it could

simply be collapsed. The remaining material would have just one-thousandth of its original volume – and it would make it easier to access the chemical components."

Whipping up something tasty

The food industry, on the other hand, is interested in completely different properties of foam. "It wants to use foams to stabilize quality until the best-before date," says the Erlangen-based researcher. The industry is also very interested in foams because they have a more intense flavor than traditional foods. The bubbles in foams give them a larger surface area, so they can give off more aromas in a shorter time. And foams appeal to healthy eaters since they are usually lightweights when it comes to calories, too. ■

Silence from above: At the Barceló Raval design hotel in Barcelona sound absorbers made from Basotect® are improving the room acoustics. In Beijing, panels made from the foam guarantee a safe and decorative sound absorption for the interior of the swimming stadium.



Frustration can be the mother of invention

Sir James Dyson's inventions have earned him huge commercial success and international recognition. With the James Dyson Foundation, the British industrial designer intends to inspire the next generation of engineers.

There's a global shortfall of engineers," says Sir James Dyson, whose bagless vacuum cleaners and high-speed hand dryers have made him a household name in many parts of the world. Founded as a one man business in the United Kingdom in 1978, Dyson now sells its products in 72 countries and employs over 1,000 engineers worldwide.

Dyson is passionate about the power of design engineering to do good and so concerned about the lack of engineers that, in 2002, he set up the James Dyson Foundation, dedicated to nurturing the next generation. "To fulfill current demand we need to produce 69,000 engineers a year in the U.K. alone. Today we only produce a mere fraction of that," he says. "I set up the Foundation to help combat this decline." He hopes the Foundation will help make engineering as attractive to young people as other creative industries.

Today, the Foundation supports education in engineering, design and technology across the world, donating almost €70.2 million (£50 million) so far. The free educational resources it supplies to classrooms and workshops provide hands-on experience that helps to "ignite young people's passion for design engineering," says Dyson, while each year the James Dyson Awards challenge students to design "something that solves a





More than one in ten babies worldwide are born prematurely. Last year's Dyson Award winner invented an inflatable incubator for use in developing countries at a fraction of the costs of a normal one used in hospitals (top).

In early 2015, Sir James Dyson visited Imperial College London to discuss current projects with the students of the Dyson School of Design Engineering (bottom).

Sir James Dyson

Sir James Dyson is Chairman and Chief Engineer of the Dyson Group. He studied furniture and interior design at the Royal College of Art in England before becoming interested in engineering. His first bagless vacuum cleaner, the G-Force, was launched in Japan in 1983. In 1993, he opened a factory in England. The James Dyson Foundation was established in 2002 and, in 2014, donated €11.2 million (£8 million) to create a tech hub at the University of Cambridge. This year has seen the foundation of the Dyson School of Design Engineering at London's Imperial College.



problem," with the winner receiving €42,000 (£30,000) to develop their invention.

"Last year's international winner really struck a chord," says Dyson. The problem James Roberts set out to solve was the high number of premature babies dying each year through lack of proper incubation. A student from Loughborough University in England, Roberts designed an inflatable incubator which provides the same performance as a €42,000 (£30,000) modern incubation system, but costs just €351 (£250) to manufacture, test and transport. "He's finished prototyping his machine and it's being tested in real-life conditions," says Dyson. "In a year he's come a long way, but as with all new ideas, success comes with time. He's one to watch."

If time is a vital ingredient, so is tenacity. One of the Foundation's key philosophies is not being afraid of failure – learning from mistakes and turning them into something unexpected. The students enjoy the

process: Building a prototype, finding out which elements don't work and going back to the drawing board. "Failure fuels invention. As an inventor you must be persistent and not be afraid to take risks," says Dyson, adding that it took more than 5,000 prototypes and 5 years to develop the first of his famous bagless vacuum cleaners. "Each prototype took me one step closer to success, or prompted me to challenge how I was going about the process. It was arduous, but frustration is a catalyst for better invention – it's something I instill in the engineers we have at Dyson today. You have to experience frustration and understand the problem in order to solve it."

If he could give one piece of advice to a budding young designer, what would it be? "Perseverance!" he says. "If you are fuelled by frustration and see that you're progressing to a viable solution, persist against the odds. There will be setbacks and hurdles. But without these you won't learn to succeed." ■

150 years: BASF co-creation activity

Innovation Nation – 1,000 ideas for a better Australia

Nations around the world are faced with challenges caused by growing or aging populations and increased urbanization. How will we provide enough healthy food for everyone? Where will our energy come from? What will tomorrow's cities look like? "Innovation Nation" is an ideas challenge that seeks solutions from those who will be responsible for making our future world work: young people.

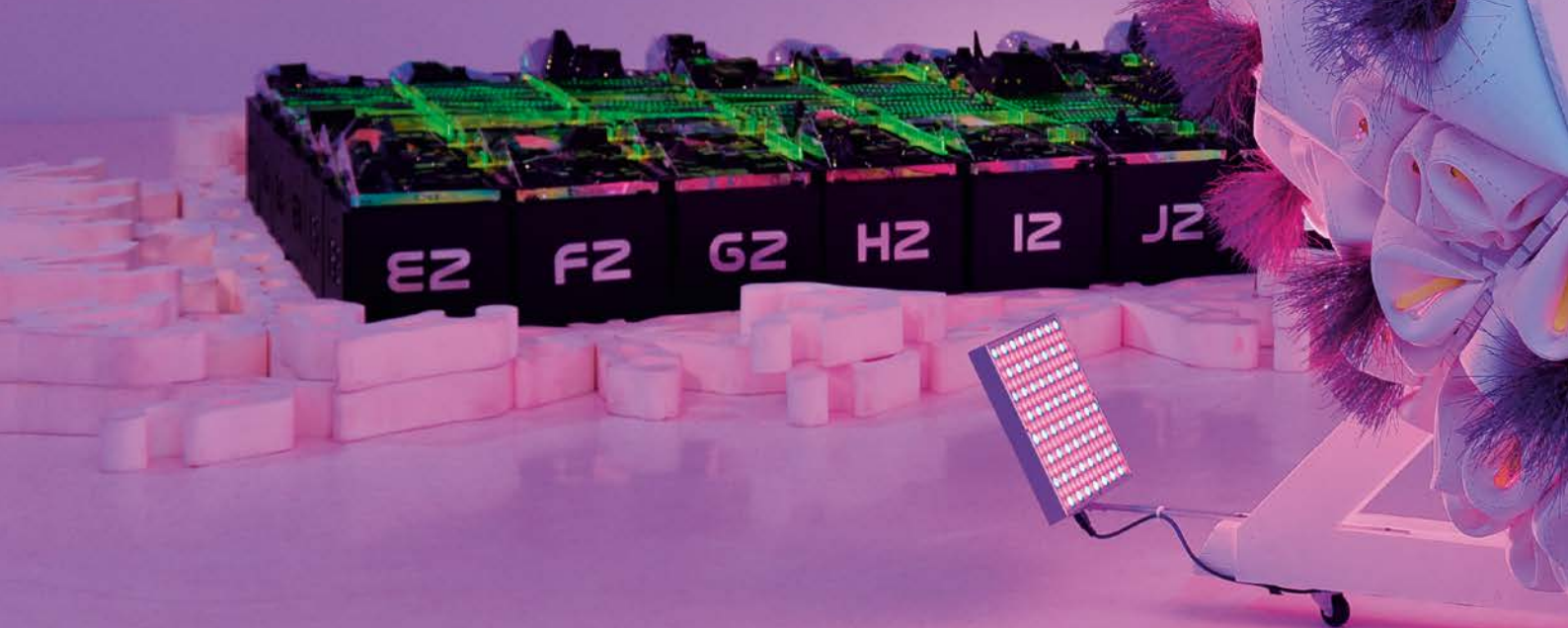
Launched in January 2015 by the Australian NGO "The Foundation for Young Australians" in partnership with BASF as part of its 150th anniversary program, the aim is to support young entrepreneurs and uncover the boldest and most innovative ideas for building a better Australia.

An app that enables restaurants to sell unused food, a campaign to make drinking straws biodegradable and an online lending platform for solar power are three of the six ideas picked by BASF to receive mentoring from industry experts before pitching their idea at a special event in Sydney. With €6,800 (A\$10,000) in seed funding on offer, the winner has the chance to turn his or her idea into reality and create a sustainable venture.

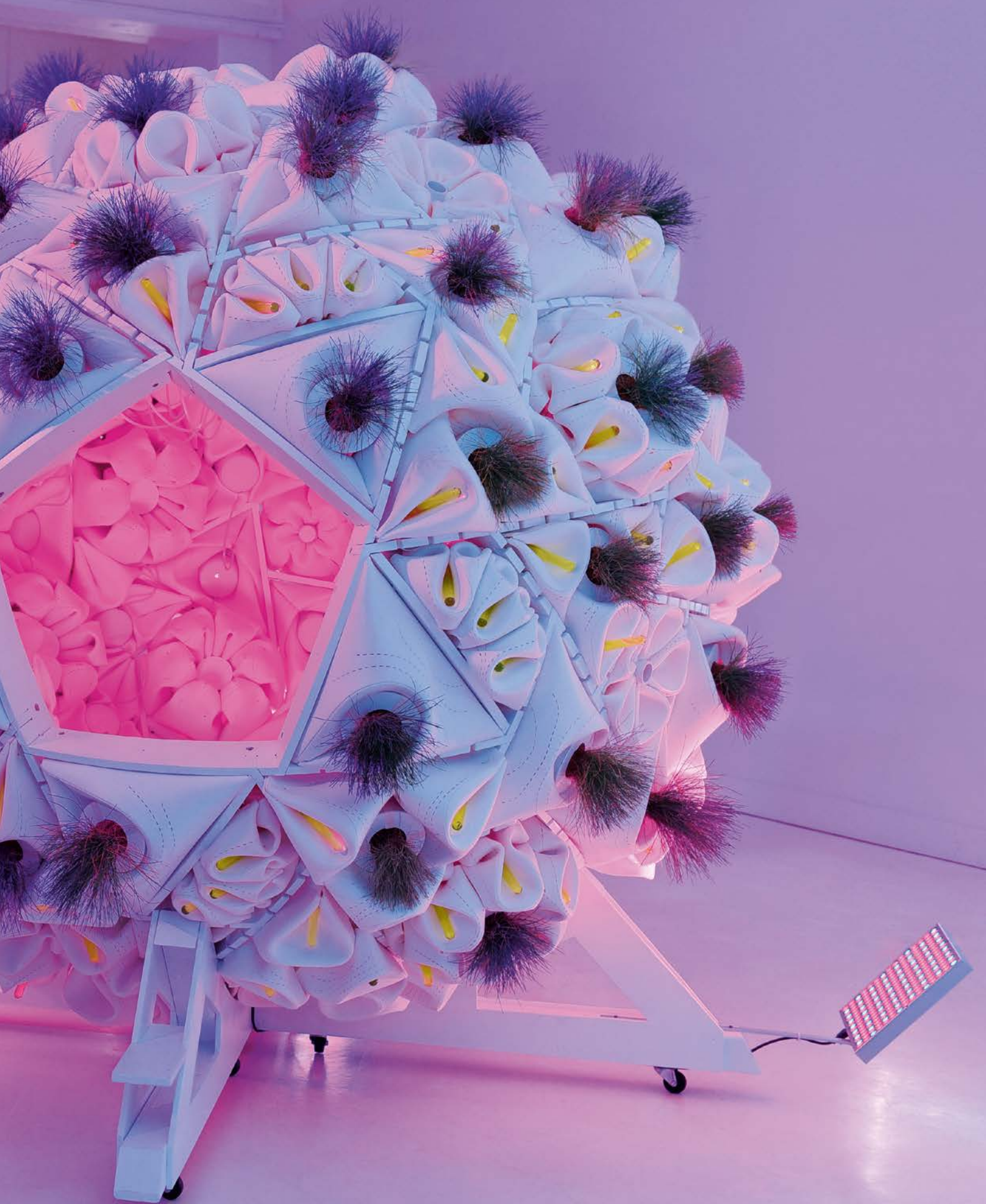
➤ To find out more, visit: www.basf.com/innovation-nation

The source of progress

Innovations are a driving force and essential to advancement. But what is the story behind them? And how can innovations be fostered? Our feature explores scientific findings, takes a look at how BASF is using new methods to cultivate a spirit of innovation during the celebration of its 150th anniversary, and observes researchers as they make breakthroughs.



How can cities provide a home for even more people, use fewer resources and offer better quality of life at the same time? This was the question participants sought to answer at the Creator Space™ tour stop in New York in May 2015. One source of inspiration was the “Urban Farm Pod” concept developed by the NGO Terreform ONE. It unites science and art in a vision of living space combined with a vertical garden to grow food.





Ideas for industrial water management – that was the task in a workshop in Mumbai as part of BASF's 150th anniversary events. Discussions, theatrical performances and a seminar on underground water tunnels were on the agenda to stimulate creativity.

Vital, but hard to pin down

Progress in business, science, art and society is only possible if we innovate – if we successfully transform new ideas into better technologies, products, processes and services. That is why businesses, governments and other organizations around the world invest billions of dollars in R&D every year. According to a report by management consultant PwC, last year the top 1,000 companies in terms of R&D spent over €540 billion (\$600 billion), representing around 40% of the world's total R&D spending.

It's not just about money

For those that get it right, all this effort pays off handsomely. Investors are willing to pay a premium for the stock of companies like Apple and Google, or for start-ups they believe have significant innovation potential. But innovation has proved frustratingly hard for companies to deliver consistently. It certainly isn't just about the money – after ten years of research PwC has found no direct correlation between an organization's R&D expenditure and its ability to innovate. Nor is it about formal processes. Companies and academics have postulated a range of models to describe the way from an idea or identified need to a finished innovation, but none has mapped a sure-fire route to success.

So how do we nurture this vital but elusive element? Several new approaches are emerging.

“Leading companies are asking themselves how to connect the best people inside with the best people outside.”

Dr. Ellen Enkel, Professor of Innovation Management at Zeppelin University, Friedrichshafen, Germany

Not just more ideas – better ones

In recent years, many organizations have recognized that big R&D budgets do not necessarily turn into profitable innovations. In part, that is due to what Harvard Professor Clayton Christensen terms “The Innovator's dilemma”. In his 1997 book of the same name, Christensen argued that successful firms inevitably focus their R&D efforts on meeting their customer's current, stated needs. As a result, they become vulnerable to competitors who introduce “disruptive innovations” that meet customer's unstated or future needs, use radically different technologies, or serve entirely new customer groups.

Connecting people

In an effort to better prepare for disruption, many organizations are now attempting to widen their search for new ideas. “No matter how big a company is, they will never have all the bright people or all the good ideas,” says Dr. Ellen Enkel, Professor of Innovation Management at Zeppelin University, Friedrichshafen, Germany. “So now leading companies are asking themselves how to connect the best people inside with the best people outside.” To facilitate this ‘open innovation’, as it has become known, companies develop much closer partnerships with suppliers or industry partners, and search universities and start-ups for teams and individuals with bright ideas. They encourage customers, both current and potential, to participate in the innovation processes. And they run competitions, internally and externally to look for new ideas and new solutions to tough problems.

A snapshot of innovation

Persistence pays off



Thomas Edison conducted more than

9,000

experiments in his search for a working battery, and investigated over

3,000

different concepts for the light bulb.¹



During the racing season, the McLaren F1-team engineers a new part for its car every

15 to 20

minutes.²



Nestlé bought the idea for a single serving coffee maker in 1974, but it took

30 years,

and a dramatic shift in business model to grow Nespresso into the

€2.7 billion

business it is today.

1 The Edison Papers, Newsletter The Edisonian, Vol. 9, Issue 1, 2012.
2 The Guardian, Could Innovation in Formula One drive sustainable technology?, August 5, 2013.
3 Tata, Celebrating Innovation, April 2012.

A snapshot of innovation

Embracing failure



3M's Post-it® note emerged from a failed attempt to produce a high strength adhesive.



Indian industrial conglomerate Tata awards annual innovation prizes for teams from all its business units, including a “dare to try” prize specifically for promising ideas that failed.³



The Roton Rocket was an experimental space launcher that used a combination of rotor blades and rocket propulsion. In 2001, after a few test flights, the project was abandoned. A prototype remains at the Mojave Air and SpacePort in the California desert today. To the new generation of private space companies that have sprung up in the area, it acts as a visual reminder of the importance of failure in the innovation process.

Playing with new ideas

Sometimes the biggest barrier to innovation is the need to destroy the old to make way for the new. Significant innovations upset the established order, often putting long-standing roles, skills or institutions at risk. “Any truly radical innovation is going to be disruptive,” says Ashley Hall, PhD and Professor of Design Innovation at the Royal College of Art in London, England. “And that means it’s going to threaten somebody.”

Innovation through play

It is a point echoed by Henrik Sproedt, Assistant Professor for Innovation Practice at the University of Southern Denmark. “Sometimes people only raise their creativity to the highest level in order to prevent change,” he says. That isn’t just a corporate phenomenon; the history of innovation is also one of resistance to change, from the “sabotage” of weaving machinery by angry workers in the industrial revolution to more recent concerns over some new technologies such as genetic engineering.

Sproedt’s research has led him to question many of the ways in which companies manage innovation. “A lot of organizations use a Stage Gate® review process to reduce risk,” he says, but to do that, “someone has to determine the assessment criteria.” But true innovation, he says, is too “complex and chaotic” to fit neatly into such formal evaluation systems.

Hall agrees, suggesting that companies could learn much from the way designers work. “Designers tend not to project the answer with the question,” says Hall. “They wander and experiment and are willing to take new directions as they emerge.”

In fact, according to Sproedt, innovative activity should look less like work and more like play. “It’s the most natural way for humans to grasp novelty, because in play you take away the fear of failure that limits creativity.”

Creating an open, innovative culture

So how do companies encourage and foster innovation? Agreement is emerging that it is the culture of a company that is decisive.

“There is no satisfactory measure of innovativeness today,” says Ellen Enkel, “but if I were to create one, I would want to measure two things: How willing are my employees to accept change, and how well connected is my organization with the outside world?”

Sproedt suggests that many companies need to facilitate openness inside their organization as well as outside it. “You need to get all your stakeholders together early to give them time to develop a shared language and a shared understanding,” he says. But even so, he admits, this can be hard for people to do, since the need to accept ideas and approaches from right across the company can cause them to question their own professional identities.

Anybody can engage

But even potentially uncomfortable new working arrangements and relationships can be a catalyst for innovation. “Innovation tends to happen between things, and the more challenging those spaces are, the better,” says Hall. He also highlights one of the most important realizations of recent years: “A great thing about innovation is that it isn’t owned by any one part of the organization – anybody can engage with it.” ■

“Any truly radical innovation is going to be disruptive.”

Ashley Hall, PhD, Professor of Design Innovation at the Royal College of Art in London, England

Innovation through interaction and play: At the Creator Space™ tour stop in New York stakeholders discussed various challenges and questions around the housing of the future.



Joining forces to forge new ideas

Developing ideas and concepts to shape the future: To celebrate its 150th anniversary, BASF is creating space for innovative ideas. Creator Space™ is all about creative cooperation between employees, customers, scientists and other groups. To facilitate this, numerous co-creation activities on a global and regional scale are being initiated in various formats, such as jamming sessions, idea contests and open innovation challenges.

Open Innovation Challenge

An open innovation challenge helps companies make new external contacts and establish opportunities for creative cooperation. BASF started a competition of this kind in February 2015 to find ideas to store electricity from renewable energy sources with the help of innovative chemistry. The aim is to collaborate with companies, scientists and inventors to find ways of making energy storage financially viable, for example, through lower investment costs. Up to five winners will get a prize of €100,000 each and have the chance to collaborate with BASF in a research project based on their ideas.



Empathic Design

Putting people first: Taking on a new perspective is the core idea behind a joint project in India between BASF and the organization Save the Children which aims to find tailor-made solutions to improve drinking water supplies in Mumbai. In February 2015, 26 employees from BASF, Save the Children and the charitable foundation BASF Stiftung spent a week immersing themselves in the daily lives of local residents. Some of the families they spent time with only have running water for 90 minutes a day. For these families, storing water in containers is essential. But they often don't have much room for storage. In addition, the water is sometimes contaminated. Nitin Sharma from BASF India Ltd. believes this insight into the families' day-to-day lives is indispensable:

"We can then assess whether and how innovations from BASF can contribute to the solution, whether it's a new material for stackable water containers, an innovative filter system, or a combination of existing systems. It's crucial – for commercial success as well – to understand what the people in the community really need and want, and what could change their behavior." The same applies to a second project with Save the Children, which focuses on the food security of families in rural Turkana County in Kenya.



RESEARCHERS IN PROFILE: GEORGE DE MESTRAL



Inspired by nature

Nature provided Swiss engineer George de Mestral with the inspiration for his innovation. While hiking with his dogs, he noticed that burdock burrs clung to their fur. This piqued his curiosity. Taking a closer look under a microscope, de Mestral found that although the bracts of the burrs seemed to be straight, they actually had tiny, elastic hooks on their tips. The tips do not break off when you attempt to pluck the burrs from fur. It took de Mestral many years until he was able to mechanically produce a similar "hook and loop" fastener. He filed for a patent in 1951 and introduced the first fastener of this kind (often known by the brand name VELCRO®) on the market in 1959. It was made up of two nylon strips, with hooks on one strip and around 15 times as many loops on the other strip. Until today, this practical idea is used to hold many things together – everything from shoes to baby diapers and even the spacesuits worn by astronauts.



Creatathon

The idea behind the Creatathon – derived from a combination of "creative" and "marathon" – is to bring people together for a long session of intense creativity. In Shanghai, China, for example, BASF invited six university teams to join a 24-hour Creatathon with the task of designing an app-based sustainable mobility solution to help urban consumers make transportation decisions that minimize their carbon footprints. In the end, first place was awarded to the team from East China Normal University and their idea of "Carbon Coin," a mobile platform that expands the idea of carbon trading beyond businesses down to the individual level, and allows consumers to redeem their personal contributions to sustainability as "currency."

Customer Co-Creation

Working directly with customers is an efficient way of finding need-based solutions. Simultaneously, it strengthens customer relationships because people have the chance to get to know each other better



while working together on developing their ideas. A co-creation workshop gives both groups of participants insights into their respective working environments. Each side brings its own expertise, perspective and approaches to the table. A customer innovation workshop held in April 2015 as part of the Creator Space™ program celebrating BASF's 150th anniversary focused on ideas for the bus of the future. BASF employees from various divisions and experts from Daimler Buses engaged in discussions about solutions to future challenges in buses, including specialty coatings, lightweight construction concepts and greater comfort in interiors. At the same time, one-on-one conversations allowed each person to learn more about the structures of the other company. By the end of the year, lighthouse projects will be derived from ideas generated at the workshop.



Idea Contest & Idea Pitch

The idea pitch was initially employed in the area of venture capital and then applied to TV game shows but has since spread to the corporate world: It is an unconventional way to uncover innovative ideas, discover creative talents and promote an entrepreneurial spirit. It is often linked to a preceding idea contest or jamming session. Tapping into the power of the crowds it aims to find the winner amongst a number of finalists who get to pitch their idea in only a few minutes to a panel of senior managers and experts. In June 2015, BASF invited staff to submit ideas for addressing challenges posed by urban living. The finalists of this idea contest get mentoring to improve their presentation skills and to challenge their ideas before the big event. The winning team then receives funding and support from the company to further develop its proposal.

Graphic Recording

Transforming words into pictures: Graphic recorders are artists who create a visual record of an event, such as a jamming session, in real time. Using simple visual language, they get to the heart of complicated concepts, and create an aide-mémoire. BASF used this visual method at its Science Symposium held in Ludwigshafen, Germany. Prior to the event, the graphic artist created the initial visual imagery relating to the topics. During the Symposium, he then added numerous details to the pictures based on the ideas generated by the experts. The result is a large-format work of art that illustrates the many aspects of the topic smart energy. As well as a way of documenting the process, it also serves as a basis to develop more ideas and for discussion, talks and projects.



RESEARCHERS IN PROFILE: DR. MIRAN YU

Reaching the goal in record time

Nobody expected to find a solution so fast. It took just six months for an in-house team of researchers to successfully develop the resin coating for BASF's Palusol® fire-protection panels. The scientists were able to draw on their experience and intuition to find six appropriate test materials. Thanks to close cooperation with production staff, the R&D proceeded quickly. "The new epoxy resin flows better and is less permeable. It protects the panels from external influences and serves as a barrier for moisture and CO₂," explains Dr. Miran Yu, head of the research team. In the case of fire, this is essential to enable the panels to expand under the effect of foaming pressure caused by the heat and thus slow the spread of fire and smoke. The first panels with the newly developed epoxy resin should be launched on the market by mid-2016 at the latest.



"Innovative activity should look less like work and more like play. It's the most natural way for humans to grasp novelty, because in play you take away the fear of failure that limits creativity."

Henrik Sproedt, Assistant Professor for Innovation Practice at the University of Southern Denmark

Free rein for innovative spirit

How pioneering ideas arise and take shape



Creative cell division

The culture at W. L. Gore & Associates sets the company apart. It avoids nearly all the typical trappings: Instead of hierarchies and job titles, Gore's employees – known as “associates” – communicate directly with each other in a flat organization. The model encourages experimentation and is based on intrinsic motivation rather than duties. Everybody takes on responsibility and can allocate up to 10% of his or her working time to developing their own business ideas, initiating projects and getting colleagues on board to help with them. The firm operates on the “waterline” principle: Everyone at Gore must consult with other associates before taking any action that could cause damage to the company's success or its image. Gore thus achieves a steady stream of new product innovations, ranging from breathable GORE-TEX® membranes for clothing, to power plant filter hoses and medical implants. In order to maintain a structure that promotes innovation as the company expands, Gore splits teams that have grown to around 200 associates into smaller units – just like cells divide in a living organism.

Unleash the creativity of the “global brain”

No one has all the answers, but together we might just get there – this is the defining thought behind General Electric's (GE) Open Innovation Manifesto. The U.S. technology company has innovation in its DNA. From its founder Thomas Edison onward, the company has always been imbued with a spirit of experimentation. With the publication of its Manifesto in 2014, it declared a fundamental shift in the way it does business: embracing open collaboration to address customer needs more effectively. Like a market of ideas GE aims to bring needs together with expertise and capacity to create solutions. One key statement of the Manifesto is to build a relationship with the global solver community that is transparent and mutually beneficial. Indeed GE's commitment is so deep, it sees all innovators, external and internal, as one team – the “global brain” – working together to solve the world's toughest problems.



A box bursting with ideas

A red box is turning Adobe employees into innovators. Participants in a two-day innovation workshop receive a Kickbox, which contains methods that help them develop ideas as well as a prepaid credit card providing a development capital of \$1,000. The employees can use up to 40% of their working time to advance their own innovation projects. Adobe is trying to motivate as many employees as possible because the more ideas are pursued, the likelier it is that something new and promising will result. The red boxes, which were first distributed in 2013, have already helped more than 1,000 employees develop their ideas. So far, 23 innovators have received a blue box, which awards additional resources to those employees with marketable ideas. The platform Creative Cloud Libraries, for example, has its roots in the Kickbox.

RESEARCHERS IN PROFILE:
DR. MARKUS GEWEHR

A winning formula to fight fungi

Fungal infestations damage crops worldwide and can reduce yields by as much as 30%. To develop solutions for the affected farmers, a BASF team started a research project in 2001 to find a new fungicidal active ingredient with the following features: offering broad protection against a wide variety of fungi in numerous crops, long-term effect and environmental compatibility. After synthesizing more than 1,100 substances, the team led by Dr. Markus Gewehr first synthesized Xemium® in 2004. “We were confident we would find a solution and thanks to our focused approach we were able to discover an outstanding active ingredient,” says Gewehr, reflecting on the team's success. In the following years, a project team of around 30 researchers, engineers and marketing colleagues worked closely together to launch the active ingredient on the market in record time in 2011. Today, Xemium® protects more than 100 crops around the world against fungal infection.





Taking off with innovations

Start-ups are a hotbed of innovation: Their willingness to take risks, creativity and flexible structures facilitate the development of groundbreaking products and technology. This makes start-ups especially interesting for established companies. “It is impossible and unnecessary for us to invent everything ourselves. There are also young companies developing interesting technologies,” says Dirk Nachtigal, Managing Director of BASF Venture Capital. That is why BASF invests in start-ups that develop technologies with new materials based on chemistry. More and more large companies are putting out feelers into the start-up scene – via equity capital, coaching programs for entrepreneurs or with their own start-ups. This benefits both sides: While one side gets its hands on new technologies, the other one receives capital as well as access to the resources and know-how of a global company, for example, in R&D or marketing.

RESEARCHERS IN PROFILE: **MASAHIRO HARA**

Clever coding

We come across Masahiro Hara’s invention every day: The QR code is used on packaging, in advertising and for mobile ticketing. In the early 1990s, while working for the Japanese automotive supplier Denso, Hara was actually looking for a replacement for the conventional barcode which could contain more information. He tested various two-dimensional codes, but these were unsuccessful because the scanner took too long to read the data. The clear



structure of a helicopter landing pad on top of a high-rise building finally put him on the right track: He realized a new code would also need a distinctive geometric pattern to serve as orientation for the code reader. This idea resulted in the squares in three of the four corners of a QR code. The black and white pattern can contain a total of 7,089 numbers, 2,953 letters or 1,817 Japanese characters. Denso obtained a patent for the QR code in 1995, but has made it available worldwide. The company started a new business segment supplying QR scanners. Hara received the 2014 European Inventor Award for his discovery.

When science fiction inspires the real world

Visions that came true



Pioneering thinker — then

Johann Wolfgang Döbereiner

In 1823, the German chemist discovered platinum catalysis.



Self-taught chemist Johann Wolfgang Döbereiner discovered platinum catalysis and helped lay the foundations for the compilation of the periodic table of elements.

Catalysis: Molecular helper and driving force in chemistry

A catalyst is basically a kind of matchmaker. In fact, one of the two Chinese characters that make up the word 'catalyst' is the same as the one for 'marriage broker.' In a test tube, a catalyst grabs the desired reaction partners, dissolves their old bonds and quickly brings together the right partners to make a new chemical compound. It speeds up reactions without being consumed itself – although it can start to show signs of age at some point. At the same time, a catalyst also saves energy. For all these reasons, catalysts are an important tool in chemistry, where they are now used in more than 90% of all chemical production processes. The production of many everyday items – including medication, fertilizer, dyes and plastics – would not be possible without this key technology.

In 1823, the 43-year-old chemist Johann Wolfgang Döbereiner was able to ignite an oxyhydrogen mixture using the catalytic effect of platinum sponge. For him, it was a “contact phenomenon,” today it is considered one of the most important discoveries in early catalytic chemistry. Platinum sponge can accelerate the reaction between hydrogen and oxygen, and in doing so, it remains nearly unchanged in mass and chemical composition – this is one of the special properties of all catalysts. The reaction releases so much energy that a flame is instantly formed. Döbereiner, fascinated by this phenomenon, knew how to turn his discovery into a successful technology: He invented the platinum lighter. The lighter became a very sought-after item and the catalytic process behind it became a milestone and a driving force in chemistry.

Just one year after that, observing that oxyhydrogen can also be made to explode using mixtures of iridium and osmium, Döbereiner formulated the principle behind the mixed catalysts later used by the chemical industry. By that time, he had already been an associate professor of chemistry, pharmacy and technology for 14 years, a post he held thanks in part to gaining the support of Johann Wolfgang von Goethe, one of the most important German writers and polymaths.

Döbereiner was self-taught, he had neither completed school nor attended university; his only education was an apprenticeship as a pharmacist. But this son of a coachman caught Goethe's attention with his writings on chemical-practical phenomena. Goethe, who later became minister of cultural affairs, helped Döbereiner secure a position at the University of Jena. One year after his appointment, the faculty of arts awarded Döbereiner the title of Dr. phil. in recognition of his previously published works, which were said to “undeniably bear the hallmarks of genius and perfection.”

Grateful for the opportunities given to him, Döbereiner stayed in Jena until his death in 1849 despite receiving offers from other renowned universities. His enduring legacy is carved in stone as the inscription on Döbereiner's grave says: “Advisor to Goethe, creator of the triadic system, discoverer of platinum catalysis.” ■

Pioneering thinker — now

Ferdi Schüth

The German chemist paved the way for high throughput technology to be used in catalysis.

Shortly after New Year's Eve 1971, 11-year-old Ferdi Schüth had already decided he wanted to be a chemist when he grew up. His enthusiasm was sparked by filling up used fireworks with gunpowder that had been mixed by his friends. The firecrackers didn't fly, but they certainly made a big bang. One year later, he set up his new chemistry set in a corner of the family's basement and continued his observations on what happens when substances are mixed together. "Just wanting to see if something works is still today my main motivation for successful research," says Professor Dr. Schüth, who is now a scientist with many honors and prestigious posts to his name, including Vice President of the Max Planck Society, Director of the Max Planck Institut für Kohlenforschung and winner of the Carl Friedrich von Weizsäcker Prize and the Leibniz prize, to name just a few.

This curiosity – along with the fact that he has a mind of his own – is the reason why Schüth was able to make his discovery that has so far had the greatest impact: high throughput technology in catalysis (see box). In 1996, he participated in a scientific colloquium on how new and better catalysts could be developed faster. The model being considered was high throughput experimentation, as used by the pharmaceutical industry to speed up research on new active ingredients. However, among researchers doubts were quickly expressed as to whether this method could be implemented under the much more difficult conditions found in oil refineries and the production of basic chemicals. But the idea intrigued Schüth, at the time a professor at Goethe University Frankfurt in Germany, and he started jotting down his first ideas during the event. Back at his institute, he asked his doctoral students if any of them were interested in developing this idea further. After around a year of joint research, the first high throughput reactor started up. In 1999, the company hte was founded to market the process. "A scientific challenge thus led to the birth of a new technology," says Schüth.

One of the questions the chemist is working on these days is how catalysts can be custom-made right down to the atomic level. He is also interested in new energy sources, such as hydrogen and fuels made from wood waste, and their storage and catalytic conversion – in other words, the chemical foundations for the energy of the future. And Schüth is still always up for a challenge or some pioneering thinking. ■

Ferdi Schüth likes to take on new challenges. His current research focuses on the chemical foundations for the energy of the future.

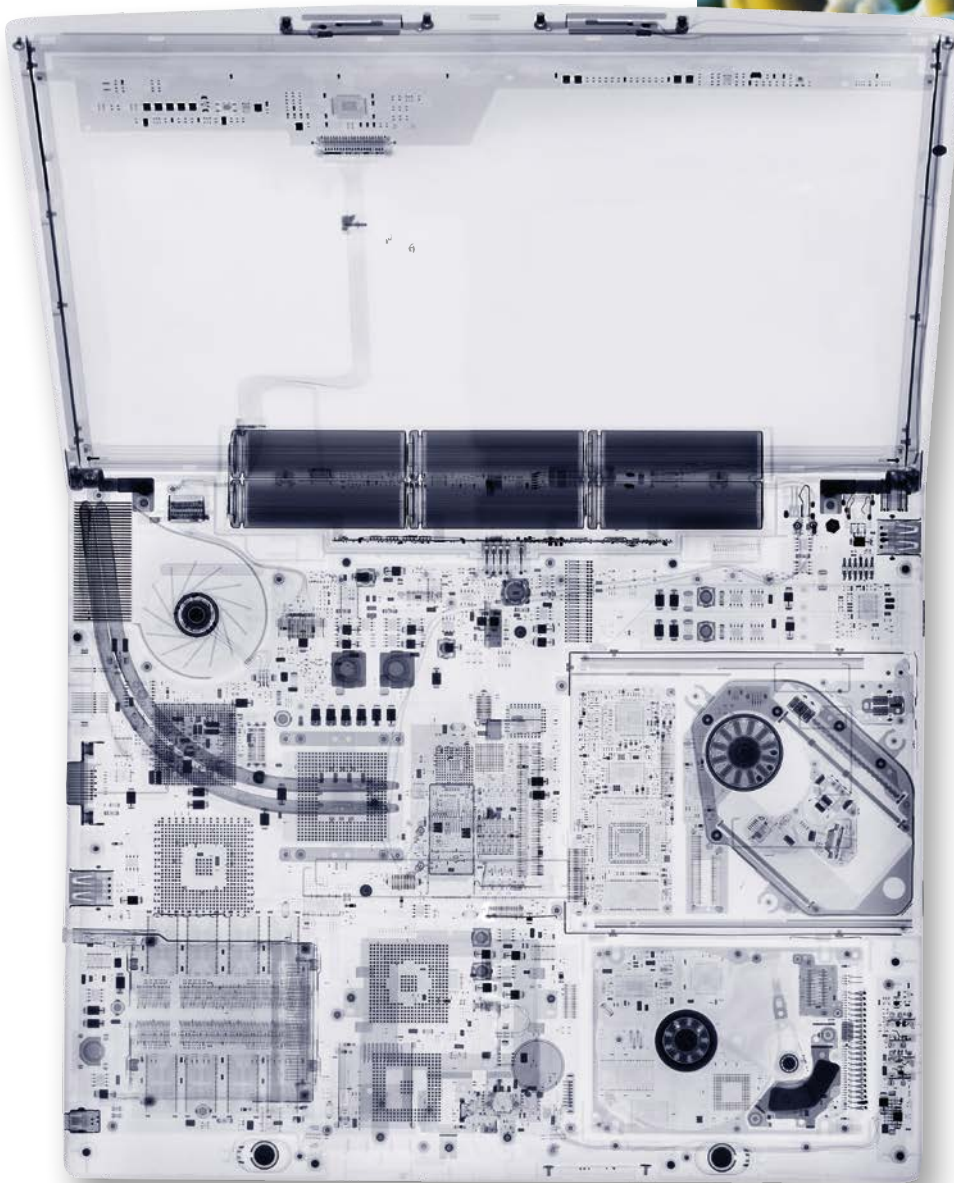
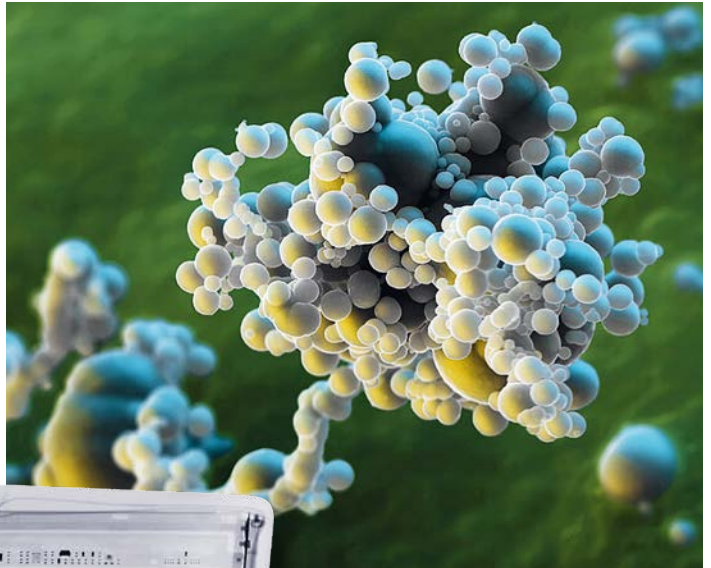
hte GmbH: Turbo testing for chemical accelerators

With the process jointly developed by Professor Dr. Ferdi Schüth and researchers from the company hte in Heidelberg, Germany, the search for new and more effective catalysts can now be carried out up to 100 times faster than was possible just a few years ago. The company's name, hte, is an acronym for this process: "high throughput experimentation." This method, which is based on a parallel and automated approach, enables the Heidelberg researchers to conduct simultaneous chemical testing of numerous catalysts. Currently, hte operates more than 50 different reactor systems, ranging from catalyst screening equipment to large-scale test plants for process optimization. The company, which has been a wholly owned subsidiary of BASF SE since 2012, now has around 270 employees.



Steady voltage, for smartphones, tablets and more?

A high-performance powder made from normal iron scrap protects important components of the electronic devices we use every day.



The smaller and more powerful notebooks, tablets and smartphones become, the greater the demands placed on their electronic assemblies. For components such as the CPU or hard drive to perform at their best, they each need a different electric voltage than the battery supplies. Voltage deviating from the required value can damage the components. One solution is normal scrap iron which BASF processes into high-purity, microscopically small ferrous spheres that have a precisely defined structure and size. Incorporated in the cores of high-frequency coils, this carbonyl iron powder intensifies the magnetic field that is generated when electricity flows into the iron core of the coils, and thus ensures stable direct current. To prevent the energy losses that typically occur with an electroconductive iron core, each of the tiny particles is surrounded by an electrically insulating layer. This suppresses leakage current in the core. In this way, carbonyl iron powder makes sure that the sensitive electronic components in the compact devices we use every day receive a steady supply of the required voltage. It protects them from voltage fluctuations and makes them more efficient, so even very small high-frequency coils can be extremely powerful. Every tablet computer contains three or four such high-frequency coils with a carbonyl iron powder core, while a notebook has up to 10. ■

The microscopically small iron spheres in high-frequency coils protect electronic devices, such as this notebook, by ensuring they are supplied with the correct electrical voltage.

➤ To find out more, visit:
www.basf.com/carbonyl-iron-powder

What did you think of Creating Chemistry?

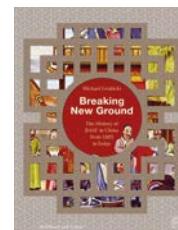
Thank you for taking the time to read our magazine.
We welcome your opinion and feedback, and would appreciate your response to our short reader questionnaire.

All completed and returned questionnaires will be entered into the prize draw to win an iPad mini 3 or one of five copies of the book "Breaking New Ground: The History of BASF in China from 1885 to Today."

The data will be evaluated anonymously by the market research institute TSM. No conclusions will be drawn about individual respondents. Return the form **by post, via fax (+49 621 5290 114)** or **enter online at: www.tsm-clicksurvey.eu/creatingchemistry**



1st prize
iPad mini 3



2nd–6th prize
Breaking New Ground

Overall, how much did you enjoy this issue of Creating Chemistry?

Not at all (1) (2) (3) (4) Very much (5)

How much did you like the following aspects of Creating Chemistry?

	Not at all (1)	(2)	(3)	(4)	Very much (5)
Choice of topics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Quality of articles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Information content	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Entertainment value	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Layout/design	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Understandability of infographics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Which articles in the current issue did you find especially interesting? (Multiple answers are possible)

- | | | |
|---|--|--|
| <input type="checkbox"/> The future of mobility | <input type="checkbox"/> Plastics under discussion | <input type="checkbox"/> 3D printing applications around the world |
| <input type="checkbox"/> Food trends | <input type="checkbox"/> Fascination of chemistry: Foams | <input type="checkbox"/> Innovation: The source of progress |
| <input type="checkbox"/> Pioneering thinker then and now: Catalysis | <input type="checkbox"/> Chemistry around us: Carbonyl iron powder | |

Are you planning to learn more about the topics covered in Creating Chemistry?

- Definitely/I already have Probably Probably not

If yes, where?

- basf.com Other BASF publications
 Other sources

What is your preferred format for Creating Chemistry?

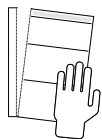
- Print Online Both

Where do you prefer to read Creating Chemistry?

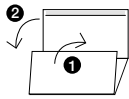
- At work At the airport On the plane
 On the train At home
 Elsewhere:

PRIORITY
PRIORITAIRE / LUFTPOST

How to return the self-mailer:



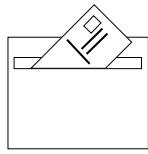
Tear out the completed questionnaire along the perforated line.



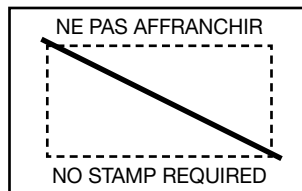
Fold the questionnaire twice from the bottom up.



Seal it with the adhesive flap.



Put it in the mail.



RÉPONSE PAYÉE / BUSINESS REPLY / WERBEANTWORT
ALLEMAGNE / GERMANY / DEUTSCHLAND

TSM Marktforschung
Creating Chemistry
Postfach 140226
67021 LUDWIGSHAFEN
ALLEMAGNE

Which topics do you remember seeing in previous issues of Creating Chemistry?

Which topics would you be most interested in reading about in future issues?

To conclude, we would like to ask you some statistical questions.

Are you ...

Male

Female

Age

<35

35–44

45–54

55–64

65+

Occupation

Self-employed/freelance

Management position

Non-management employee

Retired

Other

Thank you very much for answering our questions!

If you would like to participate in the draw, please provide your contact information.

Surname, first name: _____

Street: _____

Postal code: _____ City: _____

Country: _____

E-mail: _____

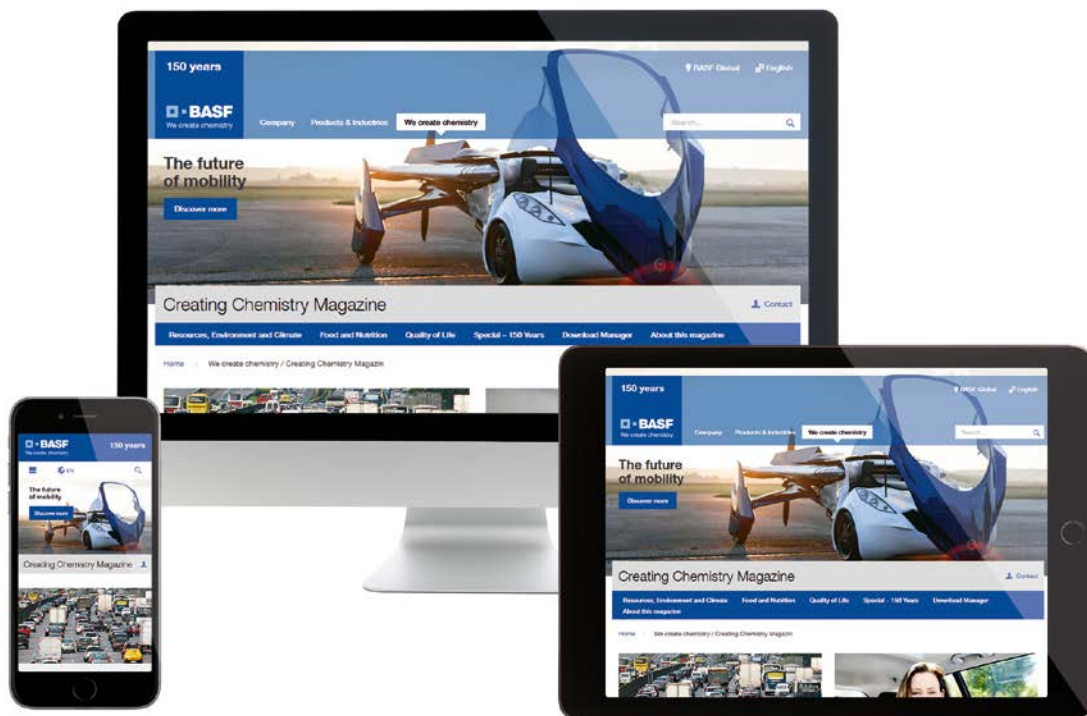
The data will be evaluated anonymously and no conclusions will be drawn about individual respondents. The personal data provided will only be used for the purpose of the draw. You may also take part in the survey without giving your contact information. In this case, you will not be entered in the draw. Participation in the competition is subject to the conditions detailed in the following.

Prize Draw Terms and Conditions:

A random draw will determine the winners. The winners will be notified by email within 28 days of the closing date. No further correspondence will be entered into.

The closing date for entries is November 30, 2015. Entry in the prize draw is restricted to entrants 18 years of age or older. No more than one entry is allowed per household. The competition is not open to employees of BASF or its subsidiaries. No cash alternative will be offered. No responsibility can be accepted for entries lost, delayed or mislaid. BASF's decision is final and it is a condition of entry to the competition that the entrant agrees to be bound by these rules. For the full terms and conditions of participation and instructions for use, go to www.basf.com/creating-chemistry/competition.

Discover our online magazine



Are you interested in gaining further insight into future challenges in the areas of resources, environment and climate; food and nutrition; and quality of life? The online magazine Creating Chemistry offers a broad variety of interesting reports, videos and interactive graphics:

➤ www.creating-chemistry.basf.com

If you would like to regularly receive the free print edition of the magazine, you can subscribe online:

➤ www.basf.com/creatingchemistry

Imprint

Published by:

BASF SE
Communications &
Government Relations
BASF Group
Elisabeth Schick

Editorial by:

BASF SE,
Editorial Office

Axel Springer AG

Designed by:

Anzinger | Wüschner | Rasp

Printed by:

johnen-druck GmbH & Co.KG

Cover photograph:

Stephanie Füssenich

Illustration:

Florian Sanger (page 12, 16-17, 24,
40, 55)

Photography credits:

www.aeromobil.com (page 2, 6-7)
BASF (page 2, 3, 4, 9, 26, 32,
36-37, 41, 44, 45, 48-49, 50, 51,
52, 53, 54, 55, 58, 59)
Daimler (page 4)
Local Motors Inc. (page 4)
Getty Images (page 5, 9, 10, 20,
33, 38, 41, 52, 54, 58)
laif (page 5, 20, 42, 43, 46)
HTT/JumpStartFund (page 8)
GM Corp. (page 8)
picture alliance/Estadao Conteudo
(page 11)
Volvo Busse Deutschland (page 13)
plainpicture (page 13)
BMW AG (page 13)
Department for Business, Innovation
& Skills (page 14)
Andre Hemstedt & Tine Reimer
(page 15)
Stephanie Füssenich (page 2, 19,
21, 28-31)
Julie Glassberg (page 22-23, 25)

Wakati VZW–Lonely Alien BVBA
(page 26)
Electrolux Newsroom (page 26)
Volvo Car Group (page 27)
New Wind R&D (page 27)
Corbis/Patricia Willocq (page 27)
Disney (page 34)
WinSun Design and Engineering
(page 34)
David Bishop, UCL Health Creatives
(page 34)
WoeLab (page 35)
Airbus S.A.S. (page 35)
Paul Jones, University of
Wollongong (page 35)
Gaston Accardi/YouTube (page 35)
Made in Space/Deejay Riley
(page 35)
Rebecca Reid/eyevine (page 38)
Beyond Meat (page 39)
Scribner (page 43)
James Dyson Foundation (page 47)
Gore (page 54)
Adobe (page 54)
European Patent Office (page 55)
akg-images (page 56)
MPI fur Kohlenforschung (page 57)
iStock (page 59)

Contact

BASF SE
Corporate Communications
Dr. Stefanie Wettberg
Phone: +49 621 60-99223

This magazine has been printed on paper made with special BASF ingredients. The raw materials originate from responsibly managed forests and the energy used in the production process is mainly generated from biomass. It is also FSC® certified



We create
chemistry
that helps
lush landscapes
love thriving
cities.



The construction industry currently accounts for about half of the world's consumption of energy and resources. It's a substantial amount - but it can be reduced, if you just add the right chemistry.

We've developed a number of solutions that make construction more mindful of the environment and buildings that are more durable and efficient throughout their life cycle. The result is that new developments are less taxing on our finite resources in the short and long term.

When we can build more while using less, it's because at BASF, we create chemistry.

www.creating-chemistry.basf.com

150 years

 **BASF**

We create chemistry