

Creating Chemistry

BASF'S SUSTAINABILITY MAGAZINE

**Waste as a
raw material**

A second life
for plastics

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**A world
without insects?**

Experts weigh up
the facts and tell us
what we can do.

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Diet for the Earth

Our current food system isn't good for us
or the planet. What can we do to fix this?

BASF

We create chemistry

Dear readers,

The population will continue to grow at high speed well into the future. Today, there are more than 7 billion people in the world, and by 2050 the number will increase to 9 billion. This means we will need significantly more food in the future, but the Earth's resources are limited. How can we manage to feed so many people healthily while at the same time preserving nature?

Our cover story clearly shows that there are no easy answers to this question. Obviously, using more and more space for agriculture would be the wrong approach, as this would come at the expense of the natural habitats of animals and plants. Instead, it is necessary to increase the productivity of the existing space sustainably, while at the same time reducing greenhouse gas emissions. This means farmers have to find intelligent cultivation methods. To do that, they especially need support from experts in science and business, whose ideas and innovations can help to make sustainable agriculture possible.

Digitalization offers great opportunities here. Intelligent use of data will enable farmers to select the right type of crop, to fertilize it efficiently, and to protect it against pests and disease. The aim is to achieve reliably high yields with the lowest possible use of resources.

For BASF, our mission is clear. We are using solutions from the world of chemistry to contribute to boosting agricultural yields. This applies especially to emerging markets and developing countries – the regions where many people are suffering from hunger, and where population growth



is strongest. Failed harvests there have grave consequences. Scientists around the world, including those at BASF, are working on creative and sustainable ideas. I am confident that we will achieve progress. The prerequisite is a society that is open to new technologies. This latest issue of Creating Chemistry shows how we can work together to improve living conditions for millions of people.

I wish you an enjoyable read!

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

Your opinion is important to us

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

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Focus

Here are some of the innovations that can turn the world's favorite fast food into a healthy and sustainable meal.



Buns from algae
The bread bun is made with spirulina, a microalga that has more protein than a hot dog.

Mushroom-based bacon
It looks like bacon and tastes good too, but it's actually made of mushroom slices.

Super healthy ketchup
The savory umami flavor replaces sugar and salt to make this healthy ketchup taste delicious.

Burger made from plants
Plant-based alternatives to beef burgers are getting closer and closer to the real thing.

Substitute for cheddar cheese
Nuts and soy replace cheese, providing healthier fatty acids.

No-till tomatoes for better soil health
These tomatoes were grown in a field that is not tilled, for better soil health.

Fortified vegetables
CRISPR/Cas9 gene-editing technology is used to produce vegetables with increased vitamin levels.

Photo: BASF

06–25

Diet for the Earth



More from less As the global population grows, we look at innovations that are helping to provide more food and better nutrition in a way that is good for people and the planet.

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Waste cycle Seeing trash as a resource

Waste mountains are growing rapidly. There is still a lot of potential for the intelligent reuse of plastic, electronic scrap and the like as raw materials.



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Recent reports state that insect populations in some parts of the world are declining. We ask different experts about the facts behind the headlines, why insects matter, and what we can do to protect them better.



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BASF Ten-year journey to a new fungicide

Crop protection plays a key role in improving yields. How does BASF develop products that are safe for people and the environment?

Photos: Bruno LEVY/CHALLENGES-REA/iaif; Gettyimages; Darrell Gullin; Photographer's Choice; featofdigital

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Fragrance makers Creative reconstructions of nature

Scents influence our senses and thoughts. How they are replicated is fascinating, too. All-rounder citral plays a major role in all this.

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Opportunity A fresh start in Santiago de Chile

Espacio Inclusivo is a car refinishing training program for young people run by BASF in Chile. Alumna Katherine Jara tells us why she joined the program and what she has gained from it.

Photos: shutterstock/Kyselova Inna, Gettyimages (Montage: ASCS); Cristobal Olivares

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



Eating together is a pleasure to be celebrated. No wonder #food is one of the most popular hashtags in social media. But the reality of how food gets on to our plates is quite a different matter. The majority of workers in the agriculture sector live in poverty. What are the new solutions that can bring these polar opposites closer together?

Diet for the Earth

Food has played an essential role in our development as humans. But today's diet is not good for our health or the planet. We need to be smarter about what we eat and how we produce our food.

01 Smart Eating

What we eat matters. Innovations can help shift us to a diet that is healthier for people and better for the environment.

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02 Smart Farming

We need to feed more people from the same amount of arable land. Which technologies can help us improve yields in a sustainable way?

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Big data down on the farm: Digital technologies are making a positive impact on agriculture. We look at what is already possible in this fast-developing area.

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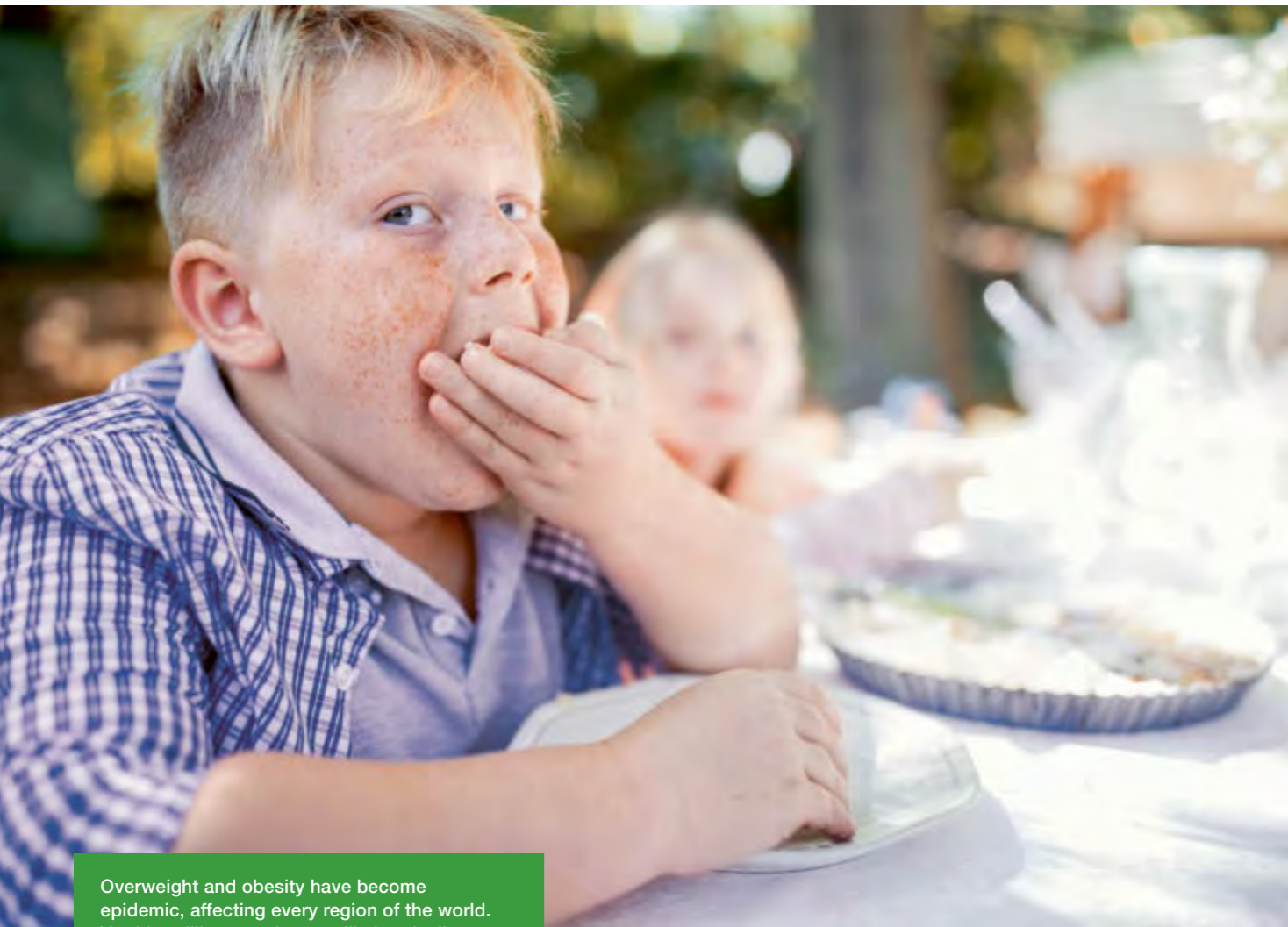
Professor Louise O. Fresco of Wageningen University & Research in the Netherlands talks about how we can improve the global food system.

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05 The Science

How BASF scientists develop crop protection products that are effective and safe for humans and the environment.

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Overweight and obesity have become epidemic, affecting every region of the world. Yet 821 million people are still chronically undernourished. Improving food security and eradicating malnutrition in all its forms requires solutions across the food value chain and wide collaboration between the public and private sectors.



Photos: Gettyimages: Westend61; The Image Bank



Rising temperatures and lower rainfall threaten crop yields, yet our food systems themselves are one of the biggest contributors to climate change – responsible for 25 percent of global greenhouse gas emissions, in part through the destruction of rainforests. How can we make agriculture both more resilient and less damaging to the environment?



Photos: Gettyimages: Carlos Fabai; Edwin Remsberg

If a time traveler from the 1950s landed in a Western supermarket today, they wouldn't believe their eyes. Asparagus, cherries and pears, available all year round; microwaveable burgers here, a whole aisle of breakfast cereals there. It looks impressive, but this abundance comes at a cost. Many experts agree that our current food system is not fit for purpose. After all, we live in a world where almost 800 million people are obese while a similar number – 821 million – still go hungry. Poor diets are linked to malnutrition and disease, and according to the World Health Organization (WHO), no country is unaffected. In the European Union, depending on the country, 30 to 70 percent of adults count as overweight, and obesity affects 10 to 30 percent.

Our diets are damaging not just our own health but also that of our planet. A 2012 World Wide Fund for Nature (WWF) report observed that we are living as if we had an extra planet at our disposal, and at this rate, by 2030 even an extra two planets wouldn't be enough. Just take our consumption of beef. It is an everyday food for a growing number of people, but it requires 20 times more land and results in 20 times more greenhouse gas emissions per unit of protein than beans or lentils.

As Western-style diets become more popular in rapidly developing countries, demand for meat is growing. Tim Searchinger, Senior Fellow at the World Resources Institute in Washington D.C., USA, draws the conclusion that “the people who eat large amounts of beef and lamb today have to hold down their consumption, making it possible to produce ▶



Supermarkets in developed countries offer more food and a greater diversity than ever before. But at what cost?

01

Smart Eating

enough meat so that others can eat a little more.” In sub-Saharan Africa, for example, many people could benefit from the protein and iron gained through eating more meat.

Taking meat off the menu?

Recent trends suggest there is actually a growing awareness, particularly among young urban consumers, that we need to eat less meat. There has been a rise in “flexitarians” – people who have a primarily vegetarian diet but occasionally eat meat or fish. A survey in the United Kingdom found that 14 percent of the British identify as flexitarian. The U.K. has also embraced veganism: in 2018, 16 percent of all new food product launches were vegan, more than in any other country. Variations on Meat-free Monday have spread to more than 40 countries in the past 10 years.

“Personalized nutrition is all about measuring, intervening and supporting a behavior change.”

François Scheffler
Senior Vice President,
BASF Global Human Nutrition,
Singapore



The food industry has moved fast to meet the growing demand for meat and dairy substitutes with innovative products. Non-dairy milk has become mainstream, with a wide variety of alternatives offered, and food technicians are working hard on making the soy protein-based burger as close as possible to the experience of eating a beef burger. It is the soy leghemoglobin, which contains the iron-rich molecule heme, that gives these burgers their meaty flavor. Meanwhile, efforts are underway to bring lab-grown meat to the market and one company is working on lab-grown chicken nuggets. Others are developing artificial fish fingers.

Do these trends have a positive net impact? Possibly, but as Michael Siegrist, Professor of Consumer Behavior at ETH Zurich in Switzerland, points out, eating soy or tofu on top of an otherwise unsustainable diet will not improve matters. “We don’t know whether people are reducing their meat consumption by substituting beef with these new products, or eating these

Photos: Gettyimages/RapidEye; Fotodesign D.W. Schmalow

new products in addition to meat,” he says. And not every new health product is more sustainable. Almond milk, for example, a popular type of non-dairy milk, is derived from a very water-intensive crop.

Food choices depend on many factors – wealth, culture, availability and personal taste. There is no one-size-fits-all diet that is healthy and sustainable for everyone in the world. Perhaps one answer for people in countries where more choice exists lies in making recommendations that are more specifically aimed at the individual.

A personalized diet

According to recent research by Rabobank, a Dutch financial services company and a global leader in food and agriculture financing and sustainability-oriented banking, personalized nutrition is set to become a game-changer. The growing ability to link health issues to physical attributes such as genes or gut bacteria makes this possible. With 3D printing technology added, it is now possible to provide food based on specific, personal nutritional needs, whether it’s for athletes or people with medical issues.

For the wider population, the value of personalized nutrition could be that it opens up a new, more compelling route to a healthy, sustainable diet. “Personalized

Tailored meals:
Personalized nutrition provides each individual with the right nutrients at the right time.



Photos: Gettyimages/MomentRF; iStock; Sara Roversi

The deepest roots



Sara Roversi
Founder of the Future Food Institute in Italy

Food is an emotive subject. It plays a central role in our social lives and culture, so changing diets is not easy. Sara Roversi’s organization recognizes this, while working to improve sustainability in the global food ecosystem. We ask her how we can improve our diets and still enjoy what we eat.

1 Why do people often persist in eating what they know to be unhealthy food?

We are not driven by what is right but by pleasure and by our own past, so it’s tough to change behavior. Think about the occasions when people come together, at big sporting events for example, and how much unhealthy food you find there like hot dogs, hamburgers, and soda. Yet these are occasions where people are having a good time, sharing positive emotions with relatives and friends, so the connection with unhealthy food is tied with some of their most positive experiences in life. That is why we are working with sponsors to make them aware of the damage they are causing, maybe without realizing it.

evaluating whether a product is good or not based only on its taste? If you work backward from there, the soil and production methods will be different, and distribution chains will be shorter.

3 The Mediterranean diet is considered to be very healthy. Why is that?

When we talk about the Mediterranean diet we are not just talking about ingredients, but also about culture – how you share meals and when you eat them. Food is a crucial part of human identity. It’s part of our DNA. The healthiest diets are those that have the deepest roots in history and tradition. In the past, food was more connected with health, because food was the starting point for medicine, so traditional diets are healthier in origin. That’s why I don’t think the right approach is to say that everyone should adopt a Mediterranean diet without considering the context. What matters is that we should eat food that is good for us, good for the planet and in balance with the culture of the place where we live.

2 What’s the best way to permanently change poor diets?

It’s not just knowledge, it’s also about mindset. Over the last decade, everything has been focused on shape and efficiency, on creating the perfect, round tomato without considering its flavor or juiciness. What if tomorrow we started

nutrition is all about measuring, intervening and supporting a behavior change,” says François Scheffler, Senior Vice President, BASF Global Human Nutrition, Singapore. “When you receive reliable feedback about the impact on your own health of what you are eating, you can do something about it.”

Fitness or diet apps already help users optimize caloric intake and nutrients. But more specialized products and services are emerging, such as BASF’s Omega-3 Index testing kit. The kit uses dried blood spot technology to accurately measure omega-3 fatty acids levels. These have been proven to have many health benefits, including reducing the risk of cardiovascular disease. With this information, consumers can adjust their intake and monitor results to ensure that any dietary changes are helping.

Conventional wisdom about eating more vegetables and fewer hot dogs will always be true. Everyone knows it. Recent diet trends

and product innovations are encouraging, but we need a big toolbox if we are going to change global diets. As Scheffler suggests, maybe personalized nutrition data will be more effective in triggering behavior change than the comparatively blunt tool of global diet recommendations, and will contribute to a much-needed recalibration of diets.

“If you stick to what you really require, you will consume far less, and that would make these calories available for others,” says Scheffler. “We need to produce the right things for the right people. There’s an environmental aspect to that, but also the social benefit of reducing the cost of health by focusing on better nutrition and having people who can live longer, active lives.”

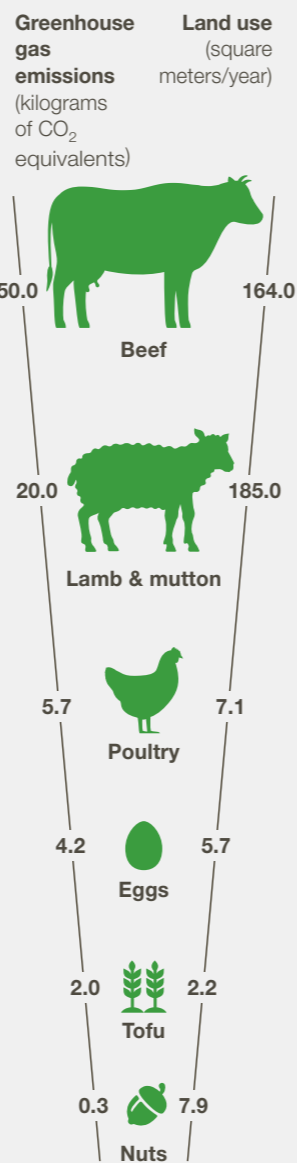
Of course, what we eat is only half the story. The other half is about how we produce food. In the next section, we find out how agriculture is changing to meet current challenges. ■



More meat: In 1990, an individual in China ate on average just 0.64 kilograms of beef and veal a year. By 2018, that figure had grown nearly six-fold to 3.8 kilograms.

Protein footprints

We all need protein in our diets, but whether we get it from beef or nuts makes a huge difference to the environment. The impact varies by region. Here are the mean averages for **100 grams** of several common sources of protein.



Source: J. Poore & T. Nemecek (2018)

Photo: Gettyimages/Allison Michaeli, Graphic: ASCS



02

Smart Farming

For centuries farmers have tilled the soil to clean the field of weeds and remnants of the old crop before planting for the new season. But Jake Freestone, a farmer in the west of England, instead operates a practice called no-till. The soil is left undisturbed with its organic matter and nutrients intact. The residue from the previous crop acts as cover to maintain the moisture in the soil. For Freestone, the benefits are clear. “We are prone to erosion here,” he says. “By not disturbing the soil we have created a more stable surface that absorbs more water. The soil is well-structured and we are getting good yields.”

No-till is one of many new ideas that farmers are trialing to increase productivity. They face a tough challenge. Meeting the nutritional needs of the world’s population in 2050 means increasing global food production by 50 percent compared to 2013, according to the Food and Agriculture Organization of the United Nations (FAO). Clearing forest to create more agricultural land is counterproductive, as deforestation is a main cause of global warming. We therefore

Photos: Andres Henn; CIMMYT/Peter Lowe

“Increased nutrition uptake by crops will improve fertilizer use, increase yield and reduce emissions into the environment.”

Julia Harnal
Vice President Sustainability
at BASF’s Agricultural Solutions division,
Limburgerhof, Germany



As climate change brings more frequent droughts, scientists at the Ethiopian Institute of Agricultural Research in Ambo are working to breed more drought-tolerant crops, such as maize.

need to grow more on existing farmland, without increasing negative impacts on the environment.

This approach is called sustainable intensification. There are many ways to achieve it. What works in the USA might not be relevant in Malawi. But all farmers have the same basic resources: soil, seeds, water, crops and livestock. Sustainable intensification needs farmers to be as smart as possible in how they use those resources.

Increasing precision

Thousands of miles from Freestone’s farm, in sub-Saharan Africa, farmers face severe challenges growing crops on degraded land without the resources to invest in sufficient fertilizer. Here, they have trialed microdosing – a way of using fertilizer more efficiently – in which small quantities of fertilizer are applied directly in the seed hole. It requires only a tenth of the fertilizer typically used. When the method was trialed by 25,000 farmers in Mali, Niger and Burkina Faso between 2009 and 2012, sorghum and millet yields increased by up to 120 percent.

Microdosing is very labor-intensive, but the principle of making fertilizers more efficient is a key to the solution. “Increased nutrition uptake by crops will improve fertilizer use, increase yield and reduce emissions into the

What is sustainable agriculture?

Definition Sustainable agriculture means meeting our needs today in a way that leaves it possible for future generations to meet theirs. That involves providing enough safe and nutritious food for a growing population at an affordable price and in a way that is profitable for farmers with as little as possible negative impact on the environment.

Approaches There are different ways to reach that balance, from organic to sustainably intensified agriculture. All sustainable farming systems ought to provide farmers with a full toolbox of innovative technologies, solutions and know-how to enable them to continue

producing the food society needs, in a way that is safe for the farmer, safe for the environment and safe for the consumer.

“It is all about increasing agricultural productivity through the efficient use of scarce resources,” says Julia Harnal, Vice President Sustainability at BASF’s Agricultural Solutions division, Limburgerhof, Germany. “To do this, we need as many tools as possible. With innovative seeds and crop protection products, together with new digital technologies, we can grow more food on less land with less water and other inputs. That is my definition of sustainable agriculture.”



Cattle are responsible for some 65 percent of greenhouse gas emissions from the livestock sector globally. Using better feeds can reduce methane generated during digestion.

– beetle banks – has shown good results. “For larger fields, we create a ridge of soil in the middle that provides habitat and food for insects, spiders and birds. These natural predators help to control pests in the crop,” Freestone says.

Encouraging natural predators is one part of Integrated Pest Management, a practice based on using a variety of pest-control methods and techniques, enabling farmers to use the best available options to balance high yield and low environmental impact. In Africa, to combat fall armyworm, some farmers are using push-pull techniques. This means intercropping maize with a plant that repels the pest, while planting a border of another species that attracts and traps them. This is a low-input approach, but it requires time.

Crop protection products therefore still have a place in the toolbox. Today they have to comply with increasingly stringent regulations. “The active ingredient has to be poisonous for the pest while being more or less harmless to everything else,” says Harnal. BASF’s new fungicide Revysol® has been developed with these requirements in mind. You can find out more about it in The Science on pages 22 to 25.

Photo: Gettyimages/John M. Scott

Photo: Gettyimages/Ian Grainger; Graphic: ASCS

environment,” says Julia Harnal, Vice President Sustainability at BASF’s Agricultural Solutions division, Limburgerhof, Germany. “That is what we have done with Limus®. The fertilizer additive blocks specific enzymes in the soil that affect the availability of nitrogen to the plant. More nitrogen during critical growth stages results in better yields.”

9

plant species account for 66 percent of total crop production globally, according to the FAO.

Stronger seeds and crops

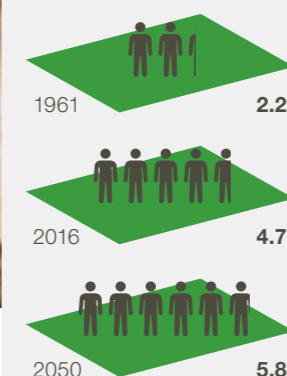
The same smart farming principle applies to seeds. We have been selectively breeding plants since farming began. Today, our ability to produce plants with specific characteristics is moving fast. A revolutionary genome-editing technology known as CRISPR/Cas9 has emerged and this will make seed customization more precise. “It makes it easy to turn genes on and off,” says Tim Searchinger, Senior Fellow at the World Resources Institute in Washington D.C., USA. “This has great potential. If you know which gene causes drought tolerance in one crop, that provides insights into what you can do in another crop.”

But even with the best seeds, all crops still need managing, especially against pests and diseases. On Freestone’s farm in England, a biological form of pest control

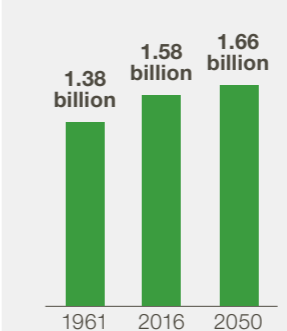
A growing challenge

In order to feed the extra billions of people predicted to be living on Earth by 2050, we have to find ways to increase the yield of available land.

Persons per hectare



Arable land (hectares)



Population 1961
3.0 billion



Population 2016
7.4 billion



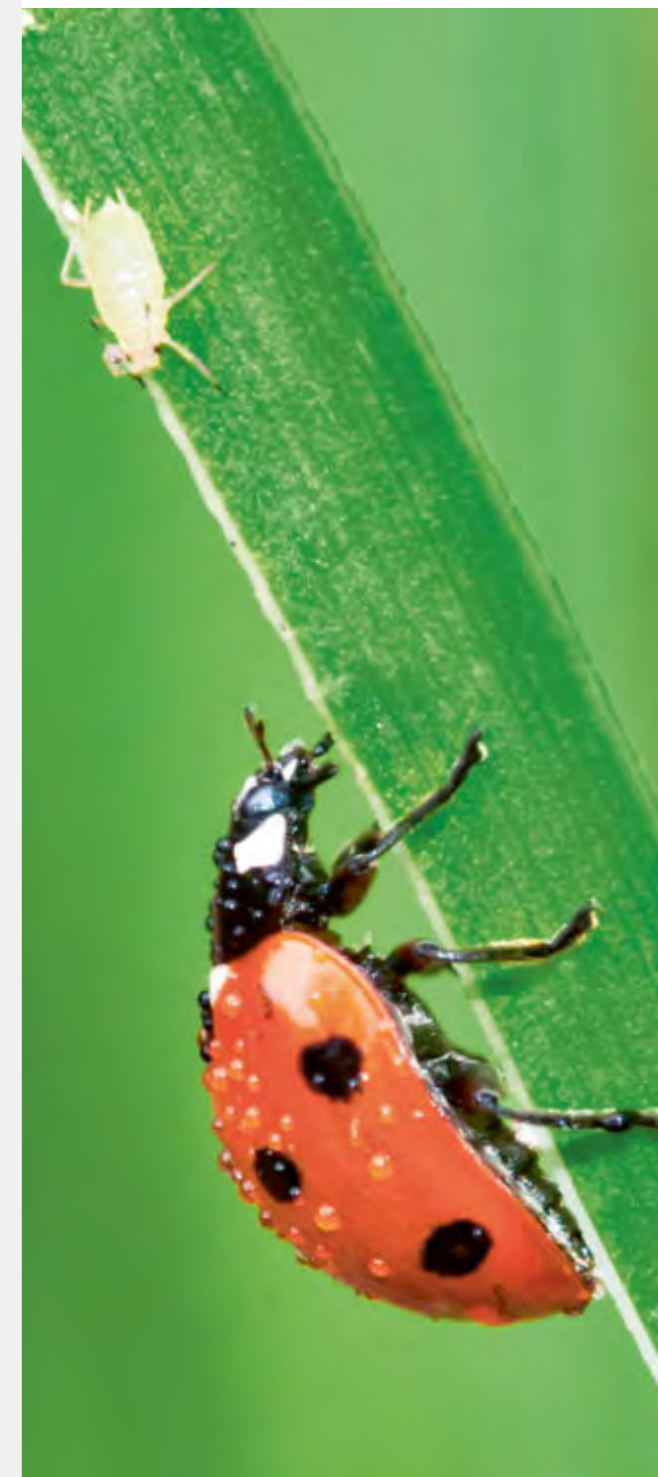
Population 2050
9.7 billion

Sources: World Bank and FAO

A smaller footprint for livestock

What about livestock? Demand for beef and dairy products is increasing around the world but cattle are a major emitter of methane, a potent greenhouse gas. Researchers at the University of California, USA, have found that cattle feed containing 1 percent of seaweed cuts methane production by up to 60 percent. For other animals, such as chicken, pigs and fish, the use of insects as feed is promising. Insects can be raised efficiently on waste matter and are high in protein. Trials have produced positive results; the challenge is to scale up production to make it competitive.

As well as being more productive and more sustainable, growing food also has to make good business sense. Farmers have a vested interest in increasing yields without depleting their finite resources. They will therefore adopt innovative tools and techniques that can help them to do so. “Farmers are the best entrepreneurs,” says Harnal. “They are keen on applying the right solutions. Whether it’s about soil, seeds, crops or livestock, innovation is essential if we are to make the most of our limited resources.”



The ladybug is one of many beneficial insects. It rids plants of aphids and other pests.

Precision farming

Digital technology has truly arrived in the agricultural sector. Sensors, smartphones, drones, and robots are now almost as common as muck and fertilizer on the farm. Machine learning, artificial intelligence and big data are helping farmers to increase yields and improve sustainability at every stage of the growing cycle from seeding to harvest. Yet farming remains a very human-centered activity, with digital technologies enabling farmers to make better informed decisions, faster.

03

Infographic



Illustration: Jörg Block

1 Air intelligence. A field of arable land holds an array of complex information that is not easily accessible for farmers. To gain intelligence and better understand their land and crops, in many regions of the world farmers use drones to deliver accurate information – for example, about crop numbers, size and health. Modern drones can fly autonomously covering huge areas.

BirdsEyeView FireFLY6 Pro, Precision Hawk, USA

2 Simply smarter crop production. Farmers today have access to a huge amount of data. Digital farming products combine imagery data with agricultural knowledge to provide farmers with field-zone-specific recommendations on how best to manage their crops, so they can produce crops more efficiently and sustainably.

xarvio™ Field Manager, BASF, worldwide

3 Precision seeding. Temperature, moisture and residue are all important factors for the successful germination of corn. A new device, already available in the USA, measures conditions in the seed furrow and delivers real-time data during the sowing process. This allows the farmer to make instant adjustments, for example to the seeding rate or the row cleaners, preventing crop residue from limiting the seeds' ability to take up moisture.

SmartFirmer, Precision Planting, USA and Brazil

4 Being prepared. Catastrophic weather events such as floods and droughts threaten the livelihoods of farmers in countries like Ethiopia. Few can afford to wait for financial help delayed by lengthy post-disaster assessments. Ethiopia's satellite system aims to provide accurate data on climate and weather, making it possible to take preplanned measures and trigger the process for insurance payouts to affected farmers early.

Ethiopian Space Science and Technology Institute, Ethiopia

5 Friend or foe? Herbicide resistance is on the rise globally and traditional broadcast spraying exacerbates the problem. New machine learning technology identifies the subtle differences between plants and unwanted weeds and, if necessary, accurately applies small amounts of the right herbicide in the right spots. The new technology is currently used in weeding for cotton and soybeans in the USA.

See & Spray, Blue River (acquired by John Deere), USA



6 Tactile sensitivity. The harvesting of some crops, such as fruits, is a complex task that still relies on the skill of human laborers. But workforce shortages can be a challenge. A new dexterous robotic harvester with digitally steered mechanisms can pick apples from the hardest-to-reach parts of the tree with precision and care. The robot is currently being tested with apple growers in New Zealand.

Robotic apple harvester, Abundant Robotics, USA

7 Bovine early warning system. Monitoring the health of an entire dairy herd is a difficult task. A health issue that requires medical attention can pass unnoticed. Ear tags fitted with sensors precisely monitor a cow's ear movements, which show characteristic rumination patterns, delivering accurate information on a cow's state of health. The system identifies health issues, and alerts allow for early treatment.

Smartbow, Zoetis, USA

8 Sharing economy goes farming. For some farmers, the cost of farm equipment is prohibitively high. For others, unused equipment is an idle resource. An online platform connects farmers in Africa who are seeking and offering local farming equipment for hire. The service is also available to manufacturers. Production machinery, tractors and other equipment is listed, processed and paid for via the platform, and can be booked by mobile phone.

AgriShare, Welthungerhilfe (German private aid organization), Zimbabwe

9 Better with blockchain. Grain is stored in a silo until it is sold. Between farm and fork, agricultural products change hands many times. Using a blockchain, an immutable ledger, for these transactions brings greater transparency and traceability. The blockchain records the quality and quantity, thus preventing fraud, while smart contracts speed up payment to the farmer.

AgriDigital pilot with Fletcher International Exports, Australia

Illustration: Jörg Block

04

Interview

At Wageningen University & Research in the Netherlands, Professor Fresco's work focuses on improving the global food system.

“We can feed the world”

Professor Louise O. Fresco, President of the Executive Board at Wageningen University & Research in the Netherlands, has devoted her career to understanding the global food system. Here, she explains how we can change that system for the better.

Creating Chemistry: Your university's motto, “two times more with two times less,” describes the challenge of feeding the world sustainably by 2050. Are we on track to achieve this?

Professor Louise O. Fresco: I think we must make a distinction between having an ambitious aim and the timeline for implementation. This will take time, but when you see the enormous inefficiency in how everything from land, water and chemical products to labor is being used today, you see how much improvement is possible. Look at how we have dealt with wheat rust in the Netherlands. We have decreased the application of chemicals by about 90 percent through better management techniques, and yields have increased substantially. There are many countries where yields can still go up and efficiency can be improved. So yes, I think we should have it as an aim. There may be countries where it is not possible. But if you don't have an ambitious goal then you're not going to get there.

What does the idea of a sustainable food system mean to you, and has your understanding of it evolved over the course of your career?

I come from a systems thinking school. Even before the term sustainability became widespread, we knew that you had to look not just at the crop but also at the environment, social conditions and so on. Over time we have come to understand much more about the impact of agriculture on the environment in all kinds of ways. An awareness of increasing productivity and efficiency goes hand in hand with an awareness of sustainability. You can't be efficient without being sustainable and you can't really protect nature unless you have a sound agriculture. So the way we look at sustainability, and the way I personally look at it, has evolved in some ways, but not the fundamental systems thinking behind it – that's always been there.

How are science and technology helping to achieve sustainability rather than just efficiency?

There are a huge number of examples of this. The fastest-growing area in food production is actually aquaculture, which has had a lot of problems with antibiotic use and water pollution. But there are systems now where, for example, you can filter the water through shellfish and

then reuse the effluent water for irrigation. There has also been a lot of breeding work in plants, but this has been focused on increasing yields and not necessarily on nutrients. You want a plant that has tolerance to pests and diseases, and which is also nutritious. It's a systems perspective about the totality of how land, inputs and water are used.

“There is definitely potential for Africa to feed itself, if you look at the amount of land still underutilized.”

You have previously suggested that a certain level of meat consumption helps us to achieve the planet's full ecological potential. What do you mean by that?

Meat is a large category and there's a big difference between pigs and poultry on the one hand, and ruminants such as beef and dairy cattle on the other. There are many areas in the world where you cannot grow crops, so in terms of

using the full biological potential of the planet, such land can be used by cattle, which convert the vegetation into meat or milk for humans. Pigs and poultry can digest food waste and leftovers. About 35 percent of all food that is produced is currently wasted. We can use that sustainably by letting it be digested by other animals. From a health perspective, while developed countries may eat on average too much meat, in a large number of countries animal protein consumption is very low. So, from a sustainability point of view, it would be unwise to have a total moratorium on meat.

Nobody wants to visit a low-tech dentist or live without electricity, but many people in the West romanticize “natural” or old-fashioned food production. Why do you think that is?

My book *Hamburgers in Paradise: The Stories Behind the Food We Eat* analyzes this problem. Most people, especially in urbanized areas, no longer have a realistic idea about how food is produced. What you see in the media is often some of the worst cases of animal welfare or overuse of chemicals. So, the perception that something is fundamentally wrong with our food system is deeply ingrained. Many may think things are getting worse, but it's simply not the case – not in our food production, not in food prices, and not in the environmental effects of food production. The world is actually much better off than it was half a century ago.

Future global population growth will be concentrated in Africa, where most food is produced by smallholders. What are the most effective and sustainable ways of improving their relatively low yields?

There is definitely potential for Africa to feed itself, if you look at the amount of land still underutilized. We need to modernize the farming system towards new methods where mechanization, in whatever adapted form, plays a role. Sub-Saharan Africa has hardly any

Looking at the whole system



Professor Louise O. Fresco

President of the Executive Board, Wageningen University & Research, Netherlands

Louise O. Fresco was born in the Netherlands but spent much of her childhood in Brussels, Belgium. After studying Rural Sociology at Wageningen University, she volunteered with the United Nations (U.N.) in Papua New Guinea before going on to complete a PhD in 1986 on cassava cultivation.

Having worked her way up the academic ladder to Professor of Plant Production Systems, in 1996 she joined the U.N. Food and Agriculture Organization (FAO), first as Director of Research and later as Assistant Director-General. In 2014, she was appointed President of the Executive Board at Wageningen University & Research. She serves as a non-executive independent member of the board of Syngenta, predominantly advising on sustainability, and is a writer of both fiction and non-fiction.

irrigation, for example; only 3 to 4 percent of land is irrigated. There is enormous potential there, and for having two crops a year. But you need concerted efforts to improve the policy environment. Governments and others, including the private sector, need to invest in a modern system and provide incentives for a new generation of farmers. I am optimistic, though, that the private sector – including seed companies, chemicals and fertilizer companies, and banks – is looking at how to work together to help farmers towards modernization.

How do we ensure that urban populations in Africa have access to a healthy diet, and what is the role of the private sector?

There is no food production without the private sector anywhere, of course, including Africa. What is important, I think, is that the private sector realizes that they have an important role in the way the whole food chain is organized. Supermarkets are increasingly becoming important in Africa and they can really play a role by engaging with consumers and citizens, farmers and producers. We also need a lot of investment in food processing, cold chains and slaughterhouses to healthily feed these growing urban populations. But it takes a concerted food policy and a concerted engagement between the government and the private sector.

Can you give an example of a country that has been particularly successful in addressing agricultural and nutritional challenges, and from which others can learn?

There's not one country that I know of in the world – including developed countries – that really has a coherent and integrated agriculture and food policy. But there are a number of countries that take agriculture and food seriously both from a domestic and export point of view. One is Ethiopia, where I think they do have a good national policy and they're trying to work with small-scale farmers and integrate them with the private sector. Vietnam is also



“Increasing productivity and efficiency goes hand in hand with an awareness of sustainability.”



At Wageningen University, research is carried out to improve yields and nutritional content of important crops, and to understand the effects of climate change on plants.

interesting because out of nothing they have organized an enormous industry in coffee and also one in aquaculture. Every country has its own unique potential but I'm always a bit worried about the idea of countries copying one another. You can be inspired, but your experience has to be linked to the specific conditions and culture of your country. Let's make sure that knowledge and training are accessible. That's the most important thing.

Do you think that we will see an end to global hunger and malnutrition in your lifetime?

It depends on the causes of hunger and malnutrition. If you look at where the hungry people are today, most of them are displaced people in areas of civil unrest. This is not a matter of production potential but of political tensions. Then there is a larger group of people that are not acutely hungry but do not have a full balanced diet. There is also an increasing group of poorly nourished overweight people in developed countries. For them, an increase in productivity and income will be beneficial. If I had a magic wand and could do something about civil unrest and wars, then I would be 100 percent sure. But from a purely technical point of view, I think it's absolutely possible. With our current techniques – let alone with modern techniques in the pipeline – we can definitely feed the world in a healthy and sustainable way. ■

The ten-year journey to a new fungicide

Protecting crops from disease is essential if we are to sustainably improve yield on existing arable land to feed a growing population. How do BASF scientists develop products that are effective and safe for people and the environment? We follow the journey from lab to market.

05

The Science

It looks like a normal greenhouse, but many of the plants appear to be on their last legs, leaves wilting and discolored. It's no wonder – they have all been inoculated with pathogens that cause fungal diseases. This is BASF's fungicide greenhouse at Limburgerhof, Germany, where new active ingredients are tested on crops such as wheat, soybeans, lettuce and tomatoes to see if they are effective. If one looks promising because it appears to protect or cure a plant of fungal infection, the active ingredient is further developed and goes into field testing.

“Modern farming relies on high yields to secure the supply of high-quality food. Fungal diseases significantly decrease yields and have a negative impact on food quality,” says Klaas Lohmann, PhD, Principal Scientist Fungicide Chemistry at BASF. “Fungal infections pose a high risk of devastating harvests. That is why farmers rely on fungicides to control these diseases.”

Maintaining efficacy

Over time, however, many pathogens that cause disease can develop a resistance to the active ingredient. As older crop protection products become less effective, there is a constant need to innovate. But crop protection products also have to meet increasingly stringent environmental and safety requirements to prove that they are safe for people, animals and the environment.

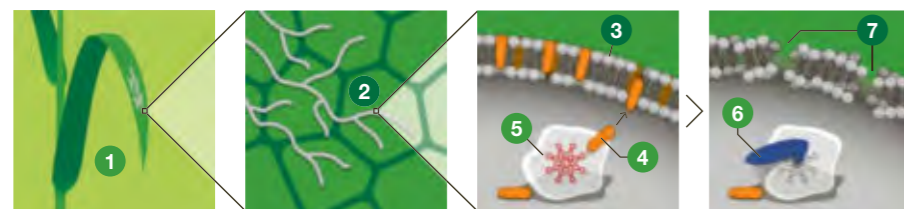
“It is a major challenge. Our task is to find new active ingredients that lessen the fungal pressure on crops and are safe for humans and the environment,” says Lohmann. “They also have to be practical and easy for farmers to use.”

It is only through a sophisticated funneling process that this task can be fulfilled. It takes around 10 years to bring a new crop protection product to market. The successful development of the new fungicide Revysol®, for example, was the end of a research ▶

Expertise across many disciplines: Klaas Lohmann, PhD, and Martin Dust, PhD, examine young wheat plants in the fungicide greenhouse at Limburgerhof, Germany. A team of biologists, gardeners and phytopathologists combine their skills to test new active ingredients.

How does Revysol work?

When a **1 fungus** infects a plant, a mycelium of thin **2 filaments** develops with a flexible **3 membrane** that is in constant motion. The membrane is kept intact thanks to **4 ergosterol** molecules. Ergosterol is produced inside the fungal cell, where the **5 enzyme** C-14 demethylase plays a vital role. **6 Revysol** resembles a flexible hook that can assume different conformations allowing efficient binding to the target enzyme, although mutations have developed. It blocks the enzyme and stops the production of ergosterol. As a result, **7 cracks** appear in the membrane of the fungus, and it collapses and dies.



and development journey that began in Lohmann's lab in the mid-2000s with the targeted screening of over 4,000 possible candidate molecules. In the end, only one complied with all the requirements.

"We start by screening compounds in the lab and then the greenhouse for activity. When we find something promising, the next step is to understand how it works," says Lohmann. If it is genuinely new, he and his colleague design and synthesize similar molecules to find the one with the best performance.

Finding sustainable solutions

As the project develops, agronomists, biologists, toxicologists and engineers are brought on board, as well as experts such as Martin Dust, PhD, Head of Global Regulatory Affairs Fungicides at BASF. "From very early on we pay attention to the safety and sustainability of our products. In the discovery phase of Revysol, we used new indicator studies to increase the chances of meeting both the highest regulatory standards and outstanding biological performance," says Dust. "New products have to pass the toughest tests to gain approval, particularly in Europe. For Revysol we conducted more than 290 studies comprehensively examining safety for humans and the environment."

Given these strict requirements and the increasing cost of development, in the European Union there are now fewer active ingredients authorized for use, and few new active ingredients being submitted for approval.

With Revysol, Lohmann and his team have developed a highly effective fungicide that not only meets these strict requirements but is also practical and uniquely flexible. "What makes Revysol so special is that it controls many different fungal pathogens even where mutations have developed. It works both on row crops like wheat and corn, and on fruit and vegetables," says Lohmann. "Farmers will therefore benefit from Revysol to safeguard their harvest."

In the careers of both Lohmann and Dust, the achievements of the Revysol project stand out. "Discovering a new fungicide involves constantly deciding which path to pursue. Even after many years of development you can end up in a dead end," says Lohmann. "There is no blueprint to follow – the correct intuition plays a role alongside rationality and hard work in almost every scientific discovery."

Motivation also plays a key role. "Our drive throughout was the desire to support farmers in growing food in a better way," says Dust. "Seeing Revysol become such a success has been very rewarding." ■

Photos: Jonas Ratermann(3); BASF; Graphic: Jörg Block



A

Automated testing in the prescreening lab enables scientists to test up to 100,000 substances a year. After initial screening, substances are then tested on plants in the greenhouse. The results indicate the direction that further research should take.

A Twenty different types of plants grow in the greenhouse, including wheat, tomatoes, grapes, apples, soybeans and cucumber. The plants are treated with candidates for new fungicides and inoculated with various pathogens. Afterwards, they are monitored to see which products work and which do not.



B

B Rusts, mildews, blights. Some of the most common fungi that affect crops worldwide are cultivated at the BASF greenhouses for test purposes. The fungus seen here is *Cercospora zeae-maydis*, also known as gray leaf spot. It affects corn, one of the world's main crops.



C

C Best conditions. Young plants are treated with a candidate fungicide and inoculated with a pathogen, then placed in a chamber in the greenhouse with the ideal climate for the pathogen to grow. They are monitored daily to see which is winning – the candidate fungicide or the pathogen.



D

D Global problem. Candidate fungicides must prove themselves against common fungal diseases such as *Septoria tritici* in wheat. A problem for cereal farmers, this grows particularly in wet and warm conditions and can devastate harvests.

Have you seen this yet?

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

Weaving the future

Product Material innovation meets modern design – for its latest streetwear collection, the New York fashion label Seven Crash has joined forces with BASF and the Taiwanese fabric manufacturer San Fang. The result is the Quantus collection, which was unveiled at the New York Fashion Week at the beginning of 2019. The BASF materials Freeflex™ and Haptex® were part of this. Many different colors, weaves and effects made the materials ready for the runway. Freeflex is spun from Elastollan®, a plastic that can be molded under heat and is extremely flexible. Haptex enables synthetic leather to be produced sustainably and shaped in a wide variety of ways.

basf-nyfw.com



Plants create light

Product Take an indigenous plant, place it in a terrarium filled with soil and position an electrode close to the roots. This is all that is needed to produce electricity from bacteria in the soil. The idea was the creation of professors and students at the University of Engineering and Technology (UTEC) in Lima, Peru. When plants grow, excretions occur. These are digested by microorganisms, releasing electrons. The electrode attracts the electrons and produces electricity, which is stored in a battery – enough to do homework in the evening under a small LED lamp, for example. In the off-grid Peruvian community of Nuevo Saposoa, 37 families benefit from these plant lights every day.

- 1 During photosynthesis, plants release nutrients in the soil. These are broken down by microorganisms.
- 2 The resulting electrons are captured by electrodes in a metal grid, creating a current flow.
- 3 The electricity is stored in a battery that charges during the day.
- 4 The energy generated can power an LED lamp with a capacity roughly equivalent to a 50-watt light bulb.

Photos: BASF; Graphic: ASCS based on UTEC



Weight watching

Concept Lightweight materials save fuel in vehicles and human energy in wheelchairs. Working with wheelchair users and partners from industry, BASF has now developed the Ren Chair by using light, long-lasting, high-performance materials. Weight-reducing soft foam provides flexibility in the seat, while the

Elastollan® backrest supports the posture. The Ren Chair also boasts sensors made out of a particularly robust plastic from BASF. A new smartphone app can use these sensors to take a user into accessible facilities, for example.

bit.ly/renchair

Energy boost from cocoa shells

Concept Cocoa plants can be found nearly everywhere in Ghana – but electric power cannot. One-third of Ghana's rural population have no access to electricity. For this reason, the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana, has been testing

a small bioenergy facility since July 2019. It burns cocoa shells and thus converts them into energy. The prototype consists of a pellet machine, a gasifier and a generator. The estimated cost is less than \$50,000. Practical validation of the system has yet to be completed.



3.8

liters is all the water that the Tetra dishwasher uses. Conventional dishwashers, by contrast, require 15 liters per cycle.



Tabletop dishwasher

Product Small, simple and economical – the Tetra dishwasher, developed by U.S. company Heatworks in collaboration with frog design, will fit on any table. It can take two sets of plates and cutlery, which are washed in 15 minutes using just 3.8 liters of water. No plumbing or installation required. Just plug it in and away you go.

myheatworks.com

The value of waste

Throwing away is a thing of the past. In the future, we will think only in cycles. The intelligent reuse of waste as a raw material still holds enormous untapped potential.

Tom Szaky's path to the global stage began knee-deep in waste. Szaky, 38, still shudders when he thinks about his first waste-recycling company. However, even then this company founder already had a clear idea of the vision that he would present some two decades later, in 2017, from a podium at the World Economic Forum in Davos – the idea of abolishing waste. After all, in nature there is no waste – only raw materials.

Szaky's company, TerraCycle, now processes even difficult waste, such as cigarette butts, into plastic pellets. Recently, this waste pioneer has even been trying to use his new deposit system start-up to completely banish disposable packaging (see page 35).

Fast-growing mountains of waste

The fact that an *enfant terrible* of the waste sector, such as Szaky, and those who hold power in business and politics are coming together is the result of a problem that, in view of its huge dimensions, also demands unconventional solutions. The Earth is drowning in waste, which is evident not only from dramatic images but also from stark figures. According to the World Bank, humans annually produce around 2 billion metric tons of waste, ranging from food leftovers and packaging to scrapped electronic devices. The development bank estimates that this figure will rise by about 70 percent by 2050, to some 3.4 billion metric tons. The biggest challenge is plastic, and politicians

are accordingly applying pressure. In May 2019, the European Union (E.U.) passed a law that will ban disposable plastics such as straws or plastic cutlery from 2021. This strong measure is in line with the action plan for closing the loop that the E.U. launched a few years ago. For some time now, the thinking of government and business leaders has revolved to a large extent around the three Rs of Reduce, Reuse and Recycle – and that principle is increasingly gathering pace.

Companies including BASF have recognized both the signs of the times and the value of acting together. In January 2019, nearly 30 companies launched the global Alliance to End Plastic Waste (AEPW), and the number of members is growing. With \$1 billion pledged, this not-for-profit initiative is promoting new solutions for minimizing the impact of plastic waste on the environment, improving processes in the waste-management business, and putting that plastic back into circulation. Partnerships for this purpose are also being formed with local organizations. "Ending plastic waste in the environment is a challenge we can overcome through sustained effort, collaboration and a commitment to innovative solutions," says Jacob Duer, president and CEO of the AEPW and former program director at the United Nations Environment Programme.

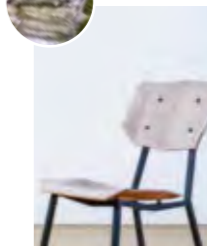
BASF is working on contributing toward closing loops in plastics with a new raw material. ChemCycling™ is the name of the project under which the company is using ▶

New life for waste



1 Butts into watering cans

The filters in cigarette butts are shredded, melted and processed into plastic pellets. These are then used to make items such as watering cans. TerraCycle has relevant collection programs in more than 50 cities in North America, as well as in other places.



2 Furniture from waste paper

The paper in newspapers is made from wood – and it can be turned back into wood. The NewspaperWood company in the Netherlands sticks layers of old newspapers together to form robust blocks. It then trims them to make lamps, furniture and other things.



242

million metric tons of plastic waste – approximately – is produced each year according to the World Bank. That equals 12 percent of the total amount of all waste.

recycled pyrolysis oil from discarded plastics as a raw material in production and thus replacing some fossil raw materials. BASF's partner companies heat various types of plastic waste to temperatures between 300 and 700 degrees Celsius in an oxygen-free environment. The long polymer chains in the plastics are dissolved in the heat and become pyrolysis oil in shorter chains and then gas in very short chains. This gas is used to heat the process. "This means that a large proportion of the energy required comes from the plastic itself," explains BASF sustainability expert Andreas Kicherer, PhD, in Ludwigshafen, Germany. The remaining liquid part can now be cleaned and processed before being fed into BASF's steam cracker. There, the oil is again broken down into its basic components so that new products, including plastics, can be produced from them. In July 2019, BASF unveiled product prototypes from the pilot phase, such as vehicle parts and cheese packaging based on chemically recycled materials. "In the past, people would have said that you could never use recycled plastics in safety-related components or in contact with foodstuffs, but we have now proven that this does work," Kicherer says. "ChemCycling has the great advantage that we are able, for the first time, to achieve the quality of completely new goods. However, it has the additional benefit that we can declare that the item was made from recycled raw materials." This works in practice through a certified mass balance process, under

which the proportion of recycled material used at the start of production is mathematically assigned to the finished product. Viewed in isolation, Kicherer explains, pure production with raw oil will probably often be cheaper, but the resources and CO₂ saved have to be taken into consideration, as the recycled plastic waste would otherwise be processed into less sophisticated products or simply burned. However, before it is possible to use ChemCycling on a large scale, there are technological requirements to meet and regulatory barriers to overcome.

Revamping electronic waste

Buried treasure lying dormant in electronic devices rather than in complex chemical processes is the domain of the scientist Rüdiger Kühr, PhD. He is conducting research at the United Nations University (UNU), which is headquartered in Japan and has taken up the cause of reducing electronic scrap worldwide through its E-Waste Coalition. Almost 50 million metric tons of electrical and electronic devices are discarded every year and, according to U.N. calculations, this figure could rise to 111 million metric tons a year by 2050 – if nothing is done. In that event, there will be a danger of serious distortions with regard

“Ending plastic waste in the environment is a challenge we can overcome.”

Jacob Duer
President of the Alliance to End Plastic Waste, London, England



3 Worn out
Tires do not only screech, they can also be very quiet. A Czech company is using crushed rubber granulate from discarded tires to make smart noise barriers.



4 By gum!
The sole of the Gumshoe is made from old chewing gum. This idea from the city of Amsterdam is intended to draw attention to the problem of that sticky residue.



5 Jeans from a bottle
You can actually wear plastic bottles with the Waste-Less-Jeans from Levi Strauss. Approximately eight PET bottles are processed to make each pair of jeans.

Photos: Jan Sandvik/EyeEm; gumshoe: Gettyimages; Raketop Tanyakam/EyeEm

Photos: Wikimedia Commons by revl, CC-BY 2.0/kr; Gettyimages; AFP/Miguel Medina; Doma Sherpa; Warwick Kent

Rethinking waste around the world

Avoiding waste, reusing things, making them smart – we look at some pioneering places.

France and Czech Republic

Compulsory donations Big supermarkets in France and the Czech Republic are required by law to give unsold food to aid organizations free of charge. The French Ministry of Agriculture says this model has been a success, and it is now planned to extend it to places such as school and staff canteens or hospitals.

Mount Everest in the Himalayas



The highest waste mountain in the world

Since 2014, every mountaineer climbing Mount Everest has had to bring at least 8 kilograms of waste down with them. Expeditions that do not comply with this lose their \$4,000 deposit. In addition, according to media reports, every mountaineer on the north side has been obliged to pay a waste-collection fee of \$1,500 to China since 2019. The authorities are doing this to counter the increasing amount of litter on the 8,000-meter mountain.



Tokyo, Japan

World champions in sorting waste

In Japan, elementary school students learn about environmental protection – receiving detailed instructions on waste avoidance, reuse and recycling. These instructions cover more than 20 pages. How to handle waste correctly is covered in greater depth at high school, and is also a topic covered in adult education.

Borås, Sweden

Almost free of waste

About 96 percent of domestic waste produced in the Swedish town of Borås is recycled, much of it to obtain energy. Modern technologies are used to convert some of the waste into fuel. This is used to power the town's public buses, for example, and private customers can also use the biogas to fill up their vehicles.



Seoul, South Korea

High-tech for food leftovers

Smart bio-bins that automatically weigh the amount of waste put into them are in use in the South Korean capital, Seoul. Users can access the RFID system with a smart card. At the end of the month, they receive an invoice for the waste that they have put in the bin, which is then processed to make animal feed or biogas.

both to disposal and to efforts to ensure that the electronics industry is supplied with raw materials such as rare-earth elements, Kühr warns. Kühr, who is director of the Sustainable Cycles Programme at the UNU, demands nothing less than a 180-degree turnaround in the production and use of electronic devices – away from disposable electronics and toward recycling and reuse. "The responsibility here rests with producers," he says. They need to focus their innovative energies not on quick switches to increasingly trendy models, but on how to get easier access to components, how to repair and recycle electronic equipment

better, and how to increase its service life across the board.

This is where new thinking about digitalization, in the spirit of sharing is the new owning, could play into the electronics industry's hands. According to the World Economic Forum report, *A New Circular Vision for Electronics*, new technologies from the Internet of Things to cloud computing hold huge potential for better product tracking, recall and recycling. Using rather than owning – already common practice in the leasing of photocopiers by companies – is a principle Kühr believes points the way to the future for smartphones, tablets and ▶

Does it make sense to recycle CO₂?

Sustainability When products are made or energy is generated, the greenhouse gas carbon dioxide is often created. Instead of just being blown out into the air, it could also be used as a raw material. In theory this is possible, but there are limits to the idea.



Using CO₂ to make diapers highly absorbent may sound like an unusual idea, but for researchers it is already in the realm of the possible. For instance, BASF is working on using carbon dioxide in conjunction with ethylene to produce sodium acrylate, an important source material for superabsorbents that does its job in diapers and other hygiene products. This is just one example among many. All over the world, companies are working on taking the chemical compound composed of one carbon and two oxygen atoms and using it to make new products, such as rigid foam or intermediates for fibers. The problem is that the carbon dioxide molecule is so inert that it takes a huge amount of energy input to get it to react with other molecules.

“After nine years of research, we achieved it for sodium acrylate. At first, the process was very complex and liable to break down – and very expensive,” says Rocco Paciello, PhD, who leads a research group for homogeneous catalysis at BASF. Furthermore, in reactions on a large scale between the gaseous compounds of CO₂ and ethylene, there are many interdependent parameters to deal with. “If you change one parameter, this will automatically influence all the others, too. Six months ago,

I would have regarded the speed of the reaction as our greatest challenge,” Paciello says. However, he continues, that is now good enough with the help of a suitable catalyst. “At present, our main problem is the excessively high energy consumption in the reprocessing of the reaction mixture.” This is because the process can be economically viable only if it is possible to reduce the energy input. Only then will the lower raw materials costs compared with traditional production processes actually pay off.

Impact on climate change? Modest

In the foreseeable future, CO₂ is not expected to have any more than a niche existence as a raw material. At BASF, CO₂ is meanwhile being used constantly as a raw material in the production of sodium acrylate on laboratory scale. It will take some more time before this will also work on an industrial scale. “We could get there in about five years,” Paciello hopes.

However, it is also clear that the impact that even extensive use of CO₂ as a raw material in the chemical industry would have on climate change would be only very small. For BASF, therefore, the emphasis in terms of the switch to climate-friendly production is on avoiding CO₂ emissions. The company

is targeting CO₂-neutral growth by 2030. In addition, BASF is conducting research into new production technologies that aim to reduce CO₂ emissions further or avoid them completely. The focus here is on basic chemicals, which are alone responsible for about 70 percent of CO₂ emissions in the chemical industry. In addition to new processes, work is in progress on how to use more energy from renewable sources in the future. For example, BASF is conducting research into ideas including an electric heating concept for steam crackers, which crack crude petroleum at a temperature of 850 degrees Celsius. If this temperature could be achieved with renewable electricity, instead of the natural gas that is used at present, CO₂ emissions could be reduced by up to 90 percent. ■

Carbon dioxide

CO₂ is a natural, non-toxic by-product of the breathing of many living creatures, and is also released when wood, coal, oil or gas are burned. It has a very small concentration in the air, at only 0.04 percent. However, it plays a big part as a greenhouse gas. CO₂ absorbs a proportion of the heat given off by the Earth into space and reflects it back.

Photo: Gettyimages/Siri Beerting

It is planned that even electronic devices will be designed in the future to be recycled and reused.



50

million metric tons of electronic devices are discarded every year. By 2050, according to the U.N., this figure could rise to 111 million metric tons a year.

Photo: Gettyimages/Bepi Ghiotti

the like. Kühn talks about dematerialization here. This means that the manufacturer remains the owner of the device, with a vital business interest in offering consumers the best possible service.

The intellectual resources for such circular thinking are something that electronics manufacturers, which are mainly from Asia, could probably find on their own doorstep. In his book, *Decoding China*, the author Diego Gilardoni points out that Western observers look at things in their own right, whereas Chinese people focus on “relationships between things.” This predisposes the country to the idea of doing business without waste. “Perhaps it is because of this thinking in terms of connections, which never loses sight of the future, that this Asian country already has such impressive examples of a circular economy,” says the Ellen MacArthur Foundation, whose China expert, Vigil Yangjinqi Yu, has collected case studies to support this. For example, the Beijing startup YCloset has declared war on throwaway clothes. For a fixed monthly payment, fashion-conscious Chinese women can hire and return up to 30 items of clothing, ranging from business suits to party outfits – all organized through a smartphone app. This is just one contribution toward curbing the extremely water-intensive and often environment-unfriendly production

of more and more new, cheap-fashion collections.

“Buyers are prepared to pay even a high deposit if the service is right.”

Tom Szaky
Founder and CEO of TerraCycle and Loop, Princeton, USA

The idea of smart use and reuse, rather than short-lived ownership and disposal, is also the business model for Tom Szaky’s newly established company, Loop. When it took its first steps in the USA, Szaky made an astonishing observation, which is also a sign of a long-term change in the mindset of consumers: buyers are prepared to pay a high deposit for a product, if the accompanying service is right. “This not only makes circular economy functional, but we now have the ability to make products that are sustainable, beautifully designed and of high quality,” he says. ■

Find out more about ChemCycling in a video at bit.ly/chemcycling

Three waste tacklers

Waste mountains are growing and growing. But so is the number of people who are not prepared to accept this. Here are three of them.

The waste banisher

Bea Johnson, blogger, San Francisco, USA

The almost waste-free lifestyle of Bea Johnson is manifested in a preserving jar. It contains her family's entire waste output for a year. Is there a garbage can in the house? No – not needed. Johnson leads a zero-waste life. She banishes waste-intensive products and limits herself to the bare essentials. This waste avoider turns all her bed linen into cloth bags, which she uses to do shopping that as a rule consists solely of unpackaged goods. Her everyday items are almost all secondhand. The same applies to her wardrobe, which has so few garments that everything fits into one small suitcase. "However, it would be a mistake to think that we have to do without because of this," Johnson says, emphasizing the gains in quality of life. She enjoys working out that she also saves money – about 40 percent compared to before. Since she started blogging about her zero-waste lifestyle in 2009, the movement has grown rapidly. This waste activist now has more than 400,000 followers on social media. ■

 zerowastehome.com

Johnson's sustainability mantra

- Refuse:** Say no to consumption.
- Reduce:** Give away things that you no longer need to the secondhand market.
- Reuse:** Choose reusable options. Repair things that are broken.
- Recycle:** Put things in the recycling collection – but only things that you cannot do without, cut back on or reuse.
- Rot:** Compost unavoidable food waste.



Photo: Gabriela Hasbun/Redux/laif



The waste reverser

Geert Bergsma, scientist, Delft, Netherlands

Geert Bergsma is "a little surprised" to find that his area of research is so suddenly attracting attention. He says, slightly in amazement, that everybody has started talking overnight about the global threat from plastic waste. "This is helpful to get more attention for the recycling of plastics," says the expert at research organization and consultancy CE Delft. For a number of years, the 53-year-old Dutchman has studied the environmental benefits of an innovative solution to the problem of chemical recycling. He discovered that a particularly promising answer is depolymerization, where plastics are turned back into their original constituent parts with only a

Photos: CE DELFT; Gettyimages/David Williams/Bloomberg

few chemical steps. "This process can cope with a lot of pollutants," Bergsma explains, "and makes possible a true circular economy in the case of packaging." In this way, a drink bottle can remain a drink bottle rather than become a lower-quality material – which would, ultimately, mean waste. "It also saves the largest amount of CO₂, similar to that of mechanical recycling and better than feedstock chemical recycling," Bergsma stresses. The calm, persevering work of scientists like him seems to be bearing fruit. A new factory employing depolymerization is now being created in the south of the Netherlands. Here is Bergsma's vision: "Mechanical and chemical recycling together could spell the end for the incineration of most plastic waste." ■

 cedelft.eu



The waste rethinker

Tom Szaky, entrepreneur, Princeton, USA

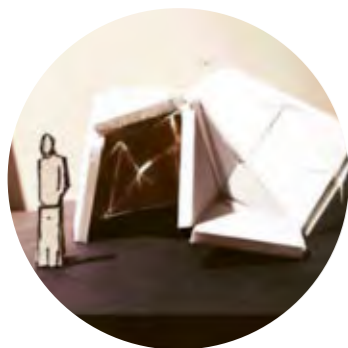
It all started with worms. Tom Szaky, then a student, fed them leftovers from the Princeton University canteen and made their feces into fertilizer. The retail giant Walmart took an interest in it, and this natural fertilizer became part of its range. That was in 2007. Now, more than 200 million people are collecting their waste for TerraCycle, the company set up by the waste pioneer from New Jersey.

What sustainability pioneer Szaky wants is nothing less than the abolition of waste. His company, with branches in 21 countries, is considered a pioneer in recycling the non-recyclable, and it does things like turning chewing gum into polymers for frisbees or diapers into park benches. However, even Szaky can see that the problem of waste cannot be solved by recycling alone. Less waste has to be produced in the first place. Szaky, 37, set up Loop, a zero-waste purchasing platform that aims to abolish disposable products by means of a global circular system for packaging. Major companies such as Carrefour, Procter & Gamble, Unilever, Nestlé and Mars are on board. Together, they have designed new, long-lasting, returnable packaging for some 300 products offered through the platform, ranging from ice-cream cartons that can be refilled again and again to packaging for stick deodorants that can be repeatedly used. "In essence, Loop is a reinvention of the 1950s milkman – then as now, products are delivered to your door in reusable packaging, and once they have been used, they are collected, cleaned and refilled," Szaky says. Loop started its pilot phase in Paris and New York in May. The next step is to expand into parts of North America and the United Kingdom. Canada, Germany, and Japan are due to follow. ■

 loopstore.com

Buildings for extremes

Deserts, storms, ice – in many places around the world, buildings need to be extremely resilient. We highlight some structures that find answers to difficult conditions.



ARCTIC

1. Ice

Igloo Insulation meets design, and the result is a dome-shaped snow house. The igloo is one of the new ideas for using the high-performance insulation material SLENTITE®, which is currently at the market introduction stage. In 2015, 150 international interior decoration and design students at the Stuttgart Technology University of Applied Sciences, Germany, were invited to take part in a competition of ideas to explore this material's potential. The winning design, Pentaglué, uses SLENTITE – which is produced as a stable, thin panel – by combining the panels to form modern igloos in a pentagon structure.

on.basf.com/slentite

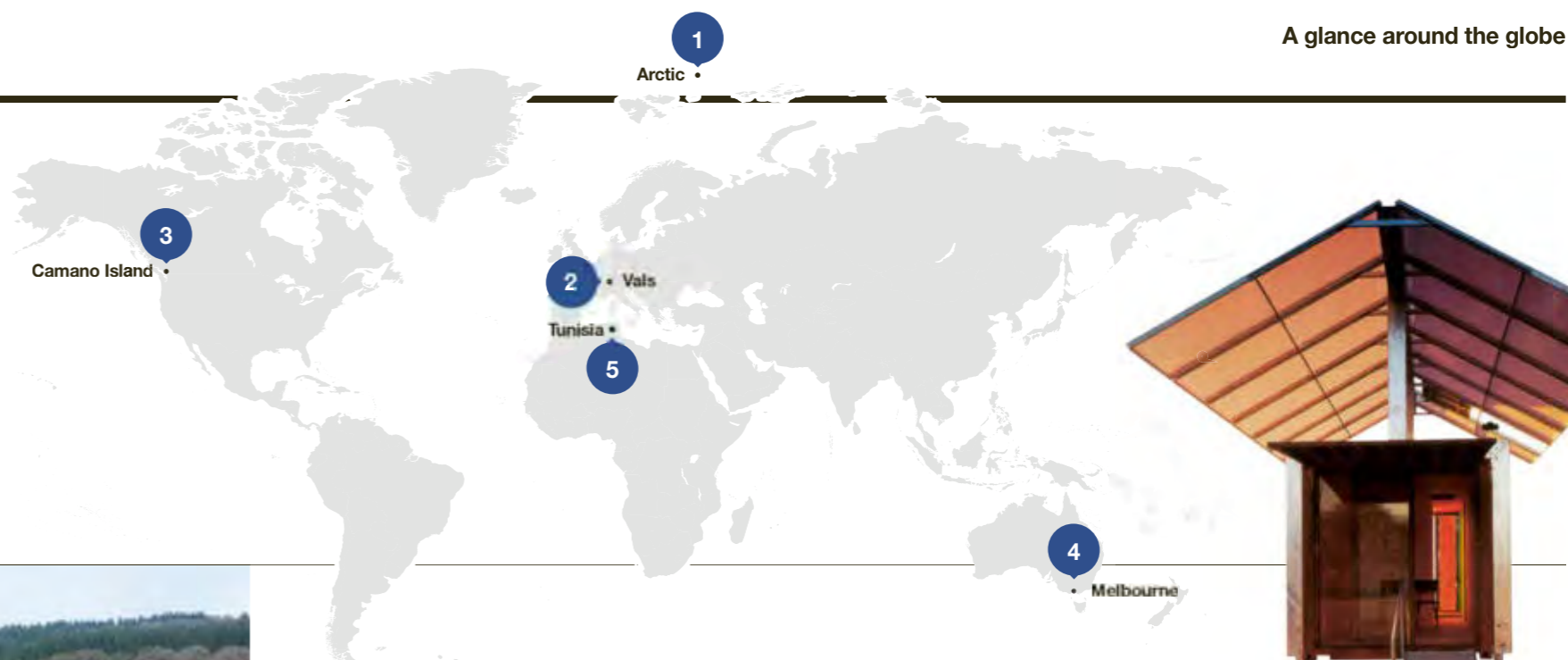
Photos: BASF, Iwan Baan

VALS, SWITZERLAND

2. Mountains

Earth house This house is cut into the mountainside like a peephole – and cut so far in that it does not need a roof. The first reason for this was to comply with avalanche-protection regulations, which require strong rear walls without windows. The second was that the building should fit in with its natural surroundings. Because the structure disappears beneath the surface, the view of the Alpine scenery of Graubünden and its famous thermal baths remains unspoiled. The camouflaged exposed-concrete structure is accessed via an old barn, to which it is connected by a tunnel.

villavals.ch



CAMANO ISLAND, USA

3. Storm surges and tsunamis

Flood room This door is intended not for people but for masses of water. If a flood wave rushes toward the tsunami house in the flood-prone part of Camano Island, the residents simply open the large gates on the first floor. The water then just pours through the house. Accordingly, all the construction materials used in this area are waterproof. The second

floor, which rests on heavy 1.5-meter-high concrete pillars, is intended to provide protection in emergencies. This type of structure was mandated for the builders by a law requiring every house on Camano Island erected or converted in this riverland zone to be capable of withstanding heavy storms.

designsnw.com

Photos: Lucas Henning/Designs northwest Architects; Earl Carter; Gettyimages/Paul Williams



MELBOURNE, AUSTRALIA

4. Natural disasters

Emergency housing When forces of nature devastate whole streets, the time may have come for Future Shack. This emergency shelter, based on a recycled container, is a transportable, self-contained system with a water tank, solar power generation facility, parasol roof and ventilation. Inside, a table and two beds are hidden within the lining of the steel shell, to save space. One additional advantage is that, if necessary, the telescopic legs enable the structure to stand upright even on uneven terrain. The prototype can also be quickly assembled. Sean Godsell Architects promise that the Future Shack will be ready for occupation within just 24 hours.

seangodsell.com/future-shack



TUNISIA

5. Desert

Mud house Natural air conditioning made of mud – this mixture of sand, silt and clay absorbs energy very well during the day and releases it at night.

This is how mud houses manage to defy the desert with its hot days and cold nights – and the northern Sahara in Tunisia is one example. Building with mud is as old as construction itself. Alongside wood, it is reckoned to be one of the oldest building materials in the world. Its use is still widespread – according to estimates, around 3 billion people live or work in mud buildings.

lehnhaus.net



A world without insects?

Recent reports have painted a bleak picture of the future for insect species and the potential consequences for the planet. We look behind the headlines to ask what causes insect populations to decline and how we should tackle this complex challenge.

No one knows for sure how many insects there are on our planet, but we do know that it's a lot – an estimated 200 million-plus for every human on Earth. Their numbers, however, are declining. The disappearance of insects from their usual habitats has been noticed in regions around the world – whether it's in Europe, Australia, the USA, or even in the tropical rainforests of Puerto Rico.

While scientists agree that this decline is real, there is conflicting evidence about its scale and causes.

Some researchers have warned that we are facing an insect Armageddon, with insects dying out entirely in 100 years if we do not take action. The United Nations Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) says that the picture is not so clear, and has made a tentative estimate that 10 percent of insect species are under threat.

Over the coming pages, we asked experts in different fields about what is causing these declines – and what we can do to reverse the trend.

Creating Chemistry: How much do we still have to discover about the insect world?

Anne Sverdrup-Thygeson: Around 75 percent of all plant and animal species on this planet are insects. That's mind-blowing. The vast majority we have no idea about. Of those we do know, only 1 percent have been evaluated as to whether they're threatened. There's a lot left to discover.

Lots of insects are a nuisance or carry disease – why do we need them?

Only a tiny fraction of insect species are bothersome. The vast majority are out there helping our lives every day. They're involved in many ecological processes, like recycling dead organic matter, whether it's dung, dead plants and trees, or dead animals. This is one of the basic processes of life. If nutrients aren't recycled into new fertile soil, there is no way plants can grow. Then there is pollination. Three-quarters of our crop types are dependent on insect pollination. That includes fruits, vegetables and a lot of nuts. Without those nutrients we'd lack necessary vitamins and lose a lot of the taste and color in our food. Insects are also necessary as food for a lot of the bigger animals, such as birds.

What are the implications when a single species becomes extinct?

If you start with a complete species-rich insect community and one species becomes extinct, usually nothing much changes. But when an ecosystem meets variations – as nature is now, in the face of climate change – a species-rich community is more robust and resilient to that sort of external pressure. I think of the natural world as a hammock that we rest in. We can pull out some threads, some species can become extinct, but at some stage the whole fabric will unravel. We really don't want to get there.

What causes insect population declines?

It is a mix of many things, but the main factor is as simple as humans taking up too much space and consuming too much of the nature around them. Agriculture is very land-intensive. Over the last century it has often changed these areas from places where insects found their habitat to a sort of monoculture. Then there is pesticide use, the introduction of species from other places that out-compete the local species and bring diseases and parasites, and on top of all that climate change. Of course, evolution is going on all the time and insects are adaptable creatures, but it's really a question of whether they can keep up with these changes. We need to think about insects when we're putting together development plans for land.



“The vast majority of insects are out there helping our lives every day.”

The entomologist: Professor Anne Sverdrup-Thygeson

is professor of conservation biology at the Norwegian University of Life Sciences at Ås, near Oslo, scientific advisor at the Norwegian Institute for Nature Research, and author of the book: *Buzz, Sting, Bite: Why we need Insects.*

What can we do to protect insect abundance and diversity?

Just learning more about insects and getting to know them is a start. If you have a garden, mow the lawn less often or make a wild corner. It's about bringing natural vegetation back into where we live and into our agricultural and forested landscapes. We need to make it easier and cheaper to do the right things and make it cost to do the wrong things. It all comes back to us in the end. All these useful things that insects do are like a life insurance for us and our children and grandchildren.

What are some of the most amazing things you have learnt about insects?

There's a rare longhorn beetle in the tropics in Asia with a color-changing structure that chemists have been able to copy. Even the common fruit fly is useful – it is ideal for research as it's cheap, easy to keep in laboratories and has lots of offspring. We share more genes with the fruit fly than you might care to know. Fruit fly research is therefore highly relevant to humans, furthering our understanding of inheritance and early development, as well as phenomena such as insomnia and jet lag. Fruit flies have been involved in the winning of no fewer than six Nobel Prizes in medicine. ■



Photos: Gettyimages; Darrell Guljin; Lifeonwhite

Photos: Kjetill Sverdrup-Thygeson; Gettyimages/Fotosearch



“Insect populations vary naturally, you need a long stretch of time to see the big picture.”

Creating Chemistry: Approximately how many types of insect are there?

James Bell: The short answer is, we don't know absolutely. There are 1.2 million catalogued insect species thus far. Beyond that it's just wild conjecture. A conservative estimate would be 5.5 million, but the truth is that while we have done a lot of work in temperate regions, we have still barely scratched the surface of places like Borneo.

How do you count insect populations?

It is not easy, particularly in environments like tropical forests where there are a lot of different habitat types, such as soil, leaf litter, herbaceous vegetation, trunks and canopies. One absolute method is to put down a quadrat to delineate a fixed area of a known size. You remove and count all the insects that you find. However, this is very labor-intensive. That's why people use relative methods or subsampling to speed things up. For example, you put a suction device on the ground and draw up everything into a net. Within seconds you can collect large amounts of insects, but you couldn't use this method in a forest, so timed searching, branch clipping, or fogging might be needed instead.

How do you estimate the absolute density of insects in a habitat?

You have to use several methods, each one designed to sample a particular aspect of the site per unit area. The same sized quadrat can't easily be used to sample bare ground, where you might collect tens of insects, compared to topsoil or leaf litter, where thousands of insects could be caught. We try to balance effort against



The Krefeld study in Germany found recently that flying insect biomass had declined by 75 percent in just 27 years. How does this compare with your study?

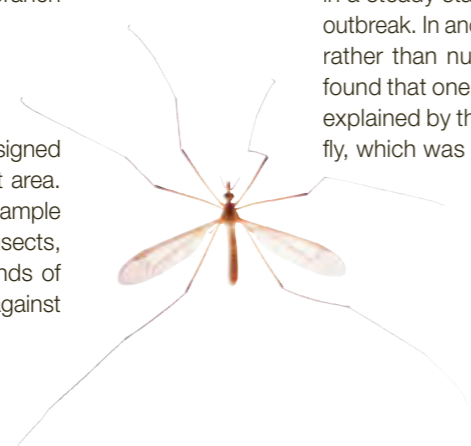
The Krefeld study involved a large number of volunteers who made their data available to scientists – an excellent example of citizen science. One assumes that the volunteers went repeatedly to many sites and monitored the populations over 27 years, but most sites were visited only once, 20 were visited twice, and only one was visited regularly for four years. These were pieced together into a time series of insect biomasses. These aren't species changes but overall sample weight changes in the insect community sampled. We work differently because we identify all aphids and larger moths to species, and many other insect groups, too. We also monitor all our sites daily and some have been running for more than 50 years. Insect populations vary naturally, so to get something meaningful you need a long stretch of time to see the big picture.

What have you observed in your study?

Our study is the world's longest standardized time series on invertebrates. We report principally on aphids and moths. Over the long term, the overall abundance of Britain's larger moths is declining at a rate of 28 percent. On the other hand, one-third of moth species are increasing. One example is lichen-feeding moths. Lichen is very sensitive to pollution. Clean air legislation means there is more lichen. The numbers of some of those moths have increased over 1,000 percent since the U.K. Clean Air Acts of the 1990s. So, you can find some success stories.

What about other species?

Depending on the model, estimates for aphids vary between a rise of 3 percent to a decline of 3.2 percent. That's not very much. Looking over 50 years they're in a steady state, accepting that in some years they'll outbreak. In another study we looked at biomass trends, rather than numbers of individuals, at four sites. We found that one of the sites was in decline. But that was explained by the decline of one very heavy fly, the fever fly, which was biasing the samples. ■



Photos: James Bell; Gettyimages; Science Photo Library RF; Fotosearch



“We need to invest more in understanding where wildlife can live alongside food production.”



How can population declines be reversed?

We need to restore habitats that defragment the countryside – put back corridors of wildflower meadows where intensive agriculture has resulted in areas with insufficient wildflowers and nesting habitat for species to breed and survive. We should be making sure that there's enough freshwater resource for wildlife as well as for humans, and that this water isn't heavily polluted. We would like to see pesticide regulations changed to establish a marketplace in which pesticides that have small-scale use, and are specific in their action, are favored over broadscale-acting pesticides. These are the big drivers, but there are many other causes. For example, the rapid importation of invasive species through potted plants and soil being transported around the planet is a huge threat to biodiversity. If we are to be responsible stewards of the planet, we shouldn't only be preventing environmental harm within the boundaries of our own countries – we have to make sure that we're not exporting the harm.

How can agriculture contribute to increasing insect abundance and diversity?

There are various ways that agriculture can operate, whether it's a restorative or organic approach, that have confirmed lower impacts on wildlife. In some of the more intensively farmed countries there's evidence that putting back wild habitats not only provides more space for wildlife to thrive, you also end up with a healthier farm that produces more food. We need to invest more in understanding the techniques, skills and science around sustainable agriculture, where wildlife can live alongside food production. There are massive trends in things like no-till agriculture, multiple cropping, changing of crop rotations.

Are you optimistic that we can make these changes?

I'm an environmentalist so I've got to be optimistic, otherwise I wouldn't keep trying to stop extinction. I think we've seen a huge shift in terms of the public's attitude towards invertebrates. People are responding to the news of the declines with growing concern. It's getting to the point where governments cannot ignore this issue. ■

Creating Chemistry: Why is biodiversity important?

Matt Shardlow: Biodiversity is essential for the healthy functioning of the planet and the continued existence of humankind. From agriculture to fisheries, climate function and soil function, all these things rely on a healthy ecosystem made up of different species, and most of the species are invertebrates – earthworms fertilizing the soil, bees pollinating the flowers, woodlice breaking down the leaves.

What impact is human activity having on insect populations?

The impact is massive. Many more species are declining than are increasing. One of the initial big drivers of insect declines is the conversion of land from natural habitat into agriculture that supports a vastly lower range of species. You end up with what is called an extinction overhang, meaning that some species may still be surviving on the fragment of habitat that you've left, but in the long term there is not enough variety and not enough robustness within that population to keep it going. Once you get to a certain level of fragmentation, individual animals are unable to move between those fragments to recolonize, so the species starts to evolve not to move at all. They become vulnerable, like island species.

What are the other causes of decline?

Layered on top of that are climate change and the chemicals we are producing. Agricultural use of neonicotinoid insecticides has had a huge impact on bees and other wildlife in Europe, Asia and America, but there are also



Photos: Sam Ashfield; Gettyimages; Photographer's Choice; Henning K. v. Vogelsang





“All information about pollinators is important. It raises awareness about the need to improve the quality of our environment.”

The international expert on pollinators: Professor Vera Lúcia Imperatriz-Fonseca

is co-chair of pollination assessment at the United Nations Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), and former professor of ecology at the University of São Paulo, Brazil.

Creating Chemistry: How do we balance the need to feed a growing population and protecting insects?

Vera Lúcia Imperatriz-Fonseca: Insects are not only a source of food for many people in the world, they also help to improve crop yields as pollinators. However, they are vulnerable to agrochemicals, changes in land use, managed landscapes and the effects of global warming. Pollinators need natural areas to reproduce and protect their eggs in order to survive. If we provide these natural areas, the crops visited by them will have more profitable yields. But the intense deforestation of recent years to create new agricultural land has left huge areas degraded and in need of restoration. We need to implement best agricultural practices from now on because pollinators are essential if we are to feed a growing population, to have larger yields in small areas, and to have a biodiversity that allows us to mitigate climate change conditions.

Is more effective cooperation needed across the different sectors?

Yes. A lot of the private sector has aligned its corporate responsibility policies with the United Nations Sustainable Development Goals in order to improve performance and efficiency, and this has opened up good opportunities for cooperation. But the agricultural private sector needs to improve best practice for the people that manage

chemical products in order to ensure they are applied correctly and in the amounts that are needed. Private sector companies can also subsidize resources for applied and innovative research on pollinator use and conservation. The Coalition of the Willing on Pollinators, initially organized by the Ministry of Economic Affairs of the Netherlands, now has 26 countries as partners. They're encouraging local action to protect pollinators and their habitats, based on the findings of the IPBES pollinators assessment, as well as promoting national strategies and sharing innovation and lessons learned. Many non-governmental organizations are also applying biocultural research to improve local knowledge and preserve ecosystems.

Does more need to be done to ensure effective risk mitigation when using crop protection products?

Of course, particularly in developing countries. The good practices applied in developed countries are needed everywhere. There is also local need for financial support to train technicians in best practice, and networks of companies could support applied research to solve local problems. This financial support could be designed through local research agencies and shared governance.

What action can we take at a local, national and international level?

At a local level, citizen science programs are very useful as they help to organize information and local practices. Training children is also needed. All information about pollinators, their use and conservation, is important, as it creates a connection with nature and raises awareness about the need to improve the quality of our environment. At a national level, museums and collections are an excellent opportunity for research and modeling. We must improve our knowledge of southern hemisphere pollinators, for example, in terms of diversity, local distribution and the drivers that will affect them in the future. At the international level, integrated research exchanges and research training of young students would provide great opportunities to make sure that the next generations continue this vital work. ■



Photos: Henrique Landulfo; Gettyimages/Westend61/Martin Moxter

Viewpoint BASF

It's all about balance



Insect habitats are under threat, which means it is vital that we find ways of producing enough food without using up more land.

The challenge we face is balancing the competing needs of producing enough food for a growing population and maintaining the rich biodiversity on which we depend. It's a complex issue, but advances in technology mean that these needs are no longer as diametrically opposed as in the past.

There are three main drivers that cause declines in insect populations: loss of habitat and food sources, climate change and pollution of soil and water. Of these, loss of habitat is probably the biggest driver. Sustainably intensified agriculture is, in my view, one solution to address this challenge. It allows us to produce more food on less land. That leaves more land for insects.

Intensive agriculture requires specific crop-protection products and precision technology to apply these only where they are needed. In addition, we need to educate farmers in how to use crop-protection products so that there is minimum risk to the applicator and the environment, as at our Farmer Field Schools in Asia. Farmers learn that if you use the chemicals correctly, you use less of the product and save money.

Focus on the environment

The development of new crop-protection products has changed dramatically. In the past, research focused on potency toward the target insect. Today, the main question early on is what issues a new chemical compound might have for humans, bees, birds, other beneficial insects and the environment in general. Each one undergoes numerous studies that are globally regulated to prove the compounds are as safe as possible.

There has also been a dramatic reduction in the amount of crop-protection product needed. Our newest insecticides require just 10 grams per hectare. In the 1970s, a typical dose was 1 to 2 kilograms per hectare. The new insecticides also have a shorter half-life in the soil, meaning the time

the compound remains in the environment has fallen dramatically.

What I find, particularly here in Europe, is that society has lost the connection to agriculture. If you do not acknowledge the need for agriculture, it's very hard to understand why we need crop protection. Modern agriculture together with a varied diet makes a big contribution to our life expectancy and our quality of life. Crop protection helps ensure that we get fresh food that is healthy and safe, delivered to our plates every day.

Our society is concerned about the safety of plant protection products and perceives them as a big risk. However, modern crop protection products are among the most highly regulated products on earth. For me, their safety is beyond doubt. What strikes me is that with other things we use, like cars for example, we are less risk averse. I believe you have to know the benefits

associated with a risk in order to make a good judgement call.

I really think that in order to create enough habitats to maintain a rich biodiversity, we need intensive agriculture. Intensifying agriculture means using all the tools that we have at our disposal, and that includes crop protection. We work closely with farmers to test biodiversity measures and demonstrate how they can go hand in hand with productive agricultural practices. That way we can create new habitats for our insects and all the animals to live and thrive. ■

Harold Bastiaans, PhD,

is Vice President Insecticide Research at BASF, Ludwigshafen, Germany. He has degrees in Chemistry and Pharmacology from Vrije University, Amsterdam, Netherlands, and was postdoctoral fellow in organic chemistry at Stanford University, USA.



“I really think that in order to create enough habitats to maintain a rich biodiversity, we need intensive agriculture.”



Fact therapy

Is the world becoming less and less palatable?

We are inclined toward pessimistic misjudgments that affect our thinking and our actions. The remedy is facts, figures and data for a realistic view of the world.

Would you believe that the world is better than we think? What with climate change, armed conflicts and child poverty, our perception is that everything is getting worse and worse. At least that's what a majority of people in 30 countries believe, according to a survey by the Gapminder Foundation. It's about time to scrutinize our prejudices and to refocus on a better understanding of the world, based on facts. Professor Hans Rosling, co-founder of just this Gapminder Foundation, demonstrated that statistics can function as a form of therapy. The Swedish doctor and statistician fought against ignorance and an outdated view of the world up to his death in 2017. Rosling's strongest weapon in hundreds of lectures was data from trustworthy sources.

Know about the good things

Rosling was convinced of one thing: "It's easy to be aware of all the bad things happening in the world. It's harder to know about the good things: billions of improvements that are never reported." Hans Rosling was by no

means an incorrigible optimist, but identified himself as a "possibilist." "Both are correct. It is both bad and better ... That is how we have to think about the current state of the world," Rosling said in his global best-seller, *Factfulness*. This means paying close attention and observing long-term trends, but also not overlooking fluctuations.

In any event, the idea that everything was better in the past is wide of the mark. When Rosling's grandmother was born in 1891, Sweden stood where Afghanistan does today – a country with one of the lowest life-expectancy figures in the world, close to extreme poverty. The progress made all over the world has also been huge. Although it is very hard to measure extreme poverty and the data is complex, a clear positive trend can be discerned (page 46). The European Union expects 5.3 billion people to belong to the global middle class by 2030 – most of them in Asia and the Pacific region. That would be well over 50 percent of the predicted world population of 8.55 billion. Thus, the widespread division of the world into us, the Western world, and the rest,

the so-called developing countries, is a typical misjudgment.

Beware of extreme examples

The Global Threat Index from the market research company Ipsos reports that an average 74 percent of those surveyed believe that the world became more dangerous in 2018. Even in one of the most successful economies, a sense of crisis is in fashion – the relevant headline being that about one in two Germans claiming to be afraid of old-age poverty. Why do we prefer to stress ourselves with a negative view of the world, rather than

A well-portioned, fact-rich worldview helps against half-knowledge and perceived truths.



Three reasons why we find it so hard to be objective

1 Optimism bias This explains the stubbornness of anti-vaxxers, for example. They certainly do believe that measles can lead to death in small children. At the same time, they are absolutely convinced that nothing will happen to their own child.

2 Consistency motive This describes the need for consistent knowledge. When a person comes across conflicting findings, what is known as cognitive dissonance occurs – a state of tension that they try to avoid. This causes facts to be declared wrong or played down.

3 Confirmation bias "I'll make the world the way I like it." In keeping with the motto of Pippi Longstocking, information is selected, found or interpreted in such a way as to match the person's own expectations. Even experienced researchers can be affected by this.

focus on improvements, prioritize problems on the basis of facts and then boldly tackle them? The answer lies in human nature – in the Stone Age, fear and generalization were vital for survival, but today they often distort our perceptions.

Rosling's recipe: To keep in mind that we all tend to simplifications and generalizations. Critically scrutinize your own perception and check the facts. Mistrust extreme examples. "Vivid images are easier to recall but they might be the exception rather than the rule," say Hans Rosling's son Ola Rosling and his wife Anna Rosling Rönnlund. The

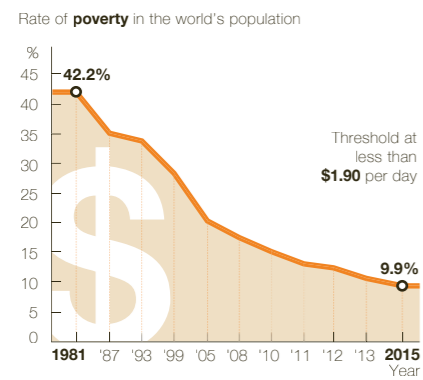
Gapminder idea, which they are pursuing with their team, is making waves globally through what is known as constructive journalism, which does not just report on problems but also points out solutions, and through open science. With workshops for companies, talks in schools, and a thousand new test questions, their charitable foundation plans to continue using statistics and data visualization to dispel stubborn clichés now and in the future. "When we think about the world, we need to stop considering our feelings and start considering the facts," Anna Rosling Rönnlund stresses. ▶

Photo: Gettyimages/Daniel Grizej



Photo: Gettyimages/Patrick A. Williams

Income Extreme poverty is declining

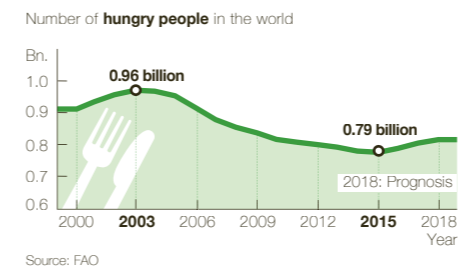


Living on less than \$1.90 a day – this is a reality for millions of people. The assessment threshold set by the World Bank corresponds to the average national poverty line for 15 of the poorest countries in the world. That includes, for example, sub-Saharan Africa, where more than half the people on extremely low incomes live. However, the poorest of the poor are falling in number. According to the World Bank, the number of people who have to live on less than \$1.90 per day (measured against local purchasing power parity) has fallen continuously since 1990, from 1.9 billion to 736 million in 2015. That means more than a billion fewer poor people. The success of the past 25 years is due mainly to progress in Asia, especially China. China opening up to a market economy and global trade led to a reduction in extreme poverty from 67 percent to less than 1 percent between 1990 and 2015. The United Nations Millennium Development Goal will, however, not be completely achieved – according to the latest forecasts, poverty will fail to become history by 2030 and continue to affect 6 percent of the global population.



Photo: Gettyimages/Andrea Pistolesi

Food A world without hunger is possible



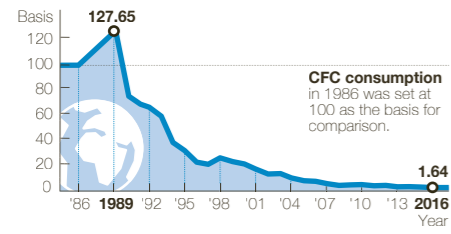
Enough food for everyone is possible. Overall, the number of malnourished people has fallen since the 1990s. According to the Food and Agriculture Organization of the United Nations (FAO), between around 850 million and just over 1 billion people – depending on the publication – suffered from hunger in 1990 to 1992. Twenty-five years later, it was only 785 million, or 10.6 percent of the world's population. However,

the FAO's data-gathering method changed with effect from the year 2000, so earlier figures are not directly comparable with today's. Also, the topic of hunger is another area where long-term trends are subject to fluctuations. According to the latest estimates, more than one person in 10 worldwide did not have enough to eat in 2018 – around 10 million more than in the previous year. This means that the number of malnourished

people rose for the third year in succession. The main causes of the latest increase, according to the FAO, are growing numbers of armed conflicts and the consequences of climate change. Zero hunger will only be achieved if "we change the rural economy, focus on small farmers, and invest in sustainable agriculture and food production," says FAO Deputy Director-General Maria Helena Semedo.

Environmental protection

Good news about the ozone hole



Source: Our World in Data

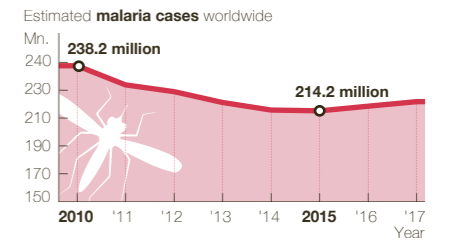
Chlorofluorocarbons (CFC) can do a lot – make foam plastics, provide the coolant in refrigerators and extinguish fires. However, they also destroy the ozone layer – the Earth’s protection against harmful UV radiation from the sun – and contribute to global warming. In 1987, an international treaty was adopted, reducing the production and release of CFC and other ozone-depleting substances worldwide. The Montreal

Protocol is having an effect. In 1986 total global consumption of CFC was around 1.1 million metric tons, but 15 years later the figure was only 110,000 metric tons. The ozone hole, which has appeared over the Antarctic every year since the early 1980s, has been shrinking since the early 2000s. The secrets of the Montreal Protocol’s success include fair burden-sharing – emerging countries were given a grace period for

getting rid of CFC – and solutions for avoiding conflicts of interest. Since the chlorine-free hydrofluorocarbons (HFC) that are used as a substitute coolant are also harmful to the climate, the Montreal Protocol has been adjusted, and 197 countries have undertaken to reduce the production and use of HFC by at least 80 percent by 2047. The gases propane, butane, pentane and carbon dioxide are already being used as alternatives.

Health

Broad line of defense against malaria



Source: WHO

A tiny bite can be deadly. If left untreated, malaria can be especially dangerous for small children and pregnant women. The disease is transmitted by Anopheles mosquitoes that are infected with the Plasmodium parasite. About 70 percent of malaria cases are concentrated in just 11 countries, 10 of which are in sub-Saharan Africa. For 15 years, global efforts to combat malaria achieved significant success. According to the World Health Organization (WHO), between 2001 and 2015, the use of insecticide-treated nets and other interventions prevented an estimated 663 million malaria cases in sub-Saharan Africa. However, in 2016 and 2017, the trend reversed and the number of cases, particularly in Africa, began rising again. One reason why progress is stalling is that mosquitoes have developed resistance to the insecticides that have been used since the 1980s. This is now being tackled by the New Nets Project, financed by non-governmental organizations including The Global Fund, Unitaid and the Bill & Melinda Gates Foundation. An important element in the New Nets Project is the new Interceptor® G2 mosquito net from BASF, which is treated with an insecticide completely new to malaria control. Millions of these innovative BASF nets, along with nets from other providers, are being tested for effectiveness and cost-efficiency in several pilot projects across Africa.

Photo: shu.istock/studio23

Photo: Gettyimages/Peter Charlesworth

Fragrance makers

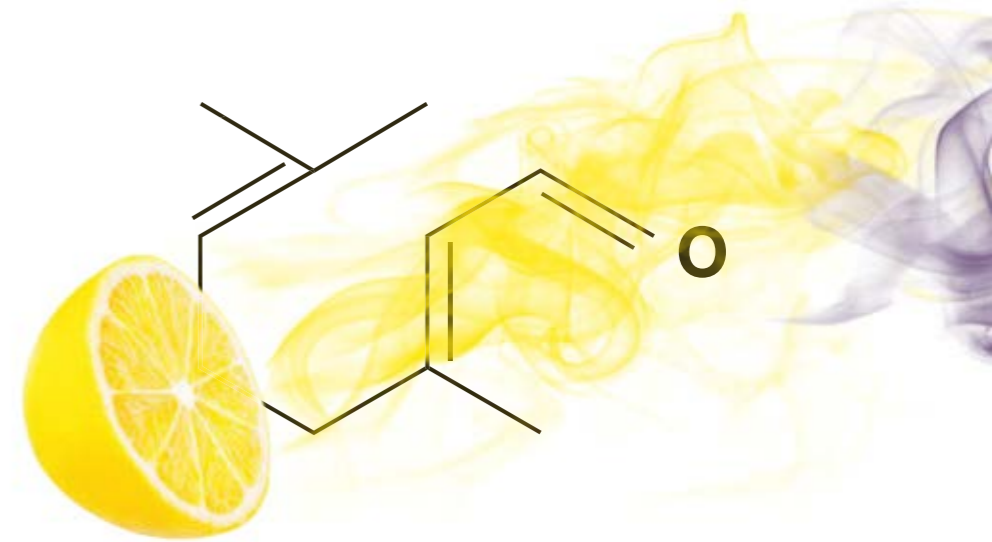
Smells influence our senses, our thinking and our metabolism. How they are produced synthetically is just as fascinating. One single odorant is the source of the scent of lavender, roses or mint.

Anyone who pokes their nose into the BASF Visitor Center in Ludwigshafen on the Rhine, Germany, is in for a sensory surprise. Just press a button on a glass flask, and you will immediately be hit by an aroma reminiscent of lavender. However, this scent that might remind you of sun-drenched Provence in France is actually a replica – a combination of the synthetic fragrances linalool and linalyl acetate.

“It is actually a minor sensation that we are able to use citral to replicate lavender or mint by means of a simple chemical transformation,” says Wolfgang Krause, PhD, New Business Development & Technical Marketing Aroma Ingredients at BASF. The synthetically produced odorant citral, which is the core product among the company’s own scents, proves to be extremely versatile here. It is not only an important component of violet, lemon, and rose scents, but is also a raw material for vitamin A, vitamin E and carotenoids.

One for all

Citral contains 10 carbon atoms and one oxygen atom. If the molecular structure is changed only minimally, however, this can result in linalool, which smells like lavender, or geraniol, which is responsible for a rose scent. What creates the subtle distinction is the respective position of the oxygen. This may sound trivial, but for chemists or perfumers it is an incredible operation. Like a key that has an edge added or removed, the molecules attach themselves to different olfactory receptors in the human nose, where they create the scent of lavender or



How it works:

Citral occurs in many essential oils, such as lemongrass oil. The molecule is composed of 10 carbon and one oxygen atom, which rests with a double bond at the end of the carbon chain.

For centuries, perfumers could rely only on natural fragrances, some extremely rare. The age of synthetic fragrances only began with the production of vanillin in 1874 and musk in 1888. BASF got into the production of fragrances in the 1930s with phenylethyl alcohol, a nature-identical component of rose oil that smells of rose leaves.

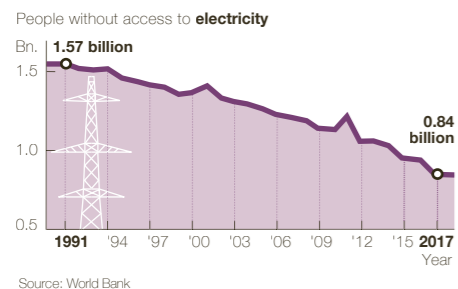
Out of about 3,000 known fragrances worldwide that can be synthetically made, the company now has about 100 in its portfolio – the ones that are commercially viable to produce. Usually, a fragrance is required in such small quantities that synthesis, although it may be technically feasible, is not worthwhile, and it is therefore better to rely on the natural substance.

Vanilla as if from nature

At the same time, more and more people are seeking products with natural ingredients. However, those natural resources are often scarce. That’s why BASF has also been using biotechnologically produced fragrances ▶

Electricity supplies

The world is getting brighter



The number of people who have to live without electricity continues to fall. In 2014, there were still more than 1 billion, whereas today there are around 840 million. People in India, Bangladesh, Kenya and Myanmar, in particular, have benefited from this trend. This is because villages with no access to electricity are trapped in poverty – children do not learn so well in schools with inadequate lighting, and they also need light

to do their homework in the evening. Electricity provides access to the internet and thus to important information and contacts. An electric oven makes cooking easier and is better for health and the environment than cooking over open fires. However, the pace of electrification is a little too slow. Progress toward the United Nations sustainability goal of providing all people with electricity by 2030 is faltering – at that

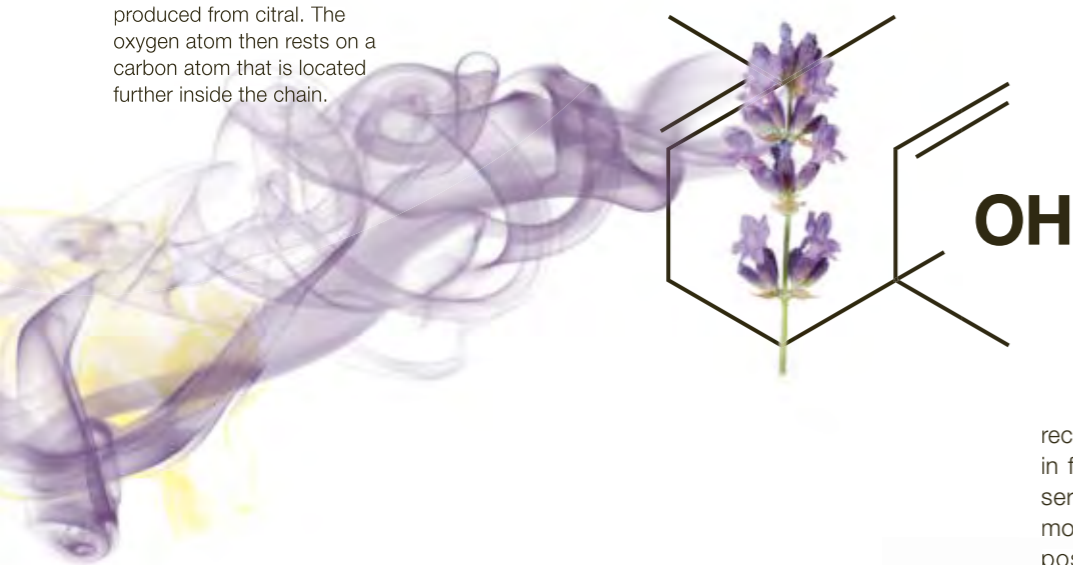
time, it could turn out that 650 million people, especially in sub-Saharan Africa, will still have no access to electricity. This warning is contained in the latest Energy Progress Report from the International Energy Agency, the World Bank and the World Health Organization. It says strategies for closing that gap include data-driven decision-making, funding for the private sector, and solutions that embrace decentralized renewable energies.

Photo: Gettyimages/Volker Mährke

Photos: shutterstock/Kyselova Inna, Gettyimages (Montage: ASCS)

How it works:

Linalool smells of lavender and calms the senses. It is produced from citral. The oxygen atom then rests on a carbon atom that is located further inside the chain.



memory. Even decades later, they still evoke strong feelings in us. Our brain stores olfactory sensory impressions and, as soon as we smell a particular scent, it brings back long-forgotten memories. How good or bad something smells depends very much on the situation in which we noticed the smell for the first time.

However, it is not only the brain that is affected, but also the intestine, which has its own olfactory receptors. These react to scent molecules in food and release the neurotransmitter serotonin, which sets the digestion in motion. Smells also have a surprisingly positive effect on the body through breathing, when the smell is absorbed ▶

and flavorings since 2019. One example of this is natural Vanillin F, based on natural ferulic acid, which is obtained from rice. Its pure vanillin character makes it particularly suitable as a flavoring in combination with chocolate, strawberries and caramel, for example. It can be described as natural partly because it is produced by fermentation. This is an ancient technique that is familiar to us from processes such as beer-brewing and bread-baking, where one substance is turned into another with the help of microorganisms such as bacteria or fungi.

Scents stimulate the brain

Our nose has some 400 different olfactory receptors. It is said that humans can identify more than a trillion different smells. Science now knows precisely how they work. “Smells very clearly stimulate brain activity,” explains Professor Thomas Hummel, who leads the interdisciplinary center for smell and taste at Technische Universität Dresden, Germany. And unlike other senses, olfactory information remains largely uncensored in the brain. “The signals land almost unfiltered in the limbic system, one of the oldest and most primitive areas of the brain, and are stored in our memory along with our emotions,” Hummel says. He adds that sight and touch, on the other hand, take a detour and first cross the thalamus, which acts as a filter. Fragrances can thus stimulate long-term

How well can humans smell?



Capacity:

A human possesses about 6 million olfactory cells, and a dog has around 300 million. But research has established that mice and rats have the best sense of smell. Nevertheless, the human sense of smell is not fundamentally bad, and humans can improve their sense of smell with appropriate training.

Habituation:

We no longer even notice our personal

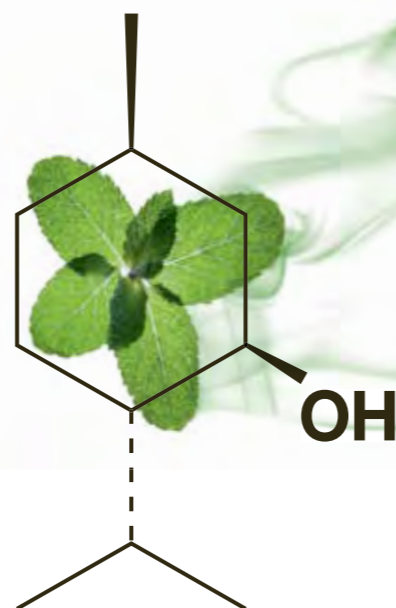
body odor or the perfume that we use daily. The nose finds all this so commonplace that it ignores it to a certain extent. In other words, smells wear off.

Imprinting:

Unborn babies can smell from as early as the 28th week of pregnancy and store the mother's scent preferences as pleasant or unpleasant – a form of imprinting for their later life.

How it works:

L-Menthol is the most popular aroma chemical worldwide – minty, cooling, and stimulating. Like geraniol, it contains 10 carbon atoms, but the oxygen atom rests in a cyclohexane ring structure.



Photos: Gettyimages; Martin Ruegner (Montage: ASCS); Blend Images

Photos: BASF/Claudia Schäfer; Gettyimages; Halldark; AFB (Montage: ASCS)

Keen noses at BASF

An olfactory bulb as a measuring instrument – BASF's environmental monitoring center has 21 employees at work, not least in order to check on the air around Ludwigshafen, Germany. They use their trained noses to identify smells.



The BASF mobile environmental monitoring team check on air, water and noise around the Ludwigshafen site.

604040 This telephone number is well known in Ludwigshafen. If a local resident is worried about an unusual smell, one of BASF's environmental monitoring team promptly sets off to the scene with an environmental monitoring vehicle to see what is happening. The team is responsible for monitoring air, water, and noise around the Ludwigshafen site. That includes having veritable supernoses to check the air for smells.

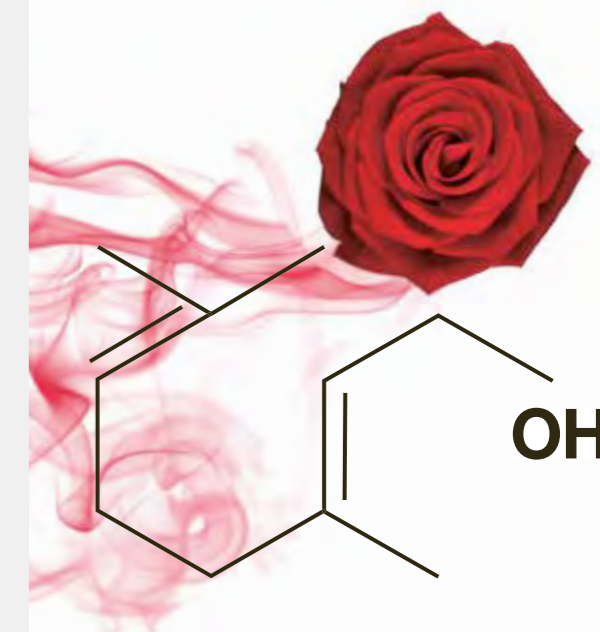
Measuring by nose Jürgen Huppert is one of 21 supernoses who work around the clock in shifts to monitor the plant. “The nose is one of our most important measuring instruments,” Huppert says. “It detects traces of chemical substances with lightning speed.” During the daily monitoring expeditions outside the plant premises, the sense of smell is initially the first thing that matters, although the measuring instruments in the vehicle are not irrelevant. They are able to identify about 150 individual substances in a very short space of time.

Team The team is composed of highly qualified laboratory staff and technicians – some of whom have several decades' experience in professionally using their noses. They undergo regular training to hone their skills by exposing their sensitive noses to a very wide range of odorants, such as benzaldehyde and citral, from a library of smells containing about 60 individual substances.

Origin The idea for the environmental monitoring center came about after a major warehouse fire some 40 years ago. The idea was to give the public a 24-hour point of contact to report any observations. In addition to the four environmental monitoring vehicles, five measuring points capture the most important air values, such as nitrogen oxides, particulate matter, sulfur dioxide, organic carbon, carbon monoxide, and ozone. Ten rotating cameras observe the site and adjacent areas, and 10 stations measure noise pollution.

Watch a video of BASF's keen noses at work at bit.ly/nosesatBASF

into the blood via the lungs. In one study, Hummel and his research team found that smells can even improve human cognitive skills. For three months, one group of test participants aged between 50 and 84 had to solve sudoku puzzles daily, while another group had pleasant scents wafted over them. At the end of the test, the puzzle solvers showed no significant cognitive changes, but the participants who had been in contact with fragrances were able to express themselves better and felt an average of six years younger than before the test. Hummel therefore offers this advice: “Our sense of smell declines with age. The best precaution against this progressive loss seems to be to sniff four or more different smells every day – this will keep both your nose and your mind equally fit.” ■

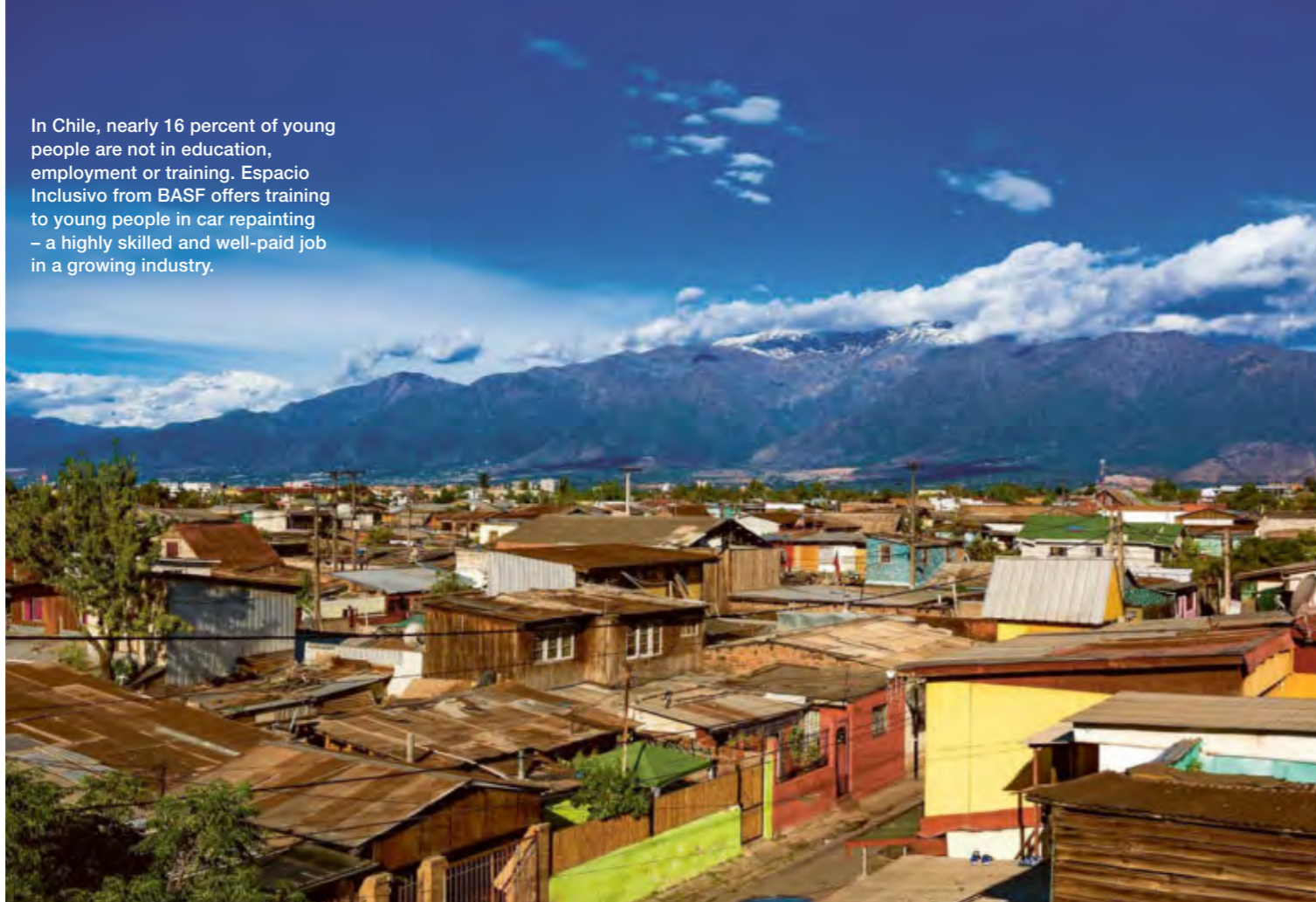


How it works:

Geraniol is a major component of roses and is one of the most sought-after floral raw materials for inspiring creations. The oxygen atom is simply bound at the end of the carbon chain.

Changing young lives

Espacio Inclusivo, a training program founded by BASF in Santiago de Chile, gives young people from low-income backgrounds the chance to learn valuable skills that can lead to great jobs.



In Chile, nearly 16 percent of young people are not in education, employment or training. Espacio Inclusivo from BASF offers training to young people in car repainting – a highly skilled and well-paid job in a growing industry.

At a workshop in the north of Santiago de Chile, a group of young people are filling in car panels with putty and sanding them down ready for painting. They are attending Espacio Inclusivo, a course in car refinishing. Now in their third week, they are finally getting a chance to put into practice some of the techniques they have learned.

Espacio Inclusivo is a three-month course run by BASF with its partners SKBergé, one of Chile's biggest car dealers, 3M, and training institutions. When the students finish, they are offered internships. In the last four years, around 150 students have graduated from the course, and many of them are now working in the sector.

A fresh start

However, the course is about more than just gaining new skills. For Katherine Jara, a recent graduate, it was a lifeline. When her father died, it tore a hole in the middle of her close-knit family. She did not leave her house for weeks. Then, browsing the Internet, she came across an advert for the course. Among nursing and secretarial

Photos: Cristóbal Olivares (5), Gettyimages/Esteban Perez/EyeEm



Katherine now runs the colorimetric laboratory at SKBergé, identifying, mixing and verifying the color for each paint job.



The course has given Katherine confidence. She copes with the pressure of preparing colors for a couple of hundred vehicles every day and stands up to demanding colleagues.



Katherine applies the color recipe on a sample sheet using an application gun.



Katherine looks up the formula on the computer database under the car's model and year, then mixes the colors by hand and checks them against the car itself to ensure they match, before mixing up a batch for the painters.

“I’ve always been interested in jobs that are considered to be for men.”

Katherine Jara
Former student
Espacio Inclusivo





The car panels are filled with putty and sanded down ready for painting with filler and primer.



Above: First, Carlos Tapia checks how level the putty is before starting sanding.



Besides training, Espacio Inclusivo provides spray guns, vehicle panels and a drying oven. When they complete the course, students are ready to take up a job at a body shop.

Next, the panel is put under a heat light to dry the putty.



courses, it was the car-painting course that caught her eye. “I’ve always been interested in jobs that are considered to be for men. I guess it comes from helping out my dad in construction,” she says. Now Katherine has a job working for SKBergé.

The project is the brainchild of Fernando Fariás, former business coordinator of BASF Chile’s car paint business, and his team. “We found that one of the main obstacles facing the workshops that buy BASF’s paints is a lack of trained workers,” says Fariás.

The number of cars in Chile has almost doubled over the last decade. Dealers sold more than 400,000 new cars in 2018, an increase of 15 percent over the previous year. That has left auxiliary industries, such as car painting, struggling to keep up. Car painting has traditionally been an artisanal business, carried out in small family workshops, with skills passed down from generation to generation. Fariás and his team saw a way to combine the company’s interests with

those of its partners and to help young people from vulnerable backgrounds looking for opportunities.

Skills for life

Mario Urra, one of the BASF trainers, says the course can turn around students who come from difficult backgrounds. One former student was from one of Santiago’s toughest neighborhoods. With his father in jail and his mother on drugs, he could hardly see a way out of his predicament. But he was one of the most dedicated on the course, staying behind to pick up tips and help clean up. When he did not show up for three days, Urra went to find out what was wrong. The student had grown disillusioned, but Urra convinced him to return. Now, a couple of years later, the student has a job at a garage, a girlfriend, and a car of his own, and he recently moved into an apartment outside his old neighborhood. “This is more than a job. It is about quality of life,” says Urra. ■

Photos: Cristóbal Olivares (6)



Above: Cristóbal Alvarado shows Michel Arce and Trinidad Chaparra how to evenly apply primer.

Chaparra carefully sprays primer under the supervision of Alvarado.

Starting Ventures

Espacio Inclusivo is a BASF Starting Ventures project. The aim of this program is to develop sustainable business solutions that empower people with low incomes to achieve a better quality of life, while at the same time expanding the market for BASF’s products and building strong business partnerships. Set up in 2016, there are now 12 projects worldwide in various industries.

on.basf.com/starting_ventures

Training with prospects



Fernando Fariás
Founder of Espacio Inclusivo



Karin Willeke
BASF sustainability consultant

“We co-founded Espacio Inclusivo because we knew that many of the body shops to which we supply our refinishing coating, Glasurit®, were struggling to find qualified staff. So, we decided with our partners to help unemployed young adults train to become automotive dent removal and spray painters. With a secure income, these young people can now pay their own way.”



Cristóbal Alvarado
Current head teacher and former Espacio Inclusivo student

“At Espacio Inclusivo, students learn step by step how to prepare the surface, mix the formulas and apply the paints. They leave here ready to work. We have developed a reputation for the quality of professional that we are producing. We’re changing the face of this activity – the workshops now come to us.”



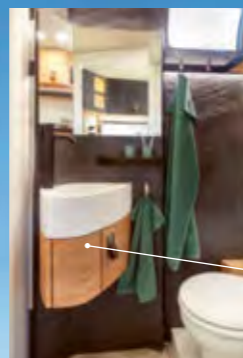
Mario Urra
Trainer and BASF Glasurit representative

“The course provides students with the skills they need for the workplace. When they first come here, some arrive late, put their feet on the desk and play with their phones. We teach them what it is to have a job, to be responsible. I keep in touch with them after the course, check how they are doing and help if I can.”

Photos: Cristóbal Olivares(3), BASF Chile

Camper van of the future

The VisionVenture concept vehicle developed by BASF and HYMER breaks new ground. It contains more than 20 high-performance plastics that are expected to set the standard in the future as convenient lightweight and energy-saving materials.



Innovative surfaces

Thanks to the global innovation of Veneo Slate®, natural stone and lightweight construction are no longer a contradiction in terms. On the outside, the material consists of a 1-millimeter-thin slate veneer – an extremely weight-reducing and space-saving solution for wet rooms, for example. The very light Elastoflex® polyurethane foam system likewise uses natural materials. The flexible combination of plastic and hemp redefines furniture finish.

Tent roof

The roof tent, which inflates itself in 60 seconds, is also a global innovation. Its Elastollan® coating creates a light but stable outer wall that is both waterproof and windproof.

Paint

The paintwork, with Chromacool technology from BASF, reflects the infrared light from the sun. As a result, the vehicle's surface heats up by 20 degrees Celsius less. The internal temperature is reduced by up to 4 degrees Celsius.

High-performance insulation

The panel material SLENTITE® provides stability and insulation in places such as window frames or the underbody. In addition, SLENTEX® mats can be fitted so as to save space, offering reliable fire protection for the battery, the engine compartment and the cooker. The high thermal insulation performance of the two materials reduces both CO₂ emissions and energy consumption.

3D printing

This technology allows new scope for customization. BASF has produced more than 100 components using 3D printing: small ones such as coat hooks, or large ones such as the lining of the wheel arches – hard or soft, carbon-fiber-reinforced or transparent.

Photos: HYMER (3)

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