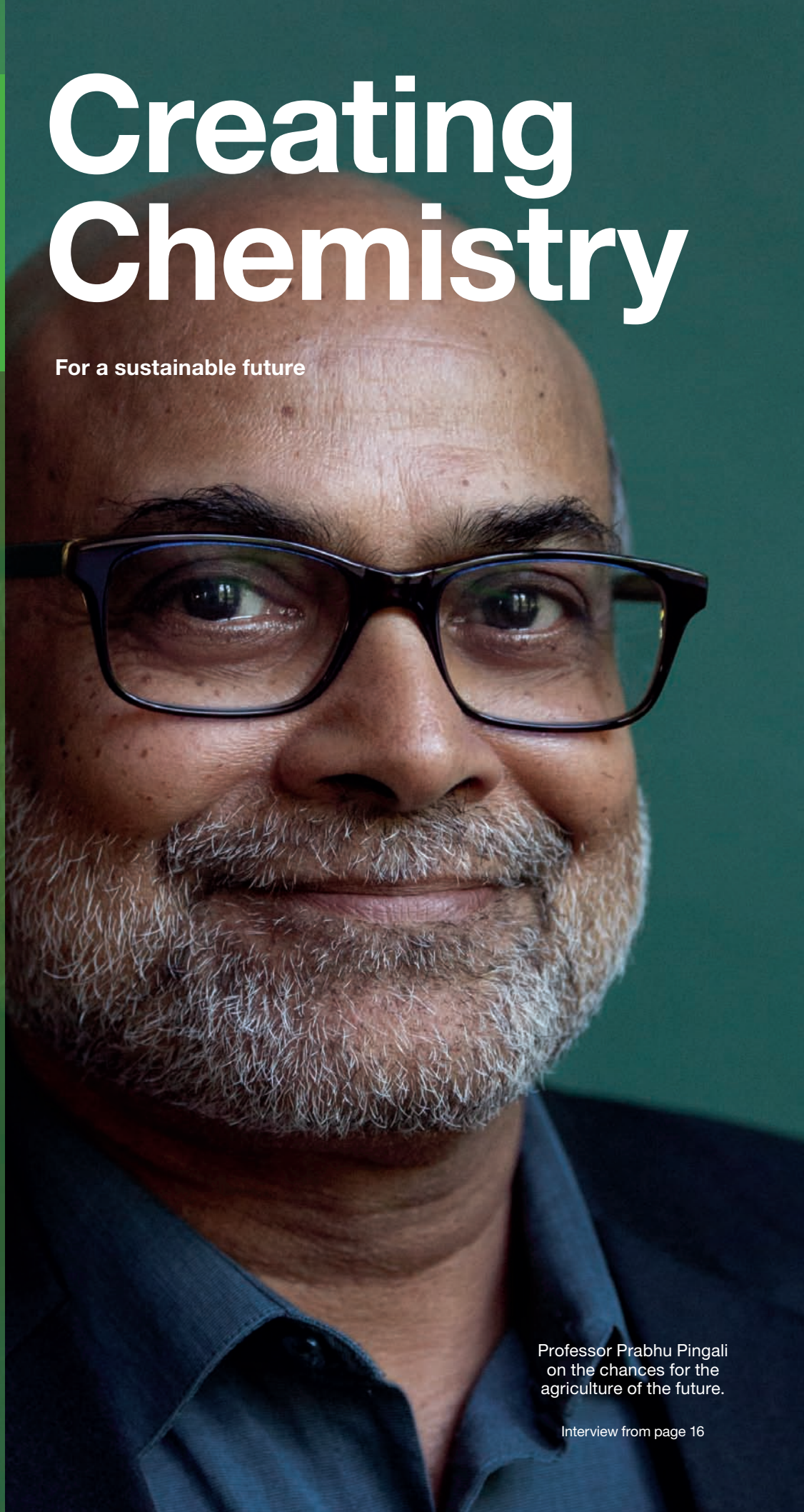
150 years

BASF
We create chemistry

Creating Chemistry

For a sustainable future



High-tech solutions to combat hunger

The population is growing, arable land is limited, food is becoming scarce. How modern technology helps to shape agriculture in an efficient and sustainable way.

Cover story from page 8

During its anniversary year in 2015, BASF combines celebration with a look at world challenges of tomorrow.

Special from page 36

Issue four 2014

Professor Prabhu Pingali on the chances for the agriculture of the future.

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Content

Editorial

150 Years of BASF

According to the founder's report, the Badische Anilin- & Sodafabrik was expected to last for only 25 years. Back in 1865, Friedrich Engelhorn had no idea that his startup would be the world's leading company in the chemical industry 150 years later.

Our recipe for success is the same today as it was back then: we combine an instinct for what people need with the drive to meet those needs. We use our creativity and knowledge of science to do that. What succeeds in the lab needs to be scaled up for production in our factories. Ultimately, only what is manufactured on a large scale is affordable for a large number of people.

Having reached this 150-year milestone, we want to continue to move forward and further strengthen our networks with others. The challenges ahead are enormous and we can only solve them by working together. There will be 9 billion people living on our planet by the year 2050. How can we grow enough food for everyone? What will the cities we live in look like? Where will we get the energy we need? Examples of technologies and products we are already working on today are provided in this issue of Creating Chemistry.

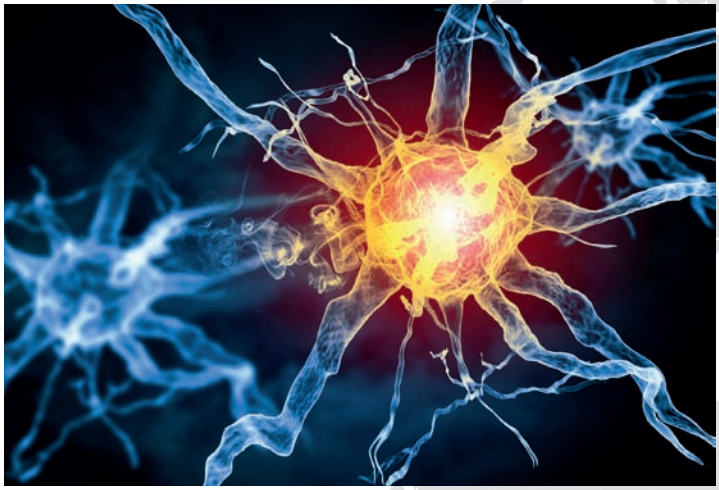
Unlike 150 years ago, digital technology now enables us to discuss these issues in real time with people all over the world. The website www.creator-space.basf.com has been set up for that purpose. If food, urban living and energy are subjects that interest you too, please use the website to share your experiences, opinions and comments with us. During the anniversary year, the site will be a kind of virtual lab for us. Specifically, we want to develop further the way we drive innovation. To achieve that, we plan to dive further into the growing universe of networks and interact more intensely than before with creative thinkers and stakeholders regarding ways to solve societal challenges.

I would be delighted to have you with us on this journey, which will take us into BASF's past, into the company's present, and proceed from there as part of our experiment to uncover ideas for the future by exploring new paths.

Best wishes,

Dr. Kurt Bock
Chairman of the Board of Executive Directors
BASF SE

The world in figures



All of the neural paths in an adult human brain laid end to end would cover a distance of around

5.8 million kilometers

That's about 145 times the circumference of the earth.[1]

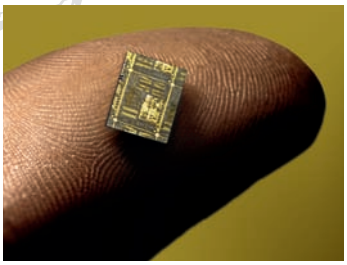
▶ "The nature of memory" see page 38 onward.

As many as

1 billion

transistors (electronic devices used to switch and amplify electrical signals) are contained on one square centimeter of a microchip.

▶ "Nanoelectronics – the miniaturizing principle" see page 54 onward.



Approximately

774 million

adults in the world today **cannot read or write**, including 123 million young people aged 15 to 24. Almost two-thirds of the illiterates are women.[3]

▶ "A chance to learn" see page 6 onward.

Every

4 seconds

a new case of **dementia** occurs.[2] 35.6 million people in the world today are affected. The WHO expects that figure to rise to 115.4 million by 2050.

▶ "Pioneering thinker – then and now" see page 60 onward.

1 Akademie für neurowissenschaftliches Bildungsmanagement (AFNB) (Neuroscience Education Management Academy), July 24, 2014
2 Alzheimer Forschung Initiative e.V. (Alzheimer's Research Initiative), *news release*, April 11, 2012
3 Deutsche UNESCO-Kommission e.V. (German UNESCO Board), *news release*, September 6, 2013
4 Food and Agriculture Organization of the United Nations, *Save and Grow*, July 2014
5 Ingenieur.de, *Größte Photovoltaikanlage der Welt geht in Arizona ans Netz*, (World's Largest Photovoltaic Facility Goes on the Grid), May 6, 2014
6 The National, *UAE sustainable skyscrapers: understanding Abu Dhabi's Al Bahar Towers*, May 18, 2014

About

40 %

of the nitrogen in a human body has passed through the **Haber-Bosch process** at some point.

▶ "High-tech solutions to combat hunger" see page 8 onward.

By 2050, **agricultural production** will need to **increase** by

70 %

to feed the world's growing population.[4] How can this challenge be met?

▶ "Sowing the seeds of the Second Green Revolution" see page 16 onward.

Expanding deserts are destroying

12 million hectares

of **arable land** every year, an area corresponding to about half the size of the UK.

▶ "High-tech solutions to combat hunger" see page 8 onward.

225,000 households

are provided with electricity by **the world's largest photovoltaic installation**, Agua Calienta. Located in the desert of Arizona, the installation comprises 5.2 million solar modules erected in an area measuring almost ten square kilometers.[5]

▶ "Buildings as powerhouses" see page 48 onward.

2,000 umbrella-like glass elements

on the façade of **Al Bahar Towers in Abu Dhabi** automatically open and close depending on the intensity of the sunlight.[6]

▶ "Buildings as powerhouses" see page 48 onward.

A chance to learn

Education is vital to sustainable development and is, officially, a human right. Yet millions of children still lack the necessary schooling to realize their potential. Japanese singer-songwriter Ai Kawashima is helping to improve this situation by building schools where they are needed.

Ai Kawashima's story is extraordinary. She has not only risen above her own childhood tragedies to become a pop star. The 28-year-old Japanese musician has also founded an NGO with the goal of building 100 schools across the globe for children who want the chance to learn but lack the facilities.

Orphaned at the age of three, her single mother's health having deteriorated rapidly after giving birth, she lived for a short time in an orphanage in her home city of Fukuoka, until she was adopted by the Kawashima family. She always enjoyed singing and playing music. Her adoptive parents encouraged her talents and at the age of just ten she sang a Japanese folk song on stage at New York's Carnegie Hall.

But a few years later she lost both adoptive parents to illness. At 16, she was once again an orphan. Yet she did not allow herself the luxury of self pity. Instead, she resolved that she would make her mother's dream come true and become a professional musician. The young teenager set off to Tokyo to start her career.

It was no easy ride. She began by performing live on the streets of the busy shopping district, Shibuya. Gradually, she started drawing crowds and gained the nickname "The Angel on the Street". In order to raise her public profile, she set herself the target of doing 1,000 street performances.

"Those street performances were the springboard to making my debut and a very important starting point for me," she says. It was on the streets that she met people from the record company that eventually signed her. Her breakthrough came in 2003, when she was just 17. Her

Milestones in Ai Kawashima's Life and Career

1986
Ai Kawashima is born in Fukuoka, Japan.

1996
Age 10, she travels to the USA to sing at Carnegie Hall, New York.

2002
Just 16 years old, she moves alone to Tokyo and starts street performing.

2003
She releases her debut single *Door to Tomorrow* (Asueno tobira).

2005
She completes her target of 1,000 street performances and commits to building 100 schools.

2006 – 2009
She builds and funds schools in Burkina Faso, Cambodia, Liberia and East Timor.

2009
She performs at the Japan Day festival in Central Park, New York.

2010
Together with Ainori Fundraising and the NGO World Vision Japan, she funds the building of a school in Bangladesh.

2011 – 2012
A second school in Cambodia and one in India are completed.

2014
Her eighth school project is underway in Laos.

first single, *Door to Tomorrow,* was a hit, selling over 900,000 copies.

The relationships she forged with her staff team during this time were vital to rebuilding her life. "They rallied round me and supported me with all their strength," she says. "It's thanks to their warmth and kindness that I was able to put it all back together a little at a time."

By 2005, she had achieved her goal of 1,000 street performances and her musical career had taken off. As a solo singer-songwriter she released several albums and singles that featured in video games and *anime* (animated films).

With this success, she was now able to set her sights on another goal close to her heart. In her teens, she became aware of the terrible problems faced by children in Africa. It made a deep impact on her. At the age of 19, she began devoting her energies to charitable education projects. "I chose school-building as a means of helping," she says, "because I have learned a lot about the power of education from many people involved with volunteer organizations. If kids can attend school, they can grow intellectually and the doors to future employment are opened to them."

Her first school was built in Burkina Faso in 2006. About 300 pupils attend classes there now. Another was completed in Cambodia in 2008. Other projects – involving collaborations with local partners on the ground and additional fundraising via a Japanese reality TV series – have led to school buildings being erected in Liberia, East Timor, Bangladesh and India.

Kawashima has now set herself another ambitious goal. "Since I had set myself the goal of 1,000 live street performances," she says, "I thought, ok, let's go for 100 schools! We've built seven so far and are currently building one in Laos."

80% of the costs of building each school are carried by Kawashima herself. Her team donates 10% and she encourages her fans to contribute the remainder.

Before any building work is carried out, Kawashima and her staff consult with NGOs that are specialists in the field and, with their help, select the right place for each project. Kawashima provides the funding, the various NGOs are entrusted with the actual building, management and maintenance of each school.

Kawashima takes great personal interest in the detailed reports they send her about the children's circumstances. She is determined that her charity work is thorough. "I think success comes only when we have a school that never has to close its doors and can be maintained. The actual building of the school is just the foundation," she says.

She personally attends the opening ceremonies of the new schools and is always moved by the reception she receives. "I'm given such a warm, heartfelt welcome by the school children and the staff. I've listened to the dreams the children have for the future. These are moments I will treasure forever," she says.

Kawashima's music career continues to go from strength to strength and she now has her sights set on performing at Tokyo's huge Nippon Budōkan arena. But her goals for her charity work are no less ambitious. "I want to continue to be a champion of education and be involved in building schools all over the world. I'll probably set myself a new goal of 1,000 schools," she says. "No matter how small, if I can make a difference, I'll do everything I can to help." ▪

In Laos, Ai Kawashima is currently building her eighth school, giving the children access to education.

Bringing science to life

ReAção means reaction. And that's what a science education project in Brazil aims to stimulate in the minds of children and young school students. The project has been running since 2006 in elementary schools in Guaratinguetá, a city in the state of São Paulo, where BASF's largest production site in South America is located. It aims to help students see for themselves how science and chemistry work in everyday life.

In the past, science education in Brazil was very theory-based. One reason for this is that teachers lacked the training and equipment to carry out practical experiments. Developed by BASF in partnership with the Guaratinguetá city authorities and implemented by Fernand Braudel Institute, ReAção tackles this problem by providing the training and support teachers need to bring practical experimentation into the classroom.

The project is run as a series of after-school workshops that are popular with students, teachers and parents alike. One teacher who has seen the benefits is Débora Valéria dos Reis Pereira, from the Dr. Guilherme Eugênio Filippo Fernandes School. "Students enjoy the workshops because the content is presented in a different way," she explains. "During lessons, they make connections with the content they learned in the workshops."

The teacher training courses are run by local organizations. With BASF's support, they develop the experiments and provide the material needed for each activity. "We focus on programs that stimulate interest in science and contribute to the intellectual and personal development of children and young people," says Flavia Tozatto, Sustainability Manager at BASF in Brazil. The results of the project, which are evaluated by the Chemistry Institute of the University of São Paulo, show that students who take part not only improve their scientific literacy but also perform better at school generally.

Since 2006, every year, about 7,200 students from 32 schools have participated in the program, which also includes training for 500 teachers per year. Stimulating children to become interested in the world of chemistry is at the heart of ReAção. "We are sharing knowledge, our greatest asset," says Tozatto.

Agriculture against the backdrop of the New York skyline: Urban farming is bringing food production right into the middle of our cities.

High-tech solutions to combat hunger

The world's population is growing, food is becoming scarcer. Without great strides in innovation, the demand for food is likely to outstrip supply. Vertical farming, urban farming, combine harvesters that are analysis laboratories on wheels, and last but not least, the smartphone: therein lie the hopes for the agriculture of the future.

The years of plenty and well-filled granaries are over. World grain reserves, the most fundamental indicator of the world's ability to feed itself, have dwindled alarmingly in the past ten years. The amount of corn, wheat and rice held in storage in 2013 would have been just enough to meet global demand for 76 days; ten years ago, the figure was 107 days.

Climate change, water shortages, soil erosion and population growth are making it increasingly difficult to grow enough food for all. Agriculture is advancing to become a key industry of the 21st century. A new era of exploding prices and rampant famine is imminent, warns Lester R. Brown in his book *Full Planet, Empty Plates*. The founder and president of the Earth Policy Institute based in Washington, D.C., is one of the great pioneer environmentalists. "Food is the new oil, land is the new gold," Brown reckons. He identifies an emerging geopolitics of food in which countries will scramble to protect their own individual interests as best they can.

Green walls for a better carbon footprint in cities have been around for a number of years. The aim now is to use these vertical spaces for actual farming too.

Land is the new gold

The world is already living beyond its means with one in eight people suffering from chronic hunger. Projections indicate that more than two billion people more will need to be fed by the year 2050. To provide enough food so that – at least in theory – nobody on the planet would have to live with hunger, agricultural production would need to rise by at least 70%.[1] These United Nations Food and Agriculture Organization (FAO) figures actually understate: animal feed and biofuels are not included in the calculation.

Agriculture is facing a paradigm shift similar to the transition in energy policy. Fertile land is scarce. Desertification is destroying twelve million hectares of arable land every year, an area corresponding to about half of the UK. The demand for arable land is increasing as more people turn to a westernized, meat-based lifestyle – cattle and pigs need feeding too, after all. "No more than 10% of the additional global demand can be met by increasing the amount of land devoted to crops. We need to make up the rest by raising yield," Dr. Harald von Witzke, Professor of International Agricultural Trade and Development at Humboldt University, Berlin says. Unless we produce our food not only more efficiently but more sustainably too, we will end up depriving ourselves of the natural resources we need to survive.

Farming goes vertical

The 'how' is not even the biggest problem. "The scarcest resource of all is time," Lester R. Brown warns. The urgency is suddenly making solutions attractive that many would have considered absurd just a few years ago. In Singapore, where more than five million people are squeezed into an area of 700 square kilometers, farming is gradually shifting to the vertical. In an urban vertical farm run by a company called Sky Greens, spinach, cabbage and lettuce plants rotate in 120 nine-meter-high aluminium shelves to get their place in the sun. Japan, too, is experiencing a veritable boom in similar schemes since the Fukushima nuclear disaster not only ruined tracts of arable land but also compromised public confidence in the quality of local agricultural produce. Spread Co., the largest Japanese vegetable factory, produces 7.3 million heads of lettuce every year in a windowless factory hall that looks more like a hangar than a greenhouse. The plants see neither sun nor soil but grow on floating beds in an aqueous nutrient medium under red and blue LED lights.

Although the 30-story luxury version of a vertical farming skyscraper advocated by Dr. Dickson Despommier ever since the late 1990s has not seen the light of day yet, the retired professor of biology at Columbia

> **"Food is the new oil, land is the new gold."**
>
> Lester R. Brown, founder and president of the Earth Policy Institute

1 Food and Agriculture Organization of the United Nations, *Save and Grow*, as of July 2014

Cultivating zucchini in outer space

The exploration of new opportunities in agriculture doesn't stop at planet Earth. New dimensions in vegetable gardening are even unfolding in outer space. In July 2012, US astronaut Dr. Donald Pettit raved about his homegrown zucchini in his blog entitled *Diary of a Space Zucchini*. This idea could help add variety to the astronauts' monotonous diet. At current rates, it costs about US $10,000 to send a pound of food into space. Therefore, fresh vegetables are a genuine rarity.

Space farming is only about isolated plants at the moment. However, scientists envision a complex artificial ecosystem in a spaceship, on the Moon or on Mars, which could regularly provide fresh food to space travelers. Algae could be used to recycle urine for use as fertilizer, colored LED lights to simulate sunlight and nutrient solutions to enable plant growth. Functioning cycles of this kind would provide a starting point for setting up longer-term or indeed permanent space colonies.

Donald Pettit never got the chance to taste his own zucchini. It was returned to earth deep-frozen and tested for cosmic microbes. Pettit claims he would never have dreamed of eating his prized vegetable, anyway: "It would have felt like cannibalism," the ISS astronaut joked.

To find out more, visit: blogs.nasa.gov/letters

Spinach, cabbage and lettuce rotate on Sky Greens' nine-meter-high shelves in Singapore, giving every plant its turn in the sun. Many similar vegetable factories also exist in Japan.

Smart farming with a tablet and a smartphone: modern apps help farmers diagnose crop diseases and thereby support more sustainable agriculture.

University, New York feels vindicated. "In ten years' time, half of the food produced in Japan will be from plant factories," Despommier believes. "Vertical farming is not just Japan's future, either. Other countries will follow suit." On average, one indoor hectare is roughly equivalent to ten hectares of field, Despommier says. Factory farmed vegetables are untouched by the effects of changing seasons, insect infestation and drought. In fact, the artificial environment teases out the full genetic potential of each grain. What's more, it takes barely a third of the water and a quarter of the fertilizer. Vegetable factories need no pesticides at all.

However, vegetable factories are only one piece of the puzzle in the fight against global hunger. The extent of their contribution to global food security is mainly a matter of cost, agriculture professor von Witzke says: "Only rich countries will be able to afford the expensive vegetable factories for the time being."

> "The more real-time information farmers have and the better it is, the more effective their decision-making will be."
>
> Professor Simon Blackmore, Ph.D., Harper Adams University in Shropshire, England

But for the world to be able to produce enough to feed more and more people, highly efficient vegetable factories are unavoidable. "We are duty-bound to go down this route," von Witzke says. Production of a mere 1% increase in agricultural resources in the EU in vegetable factories would free up 1.2 million hectares of arable land in other countries that they could use in turn to meet their own food requirements, according to von Witzke's calculations. This could preserve biodiversity equivalent to 600,000 hectares of tropical rainforest.

50% better harvests a possibility

However, the professor places his greatest hopes in plant breeding to obtain more resistant crops and tailored crop protection. Even in a highly industrialized agricultural system like Germany's, yield increases of 50% from sowing to harvest are still feasible, he believes. "The genetic potential of crops is designed even now to enable much higher yields," von Witzke says. Weather and soil quality are always going to influence harvests, true – but smart agricultural machinery and robots will be able to give each single plant more targeted care in the future.

Ideas for ways to conserve natural resources abound. Camera-assisted sprayers precisely targeted for application to the leaves of plants could contribute to a more efficient use of crop protection agents, says Simon Blackmore, Ph.D., professor at Harper Adams University in Shropshire, England. Other robots attack weeds with laser rays. To avoid the negative effects on the accuracy of the lasers caused by uneven field surfaces, researchers are looking at unmanned agricultural drones. One thing is for sure: Soil that is expected to feed many generations to come needs better protection in future.

Ammonia for growth:
The legacy of Haber and Bosch

It was a race against time. At the turn of the 20th century, it was apparent that global reserves of fixed nitrogen would run out within the next few decades. Yet nitrogen is essential to growth for all forms of life, human, plant and animal. Although the inert gas makes up 78% of the air we breathe, plants are only able to take up fixed nitrogen.

Then, in 1908, Fritz Haber achieved a breakthrough by producing synthetic ammonia and by fixing atmospheric nitrogen for the very first time. However, there was a challenge in transferring his experimental set-up to mass production because the reactor furnaces had to be able to withstand high temperatures, high pressures and hydrogen. Carl Bosch, who was later to become Chairman of BASF's Board of Executive Directors, finally found the answer. In 1913, BASF started up the world's first ammonia plant. The two scientists went on to receive the Nobel Prize in Chemistry for their accomplishments.

The so-called Haber-Bosch process is used today for the industrial production of more than a hundred megatons of nitrogen fertilizers every year, ensuring food supplies for billions of people. Every single person, particularly in the industrialized world, carries the legacy of the two inventors: about 40% of the nitrogen in our bodies today has once been run through the Haber-Bosch process.

Reducing grain crops can help too. BASF is working on new developments in animal feed, which make a sustainable contribution to food production. Adding an enzyme combination to their feed enables poultry and pigs to utilize dietary grain more efficiently. The enzymes break down indigestible polysaccharides and make them fit for digestion; the animals can therefore utilize these components as a source of energy and need less grain as a result.

Robots conserve resources

Maximum yield coupled with minimum use of resources: Variety selection, crop protection, fertilization and irrigation can be fine-tuned using modern technology. Data is increasingly becoming a factor of production in addition to land. Nowadays, using the smartest technology is what determines whose harvest turns out best. Simon Blackmore is confident that robotics will have revolutionized agriculture in ten to twenty years' time. "We badly need new management systems to deal with the new complexity," Blackmore says. "The more real-time information farmers have and the better it is, the more effective their decision-making will be."

That is precisely what BASF set out to do in cooperation with equipment manufacturer John Deere. Plans for the cross-industry alliance were announced in late 2013. This non-exclusive alliance is based on the joint conviction that the best solutions arise at the interface between specialist agronomic know-how and equipment expertise. Farmers can now use data platforms such as myjohndeere.com to track the real-time whereabouts of their tractors by computer, tablet or smartphone. Equipped with high-tech sensors, modern combine harvester owners know thanks to GPS exactly where the machines are at any given time and can analyze yield quality on every piece of land and take suitable corrective action with pinpoint precision.

Agricultural machinery gets smart

"Every single square meter of acreage will become a test plot," Patrick Pinkston, John Deere's Vice President, Technology and Information Solutions Agriculture and Turf Division says, his enthusiasm evident. Smart agricultural machinery produces enormous data sets – think "big data." When farmers agree to participate and share their data, BASF's agronomics experts can use those data sets to generate automated recommendations. As the season progresses, farmers receive increasingly reliable simulations indicating the impact each of their decisions will have on the harvest. The information also helps to unlock more of biology's secrets, which plant breeders can use in turn for further optimization. "The necessary yield sensor technology has been commercially available for about 10 years already. The aim now is to use the data from these and other sources as a basis for decision-making to raise productivity on a sustainable basis," explains Dr. Matthias Nachtmann, head of BASF's agIT project team. BASF plans to advance the development of mobile decision-making tools based on big data with a double-digit million euro investment.

Unlike high-tech vegetable factories, smart farming gives even the poorest countries the chance of rapid gains. That's because just one smartphone is sufficient to bring important knowledge into a village. Weather forecasts, for instance, can prevent heavy rainfall from washing freshly sown seed from the fields. Other apps tell farmers the right fertilizer dosage to use. They can also help in diagnosing crop diseases. Brazilian farmers and advisors are already using a BASF tool like this. A photo of the diseased plant helps as a basis for recommending the right crop protectant. A photo can also identify the fertilizer requirement. Developed originally for the British market, the app is now also used by many Indian and Chilean farmers.

Smart farming is not a development from the high-tech niche. A 2013 study identified more than 1,600 IT-supported agricultural tools of this kind. Nachtmann concludes: "Currently available IT tools are failing to meet farmers' needs. Farmers stand to benefit enormously from integrated solutions in the future." ▪

To find out more, visit:
www.fao.org
www.deere.com
www.animal-nutrition.basf.com

Farmers' fields as nature conservation areas

Highly productive agriculture and the protection of biodiversity – hard to reconcile? On the contrary, as a joint project involving BASF, various farmers and agronomics experts reveals: eleven farms in Germany, France, the UK, Italy, Poland and the Czech Republic are leading the way in showing how modern farming throughout Europe can help protect ecosystems. An intact ecosystem in turn benefits farmers through natural pest control, pollination and humus production.

The areas covered by the eleven farms currently in the BASF farming network range from soil and water protection to conservation of bird and bee populations. Rawcliffe Bridge, the British pioneering project in Yorkshire, has been demonstrating since 2002 that small measures may have a huge impact. The Farmland Bird Index – one of the best indicators of biodiversity – has climbed steeply during this period. The number of breeding sites is now four times the British national average with no associated decrease in the farm's productivity.

The principle the farms follow is this: Less fertile areas, such as the edges of fields, are prepared selectively for colonization by plants and animals, while cultivation of cropped land continues as usual. Flower strips provide bees and butterflies with a sumptuous banquet and the seeds attract birds. Deadwood piles are a feast for fungi and bacteria as well as giving shelter to beetles, mice and hedgehogs. Nest boxes and perches invite farmland birds to populate the fields. The farms welcome visitors as an opportunity to show that conserving nature and productive farming can go together.

To find out more, visit:
www.agro.basf.com

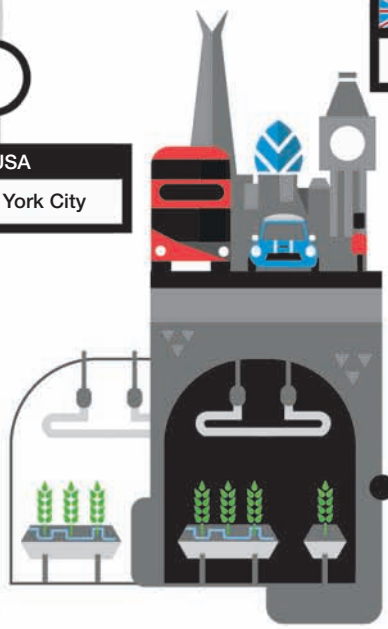
How visionaries are bringing farming back to our cities

More than half of the Earth's population now lives in cities. What could be more logical than to grow food right where it's eaten? On a global search for urban role models and innovative concepts for tomorrow's agriculture.

New York City
According to Belgian architect Vincent Callebaut's vision, Roosevelt Island could be the setting for New York's largest vertical farm. On the 132 floors of a 700 meter-high skyscraper, tomatoes and apples would grow, cows would graze and fish and chickens would be bred. If the Dragonfly architectural concept ever sees the light of day, it would provide food for more than 150,000 New Yorkers.

USA
New York City

United Kingdom
London



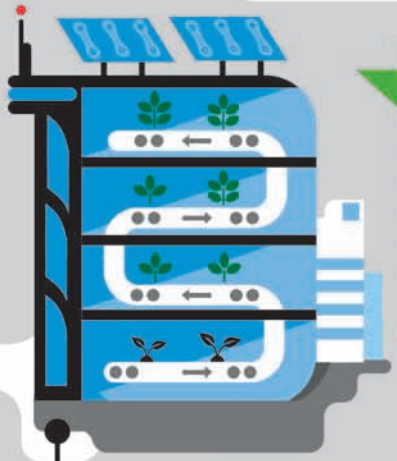
Cuba
City gardening has been official policy on the Caribbean island since the early 1990s. Agricultura Urbana, as it is known, could serve as a role model for developing countries all over the world. In Havana, a city home to millions of inhabitants, 90% of fresh food is now grown locally. Social directives are part of the political program: 10% of the harvest from urban agriculture is channeled to institutions serving the community such as hospitals, schools and homes for the elderly.

Cuba
Havana

London
The Zero Carbon Food organic farm thrives in an underground bunker. According to the founders' promise, no carbon dioxide is created in the production of the herbs, sprouts and vegetables that are grown here. Low-energy LED lights, controlled irrigation and constant temperatures keep energy consumption at a minimum – and the biomass binds carbon dioxide as it grows. The end result is carbon neutrality.

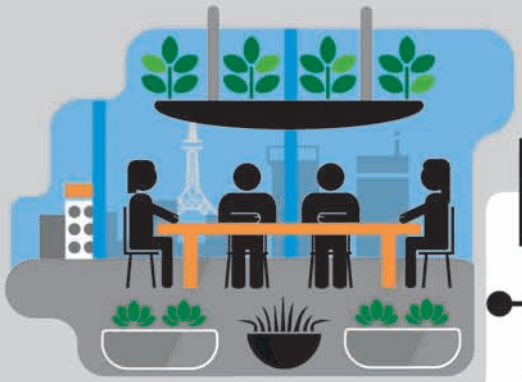
Germany
Berlin

Berlin
Europe's first commercial urban farm combining tomato cultivation with fish farming is based in Berlin and calls itself "Tomatenfisch" (Tomato Fish). The nutrient-rich water from the fish pool is used to fertilize the tomatoes. These in turn release water vapor to the environment which is captured and returned to the fish pools as fresh water. A big advantage of aquaponics – as this kind of agriculture is called – is that the combined system uses up to 90% less water than conventional farming methods.



Germany
Stuttgart

Stuttgart-Hohenheim
Skyfarm is the University of Hohenheim's visionary concept for growing rice in a skyscraper. The idea is to grow rice plants without soil in a nutrient mist. A conveyor belt carries them for 120 days from one floor to the next to ensure that they are exposed to the best set of environmental conditions for each stage of growth. Once they arrive at the very top, the former sprouts drop from the belt as fully grown plants. Cultivation in one hectare of a Skyfarm can produce about the same yield as cultivation in 10 to 40 hectares of outdoor farming land, the scientists calculate.



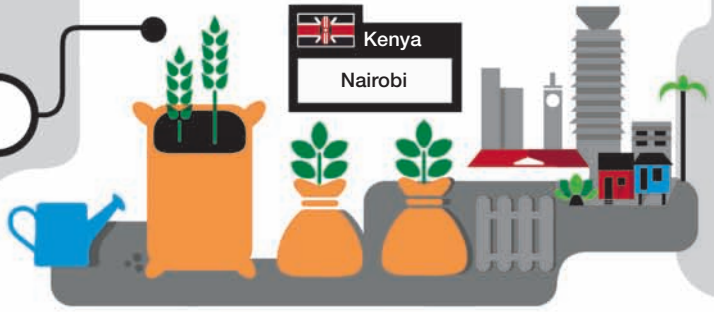
Japan
Tokyo

Tokyo
A Japanese recruitment company uses its entire office building to grow fruit and vegetables. Tomatoes flourish over conference tables, broccoli sprouts at the front desk, and lemon and passion fruit trees serve as partitions. Skilled gardeners help the staff with plant care and harvesting.

Senegal
Dakar

Dakar
The Senegalese capital lies on the coast, so farmers practicing urban agriculture benefit from a better water supply than their counterparts further inland. Local produce grown near the city travels shorter distances to get to the consumer, in that way saving money and energy at the same time.

Nairobi
On the outskirts of a slum in Kenya's capital city, hope grows. Lacking the money to buy vegetables, the people in this neighborhood are growing them for themselves: in bags, because there's no room for a field. The garden-in-a-bag idea comes from the Italian aid organization COOPI.



Kenya
Nairobi

Sowing the seeds of the Second Green Revolution

The world's population is set to reach 9 billion by 2050. Can our food system provide everyone with enough food for a healthy life, while maintaining a healthy environment? Professor Prabhu Pingali, Ph.D., director of the Tata-Cornell Agriculture and Nutrition Initiative, is cautiously optimistic but says sustainable intensification of agriculture and collaborative policymaking will be essential.

Creating Chemistry: There's widespread interest today in the sustainability and efficacy of the global food system. How does this level of attention compare to the early 1980s, when you were starting your career?

Professor Prabhu Pingali, Ph.D.: When I started to work on agriculture and food in the early 1980s, almost all the emphasis was on staple grains – rice, wheat and maize – and the emphasis was very much on increasing overall production. There was very little understanding at that time of the overall food system and of the importance of building up a diversity of food available to consumers. That's been the big change over the last three decades: moving away from this focus on staples to looking more broadly at the food system from farm to plate.

In 2013, you became the founding director of the new Tata-Cornell Agriculture and Nutrition Initiative, which focuses on finding 'agricultural pathways out of poverty and malnutrition in rural India'. Do you think the architects of the first Green Revolution would have expected such an initiative still to be necessary today?
Yes, I'm sure they'd be surprised. The Green Revolution was focused very much on rice and wheat, and on self-sufficiency. By the early 1980s, India for example was food self-sufficient. But then you had this period between 1985 and 2005 that I call the lost decades for agriculture, when governments in India and more generally across the developing world stopped investment in agriculture because they thought they'd solved the problem. That's part of the reason why we still have high levels of rural poverty.

Also, government policy never got around to looking at the importance of a more diversified diet, so investments in vegetables and livestock lagged behind the main staples. You have this anomalous situation in a country like India where you've seen rapid economic growth but very high levels of malnutrition, especially among the poor. The institute was set up as a way to address this anomaly and figure out how to bring agriculture and nutrition back together again.

By 2050, the global population is projected to increase by about one third, which the UN Food and Agricultural Organization has said requires a 70% increase in food production. How can we achieve this sustainably?
I think we can do it and do it sustainably. For agriculture today in many developing countries, yield levels are significantly lower than their potential, and that gap needs to be filled. If the focus over the next two to three decades is on intensification in areas where agricultural production is currently taking place, we will see overall increases in productivity without having to expand land areas. And sustainable intensification is possible: One can look at various options for improving efficiency in fertilizers and water, for example. Intensification and sustainability work hand in hand.

Meanwhile, there is also a huge problem of food waste. In developing countries, this occurs early in the supply chain, with crops lost before they can be eaten or sold. How do we address this?
Much of the farm waste in developing countries takes place at harvest and post-harvest level. I think the way to solve these problems is for significant private sector investment to take place in these areas. This can be small-scale, with improved bags for storing grain, for example, to pre-

> "We've got the technologies, the land resources, and if government policies are focused on eliminating hunger and malnutrition, then we can see that change happen."
>
> Professor Prabhu Pingali, director of the Tata-Cornell Agriculture and Nutrition Initiative

Professor Prabhu Pingali

Professor Prabhu Pingali, Ph.D., is a leading expert in the role of agriculture and nutrition in global development. An economist by training, he began his career with the World Bank in 1982, with subsequent posts as an agricultural economist at the International Rice Research Institute (1987–1996) and director at the International Maize and Wheat Improvement Center (1996–2002). He was the director of the Agricultural and Development Economics Division of the Food and Agriculture Organization (FAO) of the United Nations from 2002 to 2008, and deputy director of Agriculture Development at the Bill & Melinda Gates Foundation from 2008 to 2013.

Currently a professor at the Dyson School of Applied Economics and Management at Cornell University, Pingali is also director of the newly established Tata-Cornell Agriculture and Nutrition Initiative, which is researching the causes of malnutrition and agriculture-based solutions to address it in India and across the developing world.

vent insects from attacking the grain. One can also look at cold storage systems and at improved transport systems. But many of these need to be done in a way that's focused on small farmers. Governments can play a big role in promoting small-scale enterprises for post-harvest operations.

Last year's Nutrition for Growth summit in London delivered a commitment from rich countries to double spending on global nutrition from about $418 million to $900 million a year between now and 2020. How would you like to see that money used?
I think this should be seen as an opportunity to focus sharply on the rural poor, on rural malnourishment and look at ways in which we can address that problem. Let's focus on smallholder productivity growth, let's look at the role of bio-fortified crops in addressing immediate nutrition needs for these populations. And let's look at opportunities for diversifying their production systems. If we can bring all these together, along with complementary investments in water and sanitation, then I think we can make a big leap forward in improving nutrition security.

How significant are some of the recent advances in genomics and crop improvement, particularly in achieving bio-fortified varieties (such as vitamin-A enriched cassava) and improved tolerance to climate stress and water salinity?
We've seen some remarkable new varieties because of genomic advances: drought-tolerant varieties and, of course, bio-fortified varieties. But the amount of material coming out of genomics in terms of finished varieties is still quite small. One of the main reasons for that is that public perception is quite negative about GM crops, and that perception carries over to genomics because public understanding of the difference between the two is not great. That's a problem. The scientific community hasn't been able to make the case that genomics per se is an important and independent innovation relative to GM crops. That perception needs to be addressed.

How can we best ensure that these improved crop varieties are actually made accessible to those who could most benefit from them?
In the early years of the Green Revolution, there were these networks of breeders set up around the world, and these networks were able to share genetic materials and improved varieties freely. Breeders were able to test improved material in their own environment and then have it released in their own countries. It was a major operation. By the 1990s many of these networks stopped working. Public support wasn't there, and that's been a big problem in being able to disseminate new modern materials. If there's a way to come back to those types of breeding networks that can allow breeders to share material freely that would be a big step forward.

Background

Genetic modification involves changing a plant's DNA to equip it with characteristics that cannot be achieved through conventional breeding.

Genomics is the study of all of an organism's own genes, which control a plant's inherent traits. This knowledge can be used, e.g, to breed novel varieties more efficiently.

Technologies such as SMS and GPS have become widely available, with even the poorest farmers having access to cell phones. How can such technologies be used to improve food security and nutritional outcomes?
Certainly on price information, cell phones are filling a gap. Farmers are checking market prices and responding to that. That's an easy win. The harder issue is the real-time crop management advice that can come from the use of smartphones. There are lots of experiments around that, such as farmers taking pictures of a disease on a plant and sending that picture to a lab and getting a response. The real challenge is scaling up. How do you turn these into commercial small enterprise operations that people benefit from? There are few places in smallholder agriculture where that's happening, making small businesses of information services is the only way to sustain these operations.

Research by the World Bank tells us that putting food and income into the hands of women is the best way to improve public health, because women are more likely to invest in their children's health and nutrition. How do we unlock the productive capacity of women farmers?
Women farmers are crucial for ensuring overall agricultural productivity growth and food security. Where I see real positive change happening is in the promotion of women's self-help groups. I see it in India and I'm also beginning to see it in other parts of the developing world. Women's self-help groups came up initially as microfinance groups, but over time they have evolved to take on broader challenges around smallholder agricultural productivity, overall rural development, and rural governance. It's that platform that I think we need to focus on. We need to figure out a way in which, rather than doing lip service about gender, we look at how rural women are transforming themselves and figure out a way to work with them and build on that platform for creating change.

Assessing local vegetable value chains in an Eastern Indian village, February 2014.

Prabhu Pingali visiting a school lunch program in Bangalore, India, February 2014.

“Where I see real positive change happening is in the promotion of women’s self-help groups.”

Professor Prabhu Pingali, director of the Tata-Cornell Agriculture and Nutrition Initiative

Agriculture can be a driver of growth, but many young people in developing countries are migrating to cities. How can we ensure that agriculture remains viable and attractive to younger generations?

The draw of urban centers will continue. In my view, creating opportunities for rural entrepreneurs is probably the best way to go: rural entrepreneurs around the provision of agricultural services, information systems and post-harvest operations. If you can do that, then you create an opportunity for young people to earn enough to have a good life in rural areas. There’s very little government investment in making such rural enterprises grow and flourish.

Do you think mankind will see an end to hunger and malnutrition within the next decades?

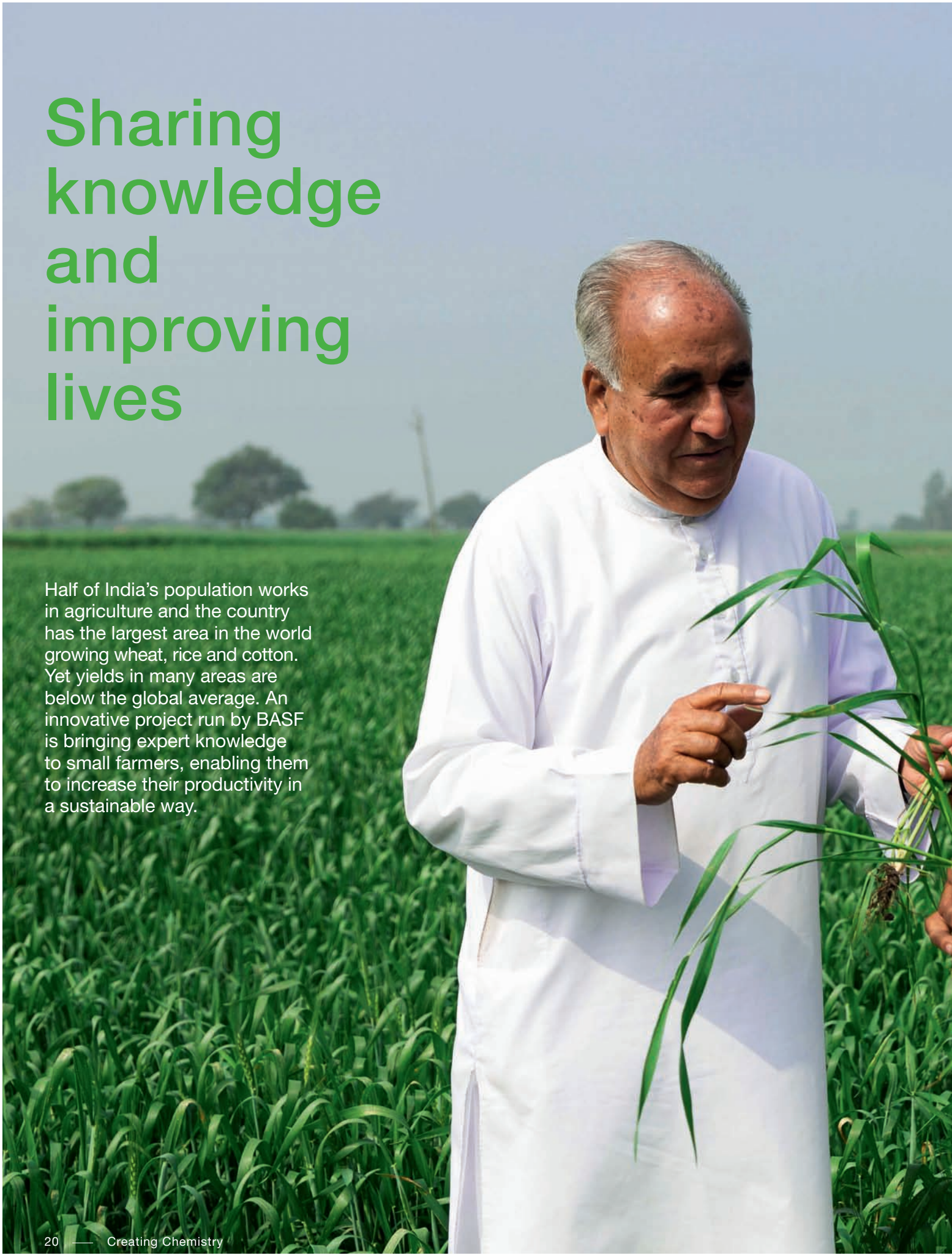
It’s a question of can we, or will we? I think we definitely can. We’ve got the technologies, the land resources, and if government policies are focused on eliminating hunger and malnutrition, then we can see that change happen. Will we? I’m not as confident. You still have a strong urban bias to government policymaking, and there is little coherence between domestic policies and international policies. Unless you get the various policymaking groups to sit together and focus on a common goal of eliminating hunger and malnutrition, we’re not going to see it happen. But we have the means. We can make it happen. ▫

To find out more, visit: www.tci.cals.cornell.edu

What was the Green Revolution?

The term “Green Revolution” is used to describe the massive technological leap that occurred in agriculture from around 1960 to 1990, with large-scale investment in agronomic research to combat widespread famine in developing countries. The introduction of cross-bred “high yield varieties” of rice and wheat, in particular, coupled with irrigation and industrially produced fertilizers, delivered unprecedented growth in crop outputs. Many acknowledge the Green Revolution’s technical success but also point to serious drawbacks, as a focus on yields over almost everything else led to some damaging environmental and public health impacts. Biodiversity and nutrition were also largely overlooked. In recent years, the term “Second Green Revolution” has been used to describe a new wave of more sustainable investment in agricultural growth.

Sharing knowledge and improving lives



Half of India's population works in agriculture and the country has the largest area in the world growing wheat, rice and cotton. Yet yields in many areas are below the global average. An innovative project run by BASF is bringing expert knowledge to small farmers, enabling them to increase their productivity in a sustainable way.

The vast majority of farmers in India have small farms that generate little income. Unlike farmers who cultivate high-value cash crops for export markets, small farmers do not have access to the latest technologies and expertise. Which is why the BASF Crop Protection team came up with the idea in 2006 of helping farmers and their communities to make agriculture more sustainable. They called the program *Samruddhi*, meaning "prosperity" in Sanskrit.

Traditionally, BASF has sold pesticides to farmers in India through distributors and retailers. The idea behind Samruddhi is to build a sustainable business partnership directly with the farmers themselves. By working with them throughout the season – from planting, to harvest and market days – by visiting them at their farms, giving individual advice, doing practical on-field demonstrations, and teaching larger groups at town halls, BASF agronomists give the farmers the means to start measuring their costs, increasing their yields and improving their earnings.

The program has been a huge success and has grown rapidly since its launch. In 2012, over 180,000 soybean farmers participated in Samruddhi and the idea has expanded to include other crops as well. In 2008, BASF established a call center so that advice can also be offered over the phone to Samruddhi farmers.

Part of the program's success stems from its holistic approach. The advice offered by the 700 BASF agronomists covers every aspect of the farm business, from seed treatment, planting methods, safe and responsible use of pesticides, through to the harvesting of crops.

Samruddhi has improved the livelihoods of farmers and their families in very concrete ways. With the additional profit, some have been able to buy extra land, others have invested in new farming machinery and equipment (see above and right).

Radhashyam Patidar is a soybean farmer in Bhesoda in the state of Madhya Pradesh. The 45-year-old has worked the land for 18 years. He first became involved in Samruddhi in 2009. "What inspired me about the program was that it offers a complete solution from seed to seed," he says. The results for him have been impressive – he now gets an additional yield of 500 kg per hectare from his land. And he is not alone. On average, in 2012, Samruddhi soybean farmers achieved a 25% increase in yield and a 39% increase in net profit, compared to non-Samruddhi farmers.

Key to the program is ensuring that the improvements are spread as widely as possible. It is therefore a basic principle of Samruddhi that the knowledge given to one farmer in a village is passed on to neighboring farmers. Known as "Margdarshaks" the lead farmers in a village not only share the experience and knowledge they have gained, but also help coordinate BASF visits, invite their neighbors to meetings and collect questions and concerns.

In 2012, Patidar took on this role for his community. "As a Margdarshak, I am a source of knowledge for other farmers, which is a matter of pride for me," he says.

The program is also aimed at improving eco-efficiency. By following the Samruddhi advice, participating farmers have been able to grow soybeans in a more environmentally friendly way, using less land, consuming less energy and fewer resources.

"Samruddhi is a classic example of how BASF partners with its customers to ensure sustainable business operations by taking into account the entire eco-system and enhancing the yield levels for farmers," says Sandeep Gadre, Head of Business South Asia, BASF Crop Protection. "Through this process, BASF makes a difference to the lives of the agricultural community."

"As a Margdarshak, I am a source of knowledge for other farmers, which is a matter of pride for me."

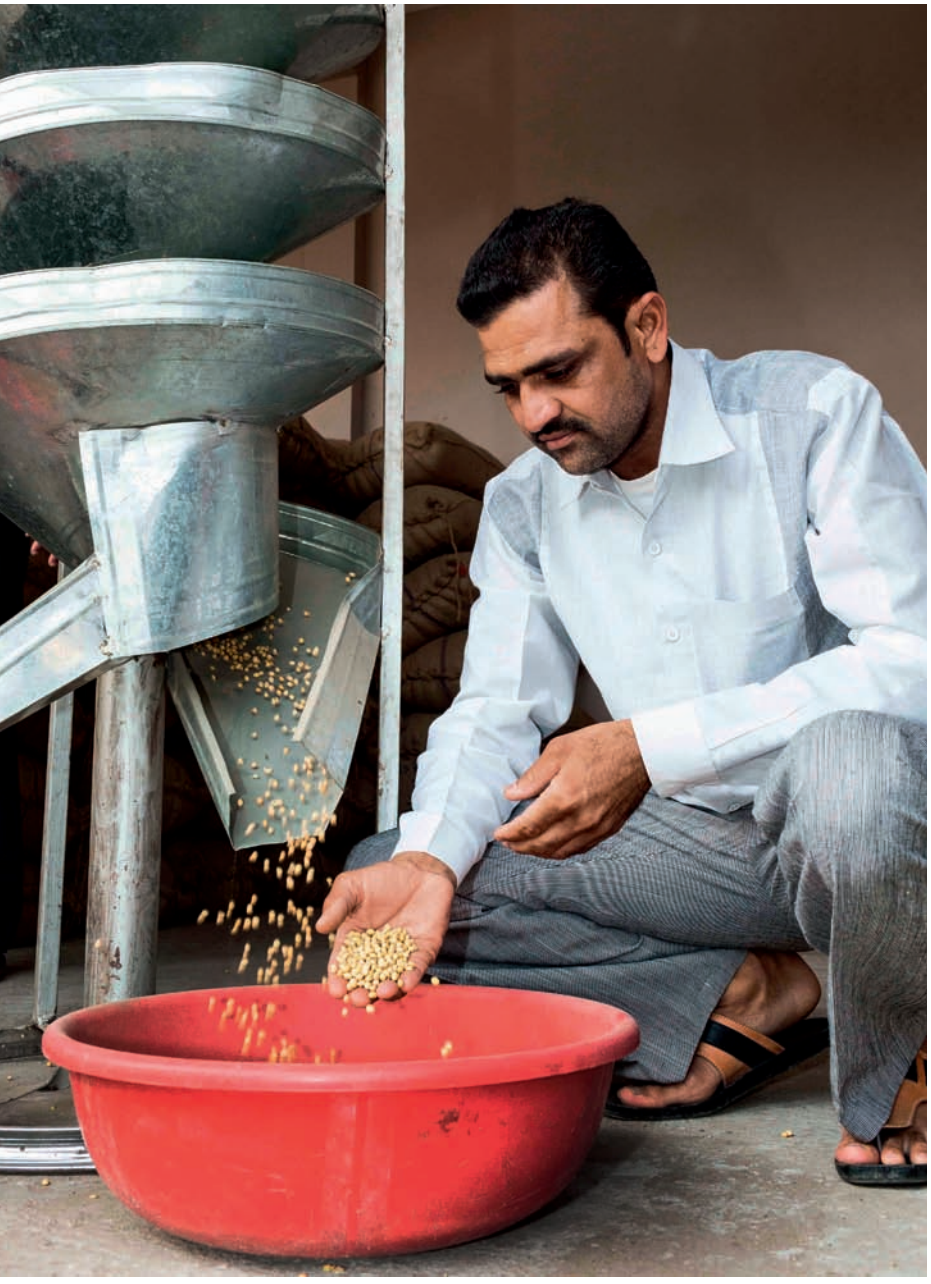
Radhashyam Patidar, soybean farmer in Bhesoda

Together BASF agronomists and farmers examine the crop or discuss the farmer's concerns. By giving presentations to groups of local farmers, BASF is able to spread the idea of Samruddhi and recruit new participants to the program.

“Samruddhi is a classic example of how BASF partners with its customers to ensure sustainable business operations by taking into account the entire ecosystem and enhancing the yield levels for farmers.”

Sandeep Gadre, Head of Business South Asia, BASF Crop Protection

The retailers who sell BASF crop protection products are given special training so that they can advise customers and explain the safest and most effective use of the products (see above).



Farmers take part in Samruddhi for two years, after which they can continue to get advice from the specially trained staff at the BASF call center (see above).

In the BASF Plant Science greenhouse, fungus-resistant maize plants are cultivated in order to test the quality of the corn.

Harvesting powers of resistance for sustainable agriculture

The organisms that cause corn stalk and ear rot continue to keep farmers, crop breeders and researchers on their toes. BASF experts are working to strengthen the immunity of corn crops with the help of biotechnology. Nature is their role model.

The Corn Belt in the Midwestern United States is cornfields as far as the eye can see. Shortly before harvest time, a seemingly unending sea of stout dark green corn juts head-high into the sky. What farmers generally can't see at this stage of crop development is the presence of fungus in the stalks. The scene can change drastically in no time. Luxuriant green corn turns brownish-gray and dies. Many plants collapse. The culprits are the pathogens causing stalk and ear rot, which may ruin entire cornfields just before harvest time. These diseases destroy valuable sources of nutrition. Annual yield loss in the United States alone is estimated at a billion US dollars.

A BASF Plant Science research project now aims to equip corn plants with the powers to resist the pests that wreak such havoc. BASF is one of the few companies in the agricultural industry with long-standing expertise in fungal resistance. An existing research project on fungus-resistant soybean plants was extended to include corn. "Using plant biotechnology, we want to equip corn with the mechanisms to protect itself against fungal infection in the future," reveals Dr. Holger Schultheiss, head scientist on BASF Plant Science's fungal resistance projects.

Many modern corn varieties do not have a naturally high degree of resistance to fungi that cause stalk and ear rots. "In contrast, other plants – certain types of grass, for instance – have developed sophisticated biological immune defenses against these pathogens in the course of evolution," Schultheiss comments. His team studies these natural mechanisms of resistance to find a way to transfer them to corn. "We are not inventing anything fundamentally new, just learning from nature. We

want to use the same biological mechanisms for corn that work to combat fungal disease in other plants." The scientists are still at the initial stages of their research. Nobody can say yet what the solution will be.

What the experts already know is that crops may be resistant to stalk and ear rot through a variety of mechanisms. Once a plant has become infected, the fungus transports toxins to the plant cells and kills them. The fungus feeds off the destroyed plant cells, spreads, produces new toxins and infects neighboring cells. The natural fungal resistance mechanisms Schultheiss and his team have identified, and which he aims to transfer to corn, may operate according to two mechanisms: one is that the plant cells display immunity to the toxins. The result is that the fungus effectively starves between the cells. The other is that the fungus is attacked directly by the plant's innate defense systems and killed, which stops it from spreading in the first place.

As easy as it is to describe the mechanisms of action, it is very difficult to understand the processes involved on a cellular and molecular level and transfer them to crops with the aid of plant biotechnology. "We spend a lot of time doing lab experiments to find out the best way to reproduce these resistance mechanisms," Schultheiss says. For example, a lab technology called laser capture microdissection is used to snip individual cells from infected and resistant plants. The gene activity of these cells is then examined. Patterns are recognized on that basis and resistance mechanisms are elucidated. If the experiments succeed, the next step is to verify the observations made in a protected and enclosed environment by reproducing them in greenhouses and field trials.

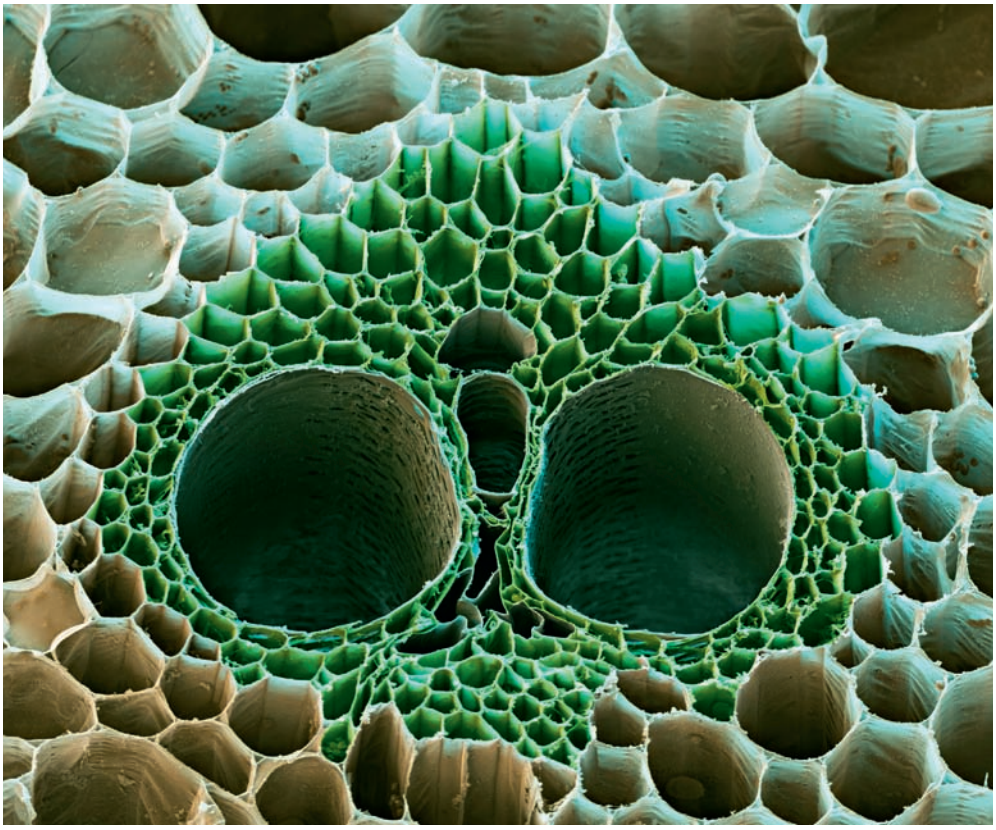
"Fungal disease depends greatly on specific individual site conditions such as climate and soil consistency," says Dr. Karen Century, fungal resistance project manager at BASF Plant Science. She noted that a plant developed in the lab may show outstanding fungal resistance properties in controlled greenhouse conditions, but not out in the field, where other conditions prevail and resistance to the fungus is suddenly much weaker. That is why the first field trials were launched in early 2014, barely a year after the start of the fungal resistant corn project. BASF experts selected sites in the Corn Belt of the US Midwest, which is precisely where the fungus-resistant corn will be planted later on.

"We are working as part of a global research team to develop the best solutions for farmers," Century says. The project is taking place with the involvement of colleagues in the US, Belgium, Germany and Canada. BASF Plant Science's academic network for this complex project is equally far-reaching. "We are currently engaged in alliances with universities and research institutions in the US, the UK and Germany," Schultheiss says. This form of research collaboration is essential in his view. "Nature has such diversity that nobody on their own would ever be able to screen every plant for natural fungal resistance mechanisms. We therefore rely on collaborating with researchers outside BASF. If their results look promising, we endeavor to get them on board as research partners," the head scientist explains.

However, it will take many years before the first corn with genetically engineered resistance to stalk and ear rot is available commercially. It's not just the research itself that is complex and lengthy. All scientific concepts need to be extensively validated in multiyear field trials and subsequent regulatory procedures involving the appropriate and required government authorities generally take a number of years, as well. According to current estimates, the first product of its kind might be introduced to the market by the early 2030s. Until then, farmers have only a few options to combat corn stalk rot as best they can with agronomic practices such as tillage techniques and reducing crop density, which can impact soil conservation and crop yield.

Green biotechnology is global

Following more than 30 years of research, genetically engineered crops now grow on about 12.5% of global arable land. While Europeans are skeptical and continue to debate the level of risk associated with the technology, plant biotechnology has gained acceptance in other parts of the world. Approximately 30 countries around the world use genetically modified crops in agriculture. The United States is the country that grows the most biotech crops worldwide. In some countries, such as the United States, Argentina or Brazil the vast majority of the soybean crop is now genetically modified. In green biotechnology, scientists develop new crop varieties by transferring genes to crop plants. These can be improved crop genes, genes from different plants or also from other organisms such as algae. Modification of the DNA is designed to produce plants that are, for example, more resistant to drought or pests and give higher yields.



Electron microscope image of a cross section of a corn stalk.

To find out more, visit: www.basf.com/plantscience_e

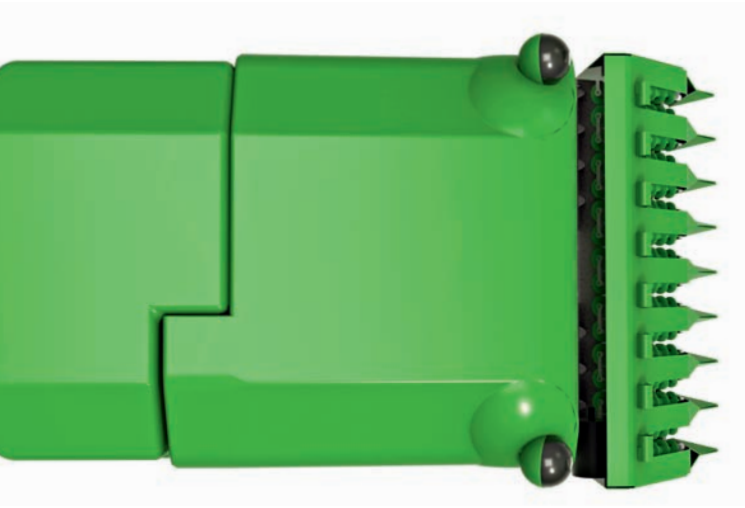
New discoveries

Wanted: inventive minds! This section presents inspiring innovations that make everyday life easier while, at the same time, improving sustainability.

Amazing gas storage systems

The volume of a sugar cube coupled with the surface area of two soccer fields – hard to imagine? Metal organic frameworks (MOFs) are just that. MOFs are porous materials composed of an extensive network of crystal grids providing a vast surface area. Gas molecules can be stacked very closely layer upon layer inside that framework. As a result, a container full of MOFs actually holds much more gas than an empty container. BASF is now manufacturing these amazing gas storage materials on an industrial scale and has started equipping natural gas powered cars with MOF tanks in the USA and Germany. At compressed natural gas (CNG) pressures, the larger quantity of natural gas in the tank could extend the vehicle's range. Moreover, storage of gas at lower pressures than CNG would enable fleet owners to reduce fueling infrastructure costs, while still having the required amount of fuel on board for operating their fleet vehicles.

www.basf.com/catalysts-energy-storage



Grass-powered lawnmowers

The idea is as spectacular as it is obvious: a lawnmower fueled by grass. A prototype has emerged from a startup originating at George Mason University in Fairfax, Virginia. EcoMow which essentially means "ecological mowing" dries freshly mown grass in its interior using a combustion engine and compresses it to biomass pellets. The mower uses up some of the pellets for its own propulsion. The remaining pellets can be used, for example, as fuel for furnaces. If everything goes according to plan, EcoMow should be available commercially in 2015.

www.ecomowtech.com

Compostable coffee capsules

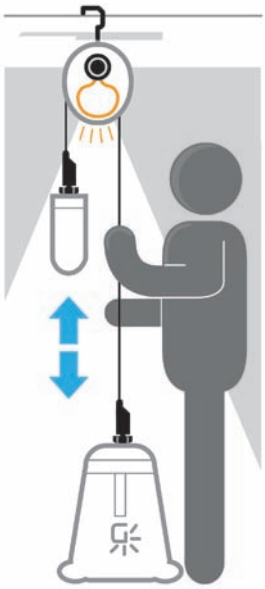
Coffee at the touch of a button is convenient. However, the trend to use coffee capsules leads to growing waste piles. This is where ecovio®, BASF's certified compostable biobased plastic, is set to provide relief. It is now being mass produced for the first time in a system specially developed for use with coffee packaging, which is mainly based on renewable resources. In this system designed by BASF researchers and developers in cooperation with the Swiss Coffee Company, both the coffee capsules themselves as well as the aromapreserving outer packaging are biodegradable. These are the first coffee capsules in the world to carry the seedling label, a quality mark indicating that a product's compostability has been demonstrated to be in line with EU certification requirements. Specifically, it means the used portion-size container has to biodegrade within twelve weeks. Trials under real conditions showed that biodegradation in fact took place within four weeks.

www.ecovio.com

Enlightenment through gravity

Old principle, new application: Two London-based designers have invented an electric light called GravityLight for developing countries that uses gravity to generate light. The principle is simple. A strap runs through the mechanism of the LED light. Pulling the strap raises a bag filled with sand, soil or stones weighing about 9 kilograms (20 pounds). As the weight gradually descends, the energy thus released is converted to electricity that lights the lamp. Three seconds' worth of effort gives light for about 25 minutes. Mass produced GravityLight will cost about six or seven US dollars a piece and help to replace the dangerous and environmentally harmful kerosene lamps currently used to light huts in many developing countries.

www.deciwatt.org



Airbags for cyclists

Until now, cyclists had helmets for protection against head injuries. Airbags were for motorists only. Two Swedish industrial design students decided it was time to change that. They have developed an inflatable cycle helmet called Hövding ("chief" or "head" in English) that is worn around the neck like a scarf. Inbuilt sensors measure the cyclist's movements 200 times per second. If the sensors detect a fall, the airbag inflates instantly, encloses the head and stabilizes the back of the neck before the cyclist hits the ground. After seven years of experimenting, thousands of simulated cycling accidents and untold calculations the helmet is now available on the market.

www.hovding.com

Bright light headsets against winter blues

When the days grow shorter and duller, many people notice that their mood darkens too. A Finnish manufacturer has developed a bright light headset to counteract this effect. Valkee directs 10,000 lux of light through each ear to the light-sensitive parts of the brain and raises energy levels there. According to the manufacturer, just 8 to 12 minutes of "bright light exposure" daily is enough to lighten one's mood. Valkee is approved in Europe for the treatment and prevention of seasonal affective disorder (SAD).

www.valkee.com


OVERSIZE LOAD

A shale gas drilling rig towers over a field in Colorado, USA.

Shale gas under discussion

The US Energy Information Administration estimates that between 2010 and 2040 global energy consumption will grow by 56%. How is the world going to meet this demand? As fossil fuel reserves dwindle, shale gas is looking like a viable alternative. But are the risks associated with its extraction too high or can those risks be avoided?

Everyone agrees that we face a challenge – unless we take action now, we will not be able to meet our future demand for energy. Many agree that we need to invest in technologies that help us use energy more efficiently. But how should we meet the remaining demand? There is a clear split between those who say investment should focus on renewable energy technologies such as wind and solar power, and those who say there is plenty of fossil fuel left if you only look for it hard enough.

According to the US Energy Information Administration's (EIA) 2013 report, renewable and nuclear power sources are the world's fastest growing sectors, at 2.5% a year, but fossil fuels still account for nearly 80% of all energy production. Natural gas consumption is increasing by 1.7% a year, thanks in part to developments in shale gas extraction.

In the US, the recent boom in shale gas production has contributed to cheaper household energy prices and helped manufacturing sectors such as plastics. Other governments are hoping to catch up. The EIA estimates the total volume of technically recoverable shale gas worldwide to be around 7,299 trillion cubic feet (tcf). It puts the US fourth on the list of countries with the largest resources, behind China, Argentina and Algeria.

But concerns have been raised by environmental groups that the process of using pressure to release shale gas from the earth – hydraulic fracturing, or "fracking" – can lead to water supplies being contaminated and that it has been proven to cause seismic activity in some cases. They also argue that, as the energy sector accounts for around two thirds of greenhouse gas emissions, countries will not be able to meet climate change targets unless they pursue renewable energy.

Professor Mohammed M. Amro, Director of the Institute for Drilling Engineering and Fluid Mining at the Technical University Bergakademie Freiberg in Germany, and Bas Eickhout, Member of the European Parliament for the Dutch Green Party, present the two sides of the argument and discuss what role shale gas should have in meeting our energy needs.

“I think people in the end will agree that we will have to go for efficiency and renewables. In that overarching strategy shale gas is not needed.”

Bas Eickhout, Member of the European Parliament for GroenLinks, the Dutch Green Party.

Creating Chemistry: European conventional gas production is decreasing. How do you believe we can best secure Europe's future energy supply?

Bas Eickhout: It's clear that if you look at EU fossil fuel production it is going down, but not dramatically quickly. It's not that we'll be out of gas tomorrow, but we have to prepare for a future where we have alternatives ready. Climate change is a crucial aspect that has to be taken into consideration. I don't see an alternative than to prepare for a world which is not built on fossil fuels. That means preparing for a shift away from gas. Gas is a transition path away from coal, but if you look at some studies out there, in 30 to 40 years time Europe can be totally independent of fossil fuels. So the best way to secure Europe's future energy supply is to invest in non-fossil alternatives, and from my point of view that means renewable energy.

Which role could gas play in securing Europe's future energy supply?

We do know there is a variability of supply with renewables. You can live with that variability if you connect the different resources and make sure you invest in energy storage as well. But until that moment, that variability is still an issue and gas is the key marriage partner with renewables because it is more flexible than coal or nuclear. Therefore you do need gas in the coming decades. A big question is how much you should expand in gas, and that is very much determined by how much we invest in energy efficiency. If you do that, then we hardly need any increase in gas. And ultimately renewables are the best option to become self-sufficient.

Could shale gas be an option?

I don't see why it should be. If you really go for the renewables and efficiency, why should we go into an investment like shale gas? I'm not of the school that says shale gas is the end of the world, but politically speaking shale gas brings us on a path that is a dead-end. You can invest a lot and try to make it a bit safer, a bit cleaner. But then why are we going for the last drop of gas when there are alternatives? Pursuing shale gas would lock us into a fossil future. If you start drilling you need to continue drilling in order to see a return on your investment – it becomes a self-fulfilling prophecy.

What kind of regulations do you deem necessary to ensure the safe production of shale gas?

First, you need to make sure water quality is not under threat. Second, the use of chemicals needs to be registered for this purpose. The third is about leakage rates, mainly of methane, which is only now being investigated in the US. The leakage rate determines to a huge extent whether gas is cleaner than coal. And the chances of higher leakage rates with shale gas are considerable.

Do you think that there is sufficient dialog between energy companies, scientists, regulators, policy makers and the general public? If not, how could this be fostered?

I think the biggest problem at the moment is that it is such a polarized debate, either 'it's the end of the world' or 'it's the only solution.' We really have to invest more in independent research. There are a lot of scientists out there who just want to know for the sake of science, and that should play a far more dominant role.

Do you think the EU could lag behind countries like China and the US in technological and economic development if it doesn't pursue shale gas?

Easy money in the first year might become very difficult money after that. In the US shale gas is already being questioned more and more. A lot of companies investing in shale gas are getting into difficulties. Going into shale gas is a 'penny wise, pound foolish' strategy. No matter what happens, towards 2020, carbon emissions will cost more and more money. So you have a cheap option now but in 10 years' time it will be far more negative than you think. Especially if you want to meet climate targets; then shale gas needs to be married with carbon capture and storage; one of the most expensive options out there. The fastest increase in energy in Europe is renewables, by 5% a year over the last 20 years. It is increasingly becoming a serious option, look at Germany. You need a trustworthy example of a group of countries – I would say that's the EU – who can show you can build a prosperous world without fossil fuels.

What do you think is the main reason why people do not support shale gas development?

The main reason is that people look at options individually and there's always a reason to be against any option. Shale gas is not alone, people don't like windmills in their back yards either. We have to make clear that there is no cheap option. Therefore we need a more overarching strategy to decide what the most viable option is, given all the circumstances. I think people in the end will agree that we will have to go for efficiency and renewables. In that overarching strategy shale gas is not needed. ▫

To find out more, visit: www.europarl.europa.eu

Bas Eickhout

is a Member of the European Parliament for GroenLinks, the Dutch Green Party. He is a member of the EU Committee on Environment, Public Health and Food Safety, and a substitute member of the Committee on Transport and Tourism, and of the Committee on Economic and Monetary Affairs. Eickhout gained a Master of Science in environmental studies and chemistry at Radboud University, Nijmegen, the Netherlands. He has worked as a researcher at the Netherlands Environmental Assessment Agency and has contributed to a number of projects on international environmental issues such as climate change, agriculture, land use and biofuels. He was a contributing author to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, which received the 2007 Nobel Peace Prize.

Creating Chemistry: Hydraulic fracturing was developed in the US in the 1940s – why has it only now hit the headlines?
Professor Mohammed M. Amro: It has become an increasingly hot topic now because people have become more environmentally conscious. But misconceptions are there because people think we have alternatives, we don't. Energy consumption worldwide is growing, we expect an increase in demand of at least 3% a year. And the number of conventional reservoirs are depleting slowly, it's hard to find new conventional reservoirs.

Which risks do you see regarding hydraulic fracturing?
I think one of the risks is the horizontal fracture length. Problems like seismicity and water contamination are associated with this. If we limit fracture length, we could minimize such potential problems. For example, we should not allow a fracture of more than two or three hundred metres, at this stage. Horizontal fracture length can be controlled by the amount of fracture fluid used. So we should regulate the volume allowed for each fracture. Another very important point – we should not frack in a tectonically active region.

You have said that at depths of 1,000 to 4,000 metres fracking can be safe as there is a layer of clay and salt stones that separates the groundwater layer. Why is this?
The deeper you go in the reservoir, the better you can control the fracture pressure – it means you can frack the well or formation more safely.

Professor Mohammed M. Amro

is Director of the Institute of Drilling Engineering and Fluid Mining, and Chair of Reservoir Engineering, Production and Storage at the Technical University Bergakademie Freiberg in Germany. From 1999 to 2009 he was a faculty member in the petroleum and natural gas engineering department of King Saud University, Riyadh. Before that he worked at the German Institute of Petroleum Engineering in Clausthal, Germany, and for the Qatar Drilling Company in Qatar. He holds a Bachelor of Science, a Master of Science and a Ph.D. in petroleum engineering from the Technical University of Clausthal in Germany and is a member of the Solution Mining Research Institute, the Society of Petroleum Engineers and the German Society for Petroleum and Coal Science and Technology. He has authored and co-authored over 60 technical papers. His current teaching and research interests include enhanced oil recovery, stimulation methods, unconventional reservoirs and underground storage.

We should avoid reaching up to the cap rock [the rock separating the shale gas formation from groundwater]. However, it is also possible to extract gas from reservoirs that are 1,000 metres deep or less, as long as you limit the fracture length.

You have said that more work needs to be carried out on developing degradable and non-toxic chemicals to use in the process. How could this be done?
This is one of the most important topics we are working on. In Germany, the UK and the US, companies are looking at which chemicals might cause problems for groundwater. Some oil and chemical companies have made progress in developing bio-polymers and starch products that can be used. We are also working on replacing the biocide in hydraulic fracturing fluid [used to eliminate bacteria that produce corrosive by-products]. There is a lot of research on this topic, for example looking into using ultra-violet instead. And efforts are also being made to reduce the number of chemicals used.

What further research needs to be undertaken into fracking, and are companies and/or governments taking steps to do this?
We can make good progress in developing monitoring methods – this is one area to examine. And we can develop methods for dealing with backflow [wastewater from the well]. Further research is also needed into the high-pressure, high-temperature cement, used to cement spaces behind the casing [a process used to protect groundwater from contamination]. And all staff need to be educated on safety issues around the hydraulic fracturing process.

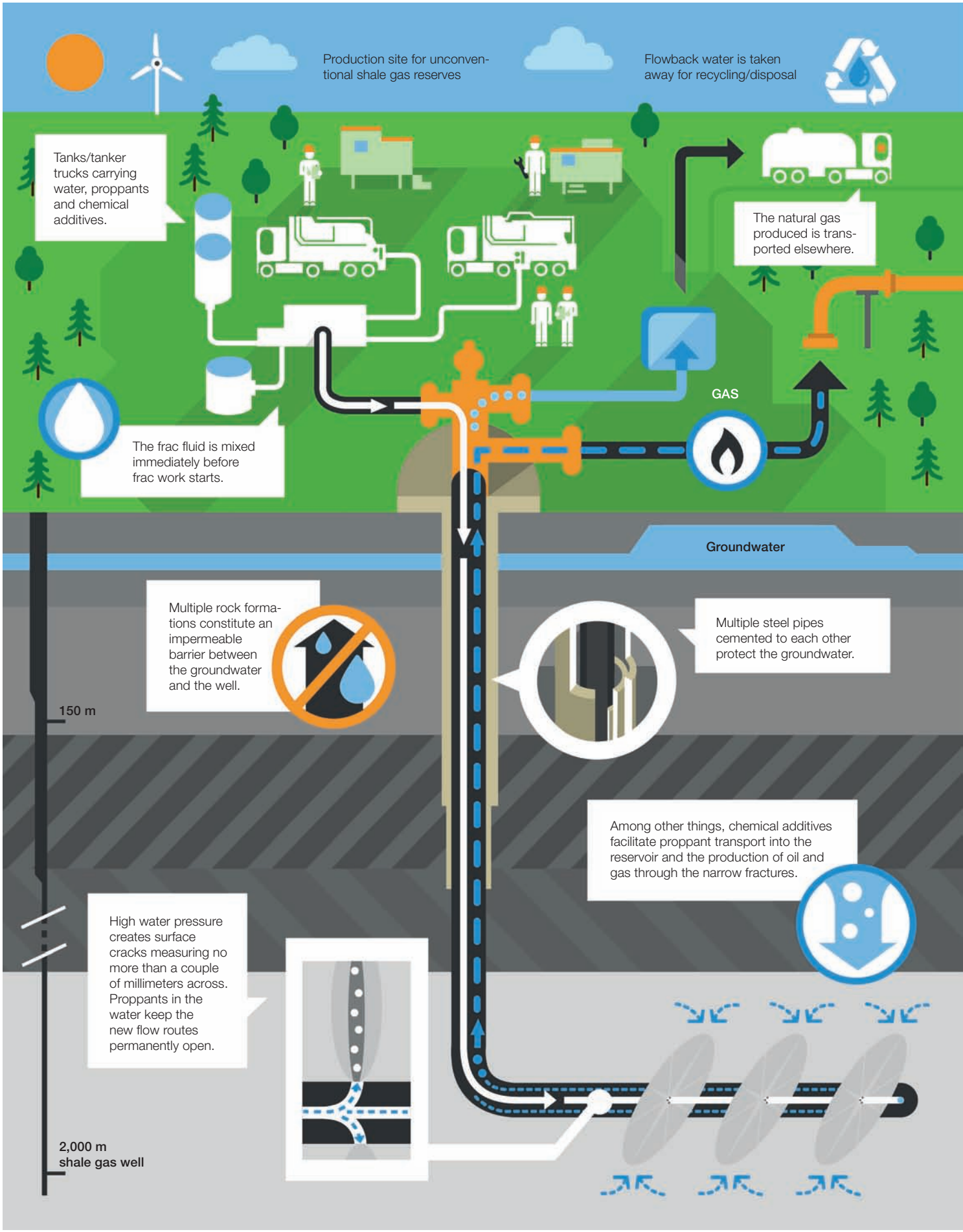
There are an increasing number of reports on shale gas. Do you think a consensus is being formed, or are opinions diverging?
The problem in our business is that different groups of people – whether they come from a financial, environmental or technical background – don't speak to each other. Each one considers the issues from their own perspective. We should come together to evaluate the topics; we need to create a dialogue between different organisations.

What do you think needs to happen for hydraulic fracturing to become more widely accepted?
The most important thing is to be transparent, to avoid hiding anything. If we are talking about unconventional reservoirs, we should say so, and not use other words. We should have regulations and show them to the public. For example, we should say we will not frack in seismically active areas, before conducting fracturing we will thoroughly investigate formations, we have the tools to monitor the fractures, we will avoid any water contamination. We should explain to the public what we are doing. Regulations should be discussed with the public directly. If any country fails to follow these procedures, we will have trouble everywhere.

To find out more, visit:
tu-freiberg.de/fakult3/tbt

“The most important thing is to be transparent, to avoid hiding anything. If we are talking about unconventional reservoirs, we should say so, and not use other words.”

Mohammed M. Amro, Professor and Director of the Institute of Drilling Engineering and Fluid Mining, and Chair of Reservoir Engineering, Production and Storage at the Technical University Bergakademie Freiberg in Germany.


Production site for unconventional shale gas reserves
Flowback water is taken away for recycling/disposal
Tanks/tanker trucks carrying water, proppants and chemical additives.
The natural gas produced is transported elsewhere.
GAS
The frac fluid is mixed immediately before frac work starts.
Groundwater
Multiple rock formations constitute an impermeable barrier between the groundwater and the well.
Multiple steel pipes cemented to each other protect the groundwater.
150 m
Among other things, chemical additives facilitate proppant transport into the reservoir and the production of oil and gas through the narrow fractures.
High water pressure creates surface cracks measuring no more than a couple of millimeters across. Proppants in the water keep the new flow routes permanently open.
2,000 m
shale gas well

Securing natural gas supply

Shale gas has brought an unexpected industrial boom to the United States. Production is now being debated in Europe. Shale gas can contribute to securing energy supply in many countries of Europe. BASF supports investigating the potential of shale gas resources in Europe and is actively involved in exploration and production in other parts of the world.

Natural gas is the most environmentally friendly fossil fuel because it generates significantly less harmful CO_2 and lower levels of emissions when combusted. For that reason, natural gas is an important stepping stone in the transition to an energy supply based on renewable resources. Natural gas is a kind of lifeblood of BASF. It is both an essential building block in the manufacturing of chemical products and is also used as a fuel to supply the major BASF sites with electricity and steam. Moreover, BASF is involved in natural gas production through its subsidiary, Wintershall, Germany's largest internationally operating oil and natural gas producer. BASF's largest site in Ludwigshafen alone has a higher natural gas requirement than Berlin, a city of more than three million inhabitants.

Shale gas is essentially no different from natural gas and the same ecological benefits apply in its utilization. The raw material in shale gas is trapped within formations of shale, a sedimentary rock that is commonly rich in oil and natural gas. As recently as the 1990s, exploitation of these resources would not have been economically viable anywhere. The gas is released from the shale by a technology called hydraulic fracturing – also known as fracking. This technology has been safely used in conventional gas production on a wide scale in Germany since the 1960s with no adverse impact on the environment or groundwater.

Shale gas fracking initially involves drilling vertically deep into the ground until the target rock layer is reached. The drilling is then redirected in a horizontal direction perforating the rock containing the gas. This is followed by the actual fracking process which means the injection of fluid at high pressures into the natural gas field to create artificial routes for the gas to flow. The fluid is about 98% water and sand. Less than 2% is made up of chemicals. These are required for various reasons, such as anticorrosion and the reduction of friction. The borewell itself is lined with multiple layers of cemented steel pipes. This creates an impenetrable barrier between the borewell and water-bearing layers (aquifers).

The technology has progressed over the years to a level of sophistication that enables economic and ecologically compatible production of shale gas in many parts of the world today. Shale gas has invigorated the US as an attractive industrial base again and attracted investment worth billions as a result of lower energy and natural gas prices. BASF wants to be part of that process and is currently planning to construct a number of new world-scale plants in the country. The benefits of shale gas to the US are not just economic, however: as natural gas is significantly more environmentally friendly than coal with regard to climate, the country has been able to achieve substantial reductions in greenhouse gas emissions.

In Europe, shale gas could maintain local natural gas supplies at today's level for many years and significantly increase European energy and raw material supply security. BASF, therefore, supports the research into the potential of shale gas resources in Europe and is actively involved in exploration and production of shale gas in other parts of the world, such as Argentina.

To find out more, visit:
www.wintershall.com/en

Dr. Harald Schwager

has been a Member of the Board of Executive Directors of BASF SE since 2008. He is responsible for Oil & Gas, Construction Chemicals, the Region Europe and Procurement. He holds a doctorate in chemistry and has been working at BASF since 1988. Prior to joining the Board of Executive Directors, he held several positions such as President of the Inorganics division and the Ludwigshafen Verbund Site Management. From 1998 to 2003, he worked for BASF in Brussels.

"In Europe, shale gas could maintain local natural gas supplies at today's level for many years and significantly increase European energy and raw material supply security."

Dr. Harald Schwager, Member of the Board of Executive Directors of BASF SE

Staying connected: BASF recollects the past and shapes the future in its anniversary year

Connectedness and strong ties between people are what make BASF what it is today. This is also the common theme underlying this special about the 150th anniversary of the company. The starting point is a look at how our brains remember things, the nature of recollection being largely based on connections between neurons. Building on that, we turn to the things that connect the past with the present and see how BASF milestones over the past one-and-a-half centuries have brought pioneering technological achievements to life. We proceed from there to the collective memory and recollected history of business organizations and then move on to BASF's anniversary concept: By combining a celebration of the company's heritage with its response to the challenges of the future, the company strengthens already close ties with employees and partners and together creates new space for creative ideas.

The nature of memory

Childhood memories, the first love, experiences at work: it is memories that put continuity in our lives and give us an identity. To enable us to remember, many areas of the brain need to interact.

Despite years of research into memory, many questions remain unanswered. One thing we do know for certain: memories help to determine who we are.

"We are who we are because of what we learn and what we remember," the famous memory scientist and Nobel laureate Eric Kandel once said. And he added: "Memory is the glue that binds our mental life together and provides a sense of continuity in our lives." Nowhere is that more apparent than in people suffering from total memory loss. They tend to feel as though they are permanently waking up from a long period of unconsciousness with no memory of what went on before.

Without recourse to memory, we have no ability to recollect the numerous episodes and experiences that make up our lives. The Canadian psychologist and retired professor, Endel Tulving, Ph.D., coined the term "episodic memory" for this part of our recollection system: "Episodic memory is the kind of memory that allows us to 'mentally travel' in time, and thus recollect our own past experiences, events we have observed and participated in," says Tulving. We are aware of the content of episodic memory and can articulate it in words.

Without the ability to remember, our own conscious biography slips away from us. Not only that, we would be unable to perform mundane everyday skills like riding a bike and tying shoes. Procedural memory tasks like these, primarily involving the use of movement, are automatic and unconscious.

But how do memories arise in the first place? What we remember largely depends in the first instance on how much attention we are paying at the time. We are subject to a ceaseless bombardment of stimuli every waking hour. Because the brain's capacity to process sensory information is limited, the main thought center of the brain separates the important from the unimportant. The part of our memory that is articulated in words only stores those things to which we pay attention. To be retained in long-term memory, an event needs to undergo a number of processing stages in the brain. "If, say, I take part in a wine-tasting session on a trip to South Africa, an autobiographic memory may emerge from this event," neuropsychologist Professor Hans J. Markowitsch, University of Bielefeld, says. "The sensory input received during the wine tasting session enters short-term memory first of all." Here incoming information can be retained for anything from a few seconds to a couple of minutes. "The information proceeds fairly rapidly from there to two circuits in the limbic system," Markowitsch says. Once it gets there, the information is checked for possible resemblance to existing events and experiences and links are established. In this process, the amygdala – essentially the emotional center of our brain – is responsible for emotional assessment and interpretation of the events. "Other areas of the limbic system subject the incoming information to social and biological assessment," Markowitsch elaborates.

If the information is classified as important, the hippocampus steps in. One of the most famous patients in psychology, an American called Henry Molaison, illustrates the role played by this part of the brain: Removal of the hippocampus was one of the procedures performed to cure his epilepsy. Molaison's epileptic seizures went away – but so did his autobiographic memory. Molaison was unable to commit new events to memory. "The hippocampus is evidently one of the limbic system structures involved in transferring information from short-term to long-term memory," Markowitsch explains. Autobiographic events are then primarily stored in the right cerebral cortex.

Thinking back to the wine tasting session in South Africa after a long time has passed will reactivate those areas of the brain that were significantly involved when the memories were created in the first place. Neuroscientist Professor Itzhak Fried, Ph.D., Medical Center, University of California Los Angeles, observed this phenomenon in a study right down to the level of single neurons. Recollection arises from the activity of the very same neurons that were active during the formation of memory content, Fried says: "In a certain sense, reliving past experience in our memory is the resurrection of neuronal activity from the past."

Memory traces

Memories leave lasting traces in the brain. As early as 1949, Canadian psychologist Dr. Donald O. Hebb presumed that these traces are distributed among large groups of neurons. He summarized their exact nature in the succinct phrase: "Neurons that fire together wire together." The story of the wine tasting in South Africa may again serve to illustrate Hebb's model. Tasting the wine creates a number of impressions. As well as delighting in the wine's fruitiness, you also receive sensory input from the setting in which the session takes place. The neurons repeatedly activated in unison while you enjoy your wine and appreciate the surroundings gradually become more strongly interlinked. During this amplification process, changes occur at the synapse or junction between two neurons. Simply put, the first of these two neurons releases more transmitters, such as glutamate, which migrate across the synaptic cleft to the second neuron. The transmitters facilitate communication between the neurons and the better connection enables the first neuron to activate the second one more easily as a result.

Later, the taste of the same South African wine may be enough to resurrect the wine-tasting session in your mind's eye. American scientists recently published a paper in the journal *Nature* providing immediate proof that memory traces are laid down in this way. When the scientists weakened certain connections between neurons in their animal models, the animals were no longer able to recall an unpleasant event they had experienced.

For all the undisputed progress in memory research over the past decades, many unanswered questions remain: "For instance, we still don't know if we can truly forget," Hans Markowitsch says. "It's possible that we simply can't retrieve stored information because it has been shunted into the subconscious." He also says we don't know whether forgetting is fundamentally due to disintegration of information or whether it may not in fact be due to superimposition. Advocates of the superimposition theory say that forgetting is when the retrieval of the content of a memory is disrupted by another. "In this process, new information enters the memory on an ongoing basis and gets mixed up with old memories, resulting in their modification or disruption of their retrieval," Markowitsch says.

New research findings are reported almost daily, Endel Tulving says. His conclusion: "Yet the major insight gained from more than one hundred years of scientific study of memory may be the realization that the complexity of memory far exceeds anyone's imagination."

Milestones in BASF's history

1865

Friedrich Engelhorn, a goldsmith and entrepreneur, founds the joint-stock corporation "Badische Anilin- & Sodafabrik" (BASF) in Mannheim in 1865. He has big plans from the word go: BASF should not only produce dyes but also the raw materials and auxiliaries as well as the precursors and intermediates required. BASF has retained soda, aniline and dyes in its portfolio to this day – while continuously adding to its product range along the way.

1897

A broken thermometer sets the scene for a breakthrough in indigo research. In this example of serendipity at work, BASF scientists discover that mercury is an excellent catalyst in the manufacture of phthalic acid, a key precursor in the synthetic production of indigo. Economic industrial production of the precious blue dye seems a viable option at long last. Seventeen years of research later, it is finally ready for sale as "Indigo rein BASF" (English: Indigo Pure BASF). The synthetic indigo is sold worldwide, especially in China, where blue jackets dyed with indigo are traditional clothing and BASF has been active since 1885. Later, in the 1960s, indigo blue denim jeans are adopted by an entire generation and have become a basic wardrobe essential for many people all over the world today.

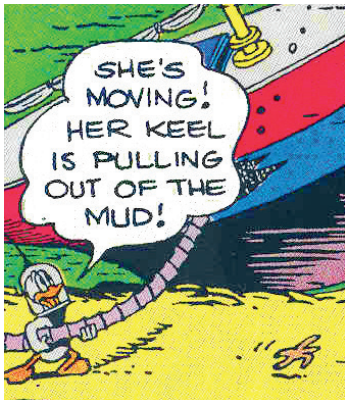
1913

By the turn of the century, reserves of atmospherically fixed nitrogen – used as a crop fertilizer in the form of sodium nitrate – are running out. New sources of nitrogen are badly needed. After five years of research and development at BASF, Carl Bosch, building on a process by the Karlsruhe-based chemist Fritz Haber, succeeds in converting atmospheric nitrogen on an industrial scale and manufacturing synthetic ammonia, which is used in turn to produce nitrogen fertilizers. The downside of the method shows itself in the First World War, when ammonia is converted into nitric acid and supplied to the explosives industry. Ammonia synthesis was developed to provide for the nutrition of billions of people – and continues to do so today.

1936

In 1936, the London Philharmonic Orchestra has a guest appearance at the BASF Feierabendhaus in Ludwigshafen. Their visit is recorded for posterity in the world's first live recording of a concert on audiotape. Tapes for the recording of sound are originally intended for dictation purposes. However, the concert demonstrates the possibilities of BASF's new magnetic tape. Radio stations are among the first to use the tapes. In 1969, the Beatles record their unreleased "Get Back Sessions", one of the band's last projects, on a BASF tape. In 1997, BASF sells its global magnetic tape business to the South Korean KOHAP Group.

Innovation has been the force guiding BASF history since the company's foundation in 1865. From indigo to audiotapes to catalysts: insights into BASF's past and present.



1951

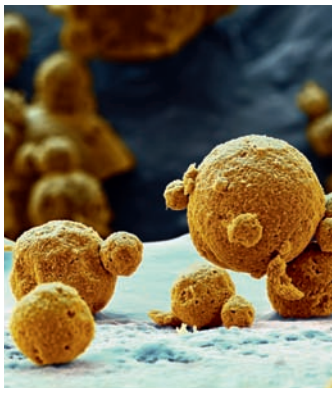
Styropor is one of the classics of plastics and a lightweight among foams. It has been produced since 1951 and is composed of 98% air. Until now it is a byword for efficient home insulation and safe packaging. In 1962, the Mona Lisa, for example, is sent off on her travels wrapped in Styropor. In 1964, Kuwait Harbor is the scene of a rescue operation with a difference: a sunken livestock carrier is raised with the aid of Styropor beads pumped into the ship's interior. Unfortunately, a patent filing for this unusual salvage method goes up in smoke when it transpires that Walt Disney told the tale of a similar salvage operation back in 1949 – the protagonist being Donald Duck, who used ping pong balls to raise a sunken yacht. In patent law terms, this constitutes a prior description that well and truly scuttled any hope of patenting the Styropor operation in its entirety.

1974

Although BASF was actually founded in 1865 as a waste recycler – producing synthetic dyes from what had been an undesirable waste product, namely coal tar – it also generates pollutants. BASF's first steps to protect water, soil and air are to introduce the removal of arsenic from fumes in 1903 and wastewater discoloring in 1905. In response to increasing environmental awareness and stricter regulations, BASF steps up its environmental protection efforts from the 1960s onward. One important milestone is the commissioning of the new water sewage treatment plant at the Ludwigshafen site in 1974. It is Europe's largest mechanical-biological sewage plant at the time. Modernized continually ever since, it is the main element in a sophisticated wastewater concept that has evolved over decades with separate sewer lines for cooling water and wastewater.

2013

There are an estimated one billion cars on the world's roads, and that has an impact on the environment. Incomplete combustion and minimal contaminant levels in fuel can produce harmful car exhaust fumes. After Engelhard Corporation, acquired by BASF in 2006, achieved a breakthrough in 1976 with the first three-way catalyst, BASF researchers went on to find the key to an even cleaner solution in 2013 by developing the first FWC™ four-way conversion catalyst for gasoline engines. This new technology filtrates and removes the most important groups of harmful emissions (hydrocarbons, carbon monoxide and nitrogen oxides) and particulate matter from engine exhaust using just one single component.



2015

Originally established in Mannheim, BASF now calls the world its home with a network of about 380 production sites and research teams at a total of 70 research sites. Innovation has always been a powerful driver of growth. Currently BASF is focusing on growth fields such as wind energy, water solutions and batteries for mobility (microscopic image).

Looking back into the future

A company's identity is essentially determined by its recollected history.

Mindfulness of the past is a valuable asset for any business organization. Knowing where a business comes from and the highs and lows it has been through inspires new visions, goals and solutions. It also plays a major role in attracting and retaining employees. "Company history is a really good way to understand the corporate culture of a firm and how it got that culture," says Geoffrey Jones, Ph.D., Professor of Business History at Harvard Business School in Boston. The associated "notional, unquantifiable value added," as Dr. Andrea H. Schneider, head of the 1976 founded, Frankfurt am Main-based Business History Society (Gesellschaft für Unternehmensgeschichte, GUG) points out, may even be relevant in mergers and acquisitions: "Corporate history is an indicator of company values. Neglecting them in the context of a merger may be one reason why it may fail," Schneider says.

Recollected history can do a lot more: "If we look beyond the form first of all, company histories have the potential to enhance and improve the reputation of a firm with all the stakeholders, customers and suppliers," Professor Jones says, adding: "In that sense, I see company history as almost a part of corporate social responsibility – it is the firm recognizing it is a very powerful force on its region of the world and taking it seriously."

The latter aspect in particular calls for an authentic portrayal of company history that is not reduced to success stories alone. "We make a point of communicating the difficult patches of company history in a transparent manner, and that includes responding to queries from historians and the media," says Úlia de Domènech, head of Corporate History at BASF. Examples of such aspects would be the company's role in the First World War and its involvement with the Nazi regime as part of I.G. Farben, the name given to the amalgamation of Agfa, BASF, Bayer, Hoechst and a number of smaller German chemical companies in 1925. These topics are presented in detail in "BASF – A Corporate History", a chronology written by leading historians and published in 2002. The book is also an example illustrating the increasing predominance of academic issues in business historiography. "It is an important element in helping to understand modern history," Schneider affirms. One current hot topic of research is the historical analysis of networks, for example.

Úlia de Domènech and her team of historians are the custodians of printed matter filling almost 3,000 meters of shelf space, as well as 30,000 historical photographs and a collection of historical exhibits stored and studied in the company archives. "It is the company's memory," de Domènech says, "a real treasure trove of knowledge and inspiration." Documents such as the reports of the first company doctor in the German chemical industry, who was hired in 1866, are a good illustration of how the documents not only tell the history of the company but, much more than that, are part of collective remembrance and cultural memory – which is why they are registered as part of the national cultural heritage. Knowledge from the past plays an important role in day to day business, too. The process of identifying potential soil contamination or its absence, for instance, would not be possible without historical information. Documents from former times also help present hard evidence in the event of patent queries.

Collective retrospection cannot deliver a blueprint for decisions facing us today. Nonetheless, Professor Jones considers it an important management tool – especially in these days of multicultural teams and the increasing speed of change in the echelons of top management in organizations. He says the beloved dictum, "this time it's different" fails to acknowledge that, though circumstances may change, certain patterns tend to repeat themselves. "A knowledge of historical facts doesn't necessarily deliver a plan of action, but it does help you to see things more clearly when analyzing a situation in the here and now," Jones clarifies.

Sticking solely to the facts and figures is not enough in that process. Without the human factor, a company and its history remain abstract and – literally – faceless. That doesn't just mean telling the story of some charismatic company founder or genius inventor, GUG head Schneider points out. "Contemporary corporate history looks at the employees as well as the leading figures."

"Company history is a really good way to understand the corporate culture of a firm and how it got that culture."

Geoffrey Jones, Ph.D., Professor of Business History at Harvard Business School in Boston

BASF has been a partner to the Chinese economy for 130 years. It began selling textile dyes, one of the most important chemical products of the time, in China in 1885. Today, BASF has a strong production base, a wide-ranging distribution network and high-performance research facilities in China. The book "Breaking New Ground" tells the fascinating story how BASF became the biggest foreign chemical investor in China. It will be published on the occasion of BASF's anniversary in German, English and Chinese in spring 2015.

The anniversary adventures

He was busy in the cutting room, they told us, when we asked for an interview with Thomas Grube. Preparations for the anniversary film Grube is making for BASF are in full swing. A chat with the documentary filmmaker in the ARRI studios in central Berlin.

Creating Chemistry: Mr. Grube, your reputation as a freelance documentary filmmaker derives mainly from your recent portraits of artists. What is it that interests you in a company?
Thomas Grube: To me, films are always a kind of expedition into the unknown, into areas that I don't know anything about. I knew that BASF is the world's largest chemical company but not much else. And I rated the audio cassettes very highly in my youth (laughs) … but apart from that, the associations I had weren't positive in the first instance: a chemical company – dirty, destroys the environment. But that's too simplistic. Our world is a much more complex place and a corporation is not a dark force. During my research I have met a lot of people, every single one of whom is passionate about their specific area. It's about the big issues of the future that affect us all: our future energy supply, food, urban living. The BASF anniversary film gives me the opportunity to explore these issues.

What criteria do you apply in selecting material for your films?
I am looking for a good challenge. It works best if the mountain is almost too hard to climb. I need a bit of a struggle and to be able to discover something new. That's where creativity comes from for me. If the going is too easy and the destination seems too close, the final product tends to be nothing special.

Can you tell us about your approach to documentary filmmaking?
I don't try to convey objective information in my films. I want to create subjective emotion. I want to reflect and make the audience relive the emotion I felt during the filmmaking process. In the case of the BASF film, it means letting them re-experience the adventure all of us who are involved in this anniversary project are now going through together.

In your films, such as *Rhythm is it* and the one about the Berlin Philharmonic Orchestra, you invariably succeed in showing how people develop in the course of a project. Is this also your goal for the BASF anniversary film?
Yes. Absolutely. The Berlin Philharmonic Orchestra is a pretty special organism, as they elect their boss themselves. At the same time, each individual member is responsible for the quality of the whole. There are Harvard Business School studies on how a structure of that kind can have succeeded for more than 130 years. You can apply the same principle to an organization like 150-year-old BASF: How do systems manage to maintain quality as times and traditions change? How do you perform at your best while at the same time integrating your ego within the community?

One important aspect of the film is co-creation, creating things together. What do you think of this approach?
In my view, it has a lot to do with a highly sustainable corporate culture: it's not easy to manage 150 years with a short-sighted focus on shareholder value to the exclusion of everything else. In the anniversary project, BASF consistently looks to the future. Anyone who does that needs to be honest enough to face the facts: finding answers to the challenges of the next 20 to 30 years is so complex, that it would overwhelm any individual BASF specialist with his expertise. So it's good to be open and admit that we will find better answers by looking at problems from different angles – with the joint involvement of critics and NGOs. The film is a communication tool to reflect that co-creation process and to show that BASF has the confidence to take this path.

Do you think filmmaking is co-creation per se?
That's exactly it. Each individual is an expert in their particular area. And it takes the input of each individual to create the 'big picture'. Even as a child I loved watching the credits after a movie, the list of names scrolling from top to bottom for minutes at a time: somebody has a vision, a hundred people come together and add their skills – and a concrete product is created out of a fleeting thought.

Lights, camera, action!

The activities marking BASF's anniversary year are being captured in short video clips along with a documentary of the year's happenings. Thomas Grube's film work shows different sorts of people – experts and non-experts alike – in common pursuit of answers to the challenges of the future. Grube looks into what motivates them personally to pursue particular issues and documents the impact of the challenges on each of the people concerned.

The film sequences are available at: www.creator-space.basf.com

Creating space for innovative ideas for the future: an anniversary world of celebration and co-creation

Connectedness is BASF's core brand value and the central theme of the anniversary program. Connections between neurons are what enable us to remember things and relive the past in the present. The company's 150th anniversary celebrations are also about connectedness: The past is connected with the present just as BASF is connected with employees, customers, and a wide variety of social groups and partners. Celebration and co-creation are the underlying themes: The company celebrates its 150-year history with employees and partners while combining the anniversary of the company's founding with an in-depth look at the challenges of the future and innovation processes. Following the model of social networks, BASF has developed Creator Space™, a space for new ideas in collaboration with others.

BASF establishes Creator Space

We – together, counts for a lot. BASF's connectedness with employees, customers, scientists and the public was a traditional part of the company's ethos and remains so today. As a globally operating company, BASF appreciates the value of this connectedness in the search for solutions to current and future challenges. To mark the anniversary, BASF is taking things a step further: "Our aim with Creator Space is to open up room for creative ideas and go on to act on those ideas, for our business and for society – in fact, we want to make BASF itself a kind of Creator Space," says Elisabeth Schick, Senior Vice President, Communications & Government Relations BASF Group. The company's logo expresses this more clearly from now on with the new claim: BASF – We create chemistry.

A virtual lab

BASF promotes the energy that comes from connectedness and co-creation with an interactive anniversary platform on the internet: Creator Space online. As a kind of virtual lab, it opens doors

How can there be enough healthy food for everyone?

How can we improve urban mobility without damaging the environment?

for online discussion on the themes: urban living, smart energy and food. It is intended to appeal to anybody who wants to be involved in co-creating the future. Thus, the interactive platform grows and evolves in real time in response to input from individual contributors to the debate.

BASF is going on tour
Stopping in Mumbai, Shanghai, New York, São Paulo, Barcelona and Ludwigshafen, an accompanying Creator Space tour will breathe life to the anniversary themes. In a creative and inspiring environment, BASF discusses specific challenges with customers and partners combined with local celebrations. These co-creation activities with employees, customers, scientists and the public include jamming sessions where people are invited to join in the discussion and work out new solutions collectively. Topics discussed, for instance, are solutions to organic waste management, ways to build sustainable housing for people on low incomes, or the generation of ideas for improving water supply in cities.

Other formats include idea contests, customer co-creations, and conferences with scientists, NGOs and government representatives. Links connecting event outcomes with the relevant online debates are provided. Inspiring and receiving new ideas everywhere is the aim, and the other co-creation activities going on around the world have their place on the platform too. The various activities are captured in short video clips accompanying a documentary by Thomas Grube (see interview on page 43).

Cultural and social events including parties for employees at BASF sites will contribute to the festivities all around the world. Celebration and co-creation: these two elements in combination are the essence of BASF's 150th anniversary.

Interested? Please join in. You can access Creator Space online here: www.creator-space.basf.com

New dimensions in collaboration
The way we handle knowledge and creativity is undergoing radical transformation. The new logic is based on openness, cooperation and interaction. Networks give rise to innovative ideas, a new understanding of interaction, and new markets. Specialists will not be the only generators of new ideas in future. New concepts are just as likely to emerge from lively exchange between people, with employees, stakeholders and non-experts all contributing their input to

January 16–23: Creator Space tour in **Mumbai**, Focus: Water

March 9–10: Creator Space science symposium **Ludwigshafen**: Smart energy for a sustainable future

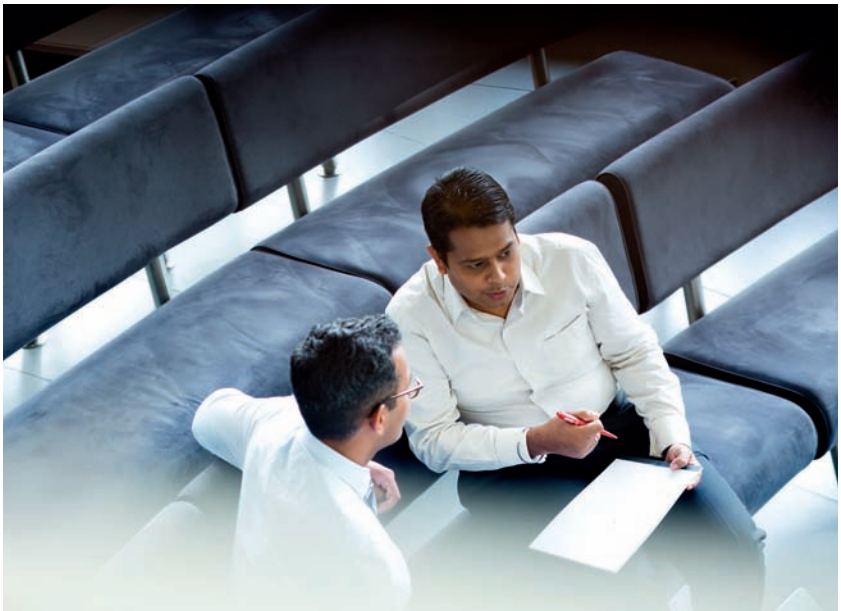
March 20–27: Creator Space tour in **Shanghai**, Focus: Urban living

April 23: Anniversary event in **Ludwigshafen**

May 26–30: 50th German Youth Science Competition ("Jugend forscht") in **Ludwigshafen**

May 26–31: Creator Space tour in **New York**, Focus: Housing of the future

2015



How can we use more clean and renewable energy resources?

How can we improve our housing quality?

facilitate networked value creation. Valuing and utilizing diversity of opinion: Inclusion of expertise on all levels across the various disciplines is becoming a key success factor.

How do we live in the 21st century? The key themes
BASF seeks to collaborate with employees, customers and partners to make a contribution to societal challenges that have significant impact on how we live in the 21st century.

These include:
- the cities we live in
- the energy powering our industry and our lives
- the food we eat.

The anniversary – and then?
Co-created visions for the future will become reality. The most promising ideas will be selected by an expert team in early 2016 and transformed into lighthouse projects with BASF's support. Thereby innovation can be taken to new levels beyond the anniversary year. This provides a long-term contribution toward solving social challenges and strengthening BASF's ties and collaboration with partners.

June 23–24:
Creator Space science symposium in **Chicago**: Sustainable food chain – from field to table

August 17–23:
Creator Space tour in **São Paulo**, Focus: Food and food loss avoidance

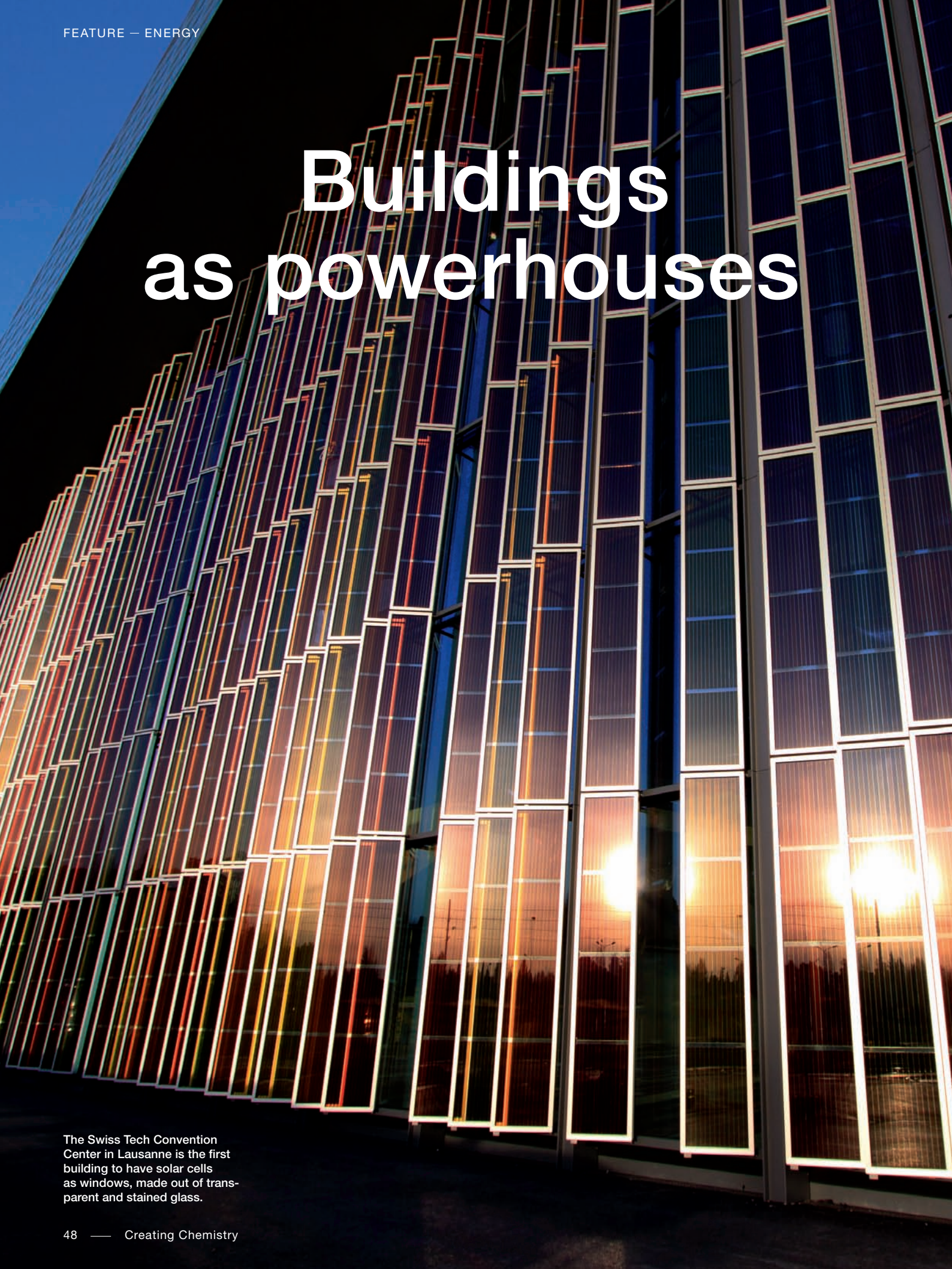
October 26–30:
Creator Space tour in **Barcelona**, Focus: Sustainable food chain

November 10–11:
Creator Space science symposium in **Shanghai**: Sustainable urban living

November 20–29:
Creator Space tour in **Ludwigshafen**, Focus: Smart energy

2016

Buildings as powerhouses



The Swiss Tech Convention Center in Lausanne is the first building to have solar cells as windows, made out of transparent and stained glass.

Sustainable building is the buzzword among architects. Yet for most of us, living in houses built decades ago, reality remains far from the futuristic designs – our homes gobble up energy, are often wasteful and inefficient. But that may be about to change, as business and academia pull together to forge a new urban landscape, where buildings become the power-houses of the future.

Ask leading scientists at the cutting edge of environmental technology to describe the house of the future and they will take you to a fascinating world, where material and biological science operate in harmony to create a living built environment.

It is a world where myriad technologies replace fossil fuels and nuclear power. A future where chemistry, biology, nanotechnology, material science and biomimicry fuse to create a living, interconnected city. A place where solar energy is harvested in different forms from every façade and stored inter-seasonally, where smart insulation regulates the environment, while living walls of algae react with sunlight to create shade and light. An interconnected world where the home, workplace, car and school mimic a living organism by interacting naturally with the environment to collect energy harvested from homes by day and workplaces by night to be pumped to where it is most needed.

Most of these recent innovations have been driven by the threat of climate change. Research by the United Nations Environment Programme reveals that smarter building construction offers the single greatest opportunity to deliver cost-effective cuts in harmful greenhouse gas emissions. Buildings globally consume 40% of our energy resources and emit a third of the planet's greenhouse gases – a figure set to rise as power-hungry populations migrate to cities.

The problem with the scientists' enticing vision of the future is that for most of us it bears little relation to our actual experience of the built world. Whether you live in Berlin, Shanghai, Rio or Milwaukee, you are likely to be surrounded by buildings that have changed little in design over the past 100 years and that use technology that has developed little over the past 50 years. The most advanced technology that we see in everyday use tends to be limited to heavy crystalline silicon solar panels and wind turbines.

This could be about to change. And the catalyst for change is a quiet revolution that has been taking place in the boardrooms of large companies and the laboratories of academic institutions. People are realizing that while there is no shortage of brilliant innovation in building design, there has not been enough focus on how to bring these new technologies to the wider market. This realization is leading some of the world's best scientific minds to shift attention from blue-sky thinking to addressing the technological challenge of scale. The question is, how to make this technology both affordable and profitable while producing it on a large enough scale to really make a difference.

40 %

Buildings globally consume 40% of our energy resources and emit a third of the planet's greenhouse gases – a figure set to rise as power-hungry populations migrate to cities.

10 GW

The scientists of the SPECIFIC project estimate that if just 10% of the steel produced each year by project partner Tata Steel had the smart coating of the transpired solar collector, it could produce 10 GW of power, or the equivalent of one nuclear power station's annual energy output.

Sustainable building: wooden façades, solar cells on the roof and high performance insulation – the Wälderhaus in Hamburg.

Greg Keeffe, Professor of Sustainable Architecture and head of research at Queens University in Belfast, Ireland, believes that architects and designers may have something to learn from the mass production techniques used by car manufacturers.

He argues that today's need to cram houses into what little urban space is left, means each building has to be individually designed. This offers no opportunity to develop the kinds of innovation that go with mass production.

"If you look at the average house with an E-Class Mercedes parked outside, that house is so dim compared to that car," says Professor Keeffe. "I believe we need a more industrialized, mass customized product, which is currently beyond our grasp because buildings are designed so differently from cars. Hundreds of man-years of thought have gone into designing each element of a car, whereas so much less thought has gone into each element of a building, because every building is so individual."

From lab experiment to industrial production

Recently set up to address this very challenge, the Sustainable Product Engineering Centre for Innovative Functional Industrial Coatings (SPECIFIC) is an industrial and academic consortium tasked with bridging the knowledge gap that exists between innovation and production. Launched four years ago, the project is led by Swansea University in Wales with funding from the Welsh and UK governments, as well as from its main industrial partners Tata Steel, NSG-Pilkington Glass and BASF.

SPECIFIC's aim is to turn buildings into the powerhouses of the future. It plans to act as a link between UK universities to exploit cutting edge, global developments in building materials and design, using smart coatings that enable walls and roofs to collect, store and release renewable energy. Working mostly with steel and glass, the project has already experienced extraordinary advances that are set to revolutionize at least one sector of the construction industry.

Kevin Bygate is Chief Executive Officer of the SPECIFIC project, heading up a team of more than 120 world-class scientists, technologists, engineers and business developers, all focusing on how best to up-scale existing technology and so turn laboratory-scale innovations into products capable of being manufactured on a large scale.

"We can make solar cells on anything, including paper."

Dr. Trisha Andrew, Assistant Professor of Chemistry at the University of Wisconsin-Madison

"There are many universities and research institutes that make the initial inventive step. What that physically means is, they have created something the size of a thumbnail, and on the thumbnail is a small dot, the size of a pin, that does something interesting," says Bygate. "We take over at that stage to replicate the function with an abundant material using a process that can be scaled up. We use pilot lines to produce one-meter-wide sheets and then a reel-to-reel line that will make a material large enough to put on a building."

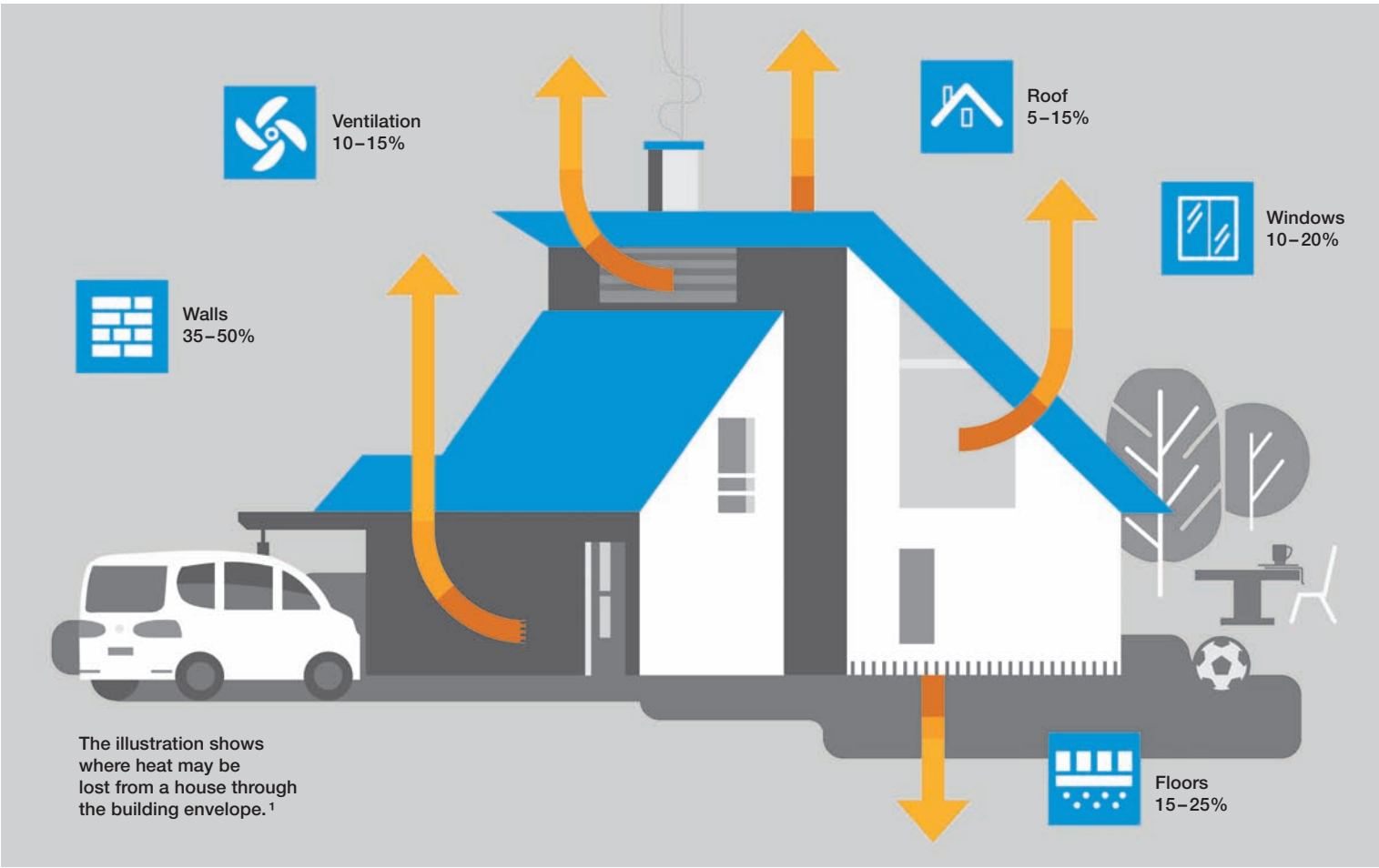
One product is the transpired solar collector, which is capable of absorbing an average 50%, and up to 75% in good conditions, of the solar energy that hits a building. Transpired solar collectors are installed as an additional micro-perforated steel skin onto an existing or new wall or roof, creating a cavity of heated air between the building's surface and the metal skin. The heated air is drawn from the cavity and fed into the building, so that it can either be used to meet the building's immediate energy needs, or be stored for later.

Partner in the project, Tata Steel, produces steel in the UK for building warehouses, supermarkets and retail outlets. SPECIFIC estimates that if just 10% of the steel produced each year by Tata Steel had this smart coating, it could produce 10 GW of power, or the equivalent of one nuclear power station's annual energy output.

Bygate believes that transpired solar collectors could become a key future energy resource. "What we have is proof of concept and now we are looking at the business model to take it to market," he says. "Depending on the rate of public acceptance for the product and the adoption curves, you could generate around one third of the UK's renewables by the 2020s using this type of technology."

As important as harvesting solar energy is its storage. Batteries, hot water storage and underground thermal storage all have potential, but tend to take up large amounts of space. While some energy needs to be stored for a matter of hours before being used, other energy needs to be drawn on inter-seasonally, typically stored in summer for use in winter.

The living façade made of micro-algae is not only beautiful to look at, it also produces biomass and heat. The raw materials can be used directly in the house.



The illustration shows where heat may be lost from a house through the building envelope.[1]

SPECIFIC is having success on this front too. Professor Dave Worsley, who heads the project's academic research program, explains: "What we are working on is a thermochemical store – the basis of which is a salt that absorbes or releases water, similar to the way we sweat – which traps or releases a huge amount of energy."

It is this ability to trap and release energy so efficiently that Worsley believes will make this solution suitable for inter-seasonal storage, while taking up ten times less space than using water for energy storage.

Solar paint

For years, scientists have been predicting the creation of an affordable photovoltaic paint that could be used on homes to harvest solar energy. But the reality is that it will still be many years before such a product reaches the market. But the work being carried out by Dr. Trisha Andrew, Assistant Professor of Chemistry at the University of Wisconsin-Madison, has taken us one step closer.
Organic photovoltaic devices that can be incorporated into a dye have been around since the 1990s. Made from materials such as carbon, hydrogen, nitrogen and sulfur, these devices have the merit of being inexpensive to produce, but suffer from inefficiency and a short life expectancy in comparison to silicon-based materials.

A couple of years ago, Andrew and her colleagues had a "eureka" moment. Why not make a virtue of this and produce a photovoltaic material, capable of powering electronic devices, but so cheap to manufacture that you just replace it when it degrades?

"The question we had never asked ourselves before was, how can you make these materials commercially," explains Andrew. "It is a question that pharmaceutical companies ask every day. We were following the same process of chemical synthesis, so the logical step for us was to ask what is the effect on price per peak watt of your chemical synthesis?"

By focusing on the manufacturing process, Andrew discovered they were already sitting on a commercially viable product, capable of powering household devices with solar energy. At a production cost of less than 50 U.S. cents each, it would not matter that the photovoltaic cells had a life expectancy of between six months and two years.

"We now have a very promising set of advanced results on which we have built a start-up company. We can make solar cells on anything, including paper. That's something you just can't do with silicon," says Andrew. "Scientifically and logically a paint is within our reach. If phase one goes well, a paint will be coming down the line, but it will probably be no earlier than a decade from now."

Green-skinned buildings

Every now and then a new technology emerges that changes the way we think about buildings. Showcased at the Hamburg International Building Exhibition, the world's first "bio-adaptive façade" house has had such an impact. It opens up exciting new opportunities for architects and designers to break down barriers between the material and biological world and so takes us that bit closer to the vision of a living city.

Known as the BIQ (Bio Intelligent Quotient) house, it is the result of collaboration between a group of architects, engineering and design companies, including international consultants Arup.

Associate Director Dr.-Ing. Jan Wurm, Arup's head of Europe re-

[1] **The percentages shown are for a single-family home built before 1970. This example is not universally applicable. Each house should be considered on its own merits.**

search and lead on the BIQ house, describes the new technology as "bio-utilisation". "We are creating micro-algae to generate heat and biomass, so it is a biological process just like a plant or a tree growing. It all follows on from the same photosynthesis, it's just that we do it in a controlled environment," explains Wurm.

The BIQ house features a façade, composed of bioreactor façades, that traps micro-algae in water between two plates of glass. Exposed to sunlight, the micro-algae double their mass every seven hours through photosynthesis. This green "skin" creates a natural shade to cool the inside of the building.

The algae also provide the house with two possible sources of energy. The first is the solar thermal heat captured by the water trapped between the glass plates. The sun's rays heat the water and, as it contains green algae, it heats faster than clear water. The heat can be drawn out of the water as it passes through a pump room and then stored underground for future use. The second energy source comes from harvesting the algae themselves. To do this, oxygen is pumped through a central floatation device so that the algae can be skimmed off the surface. The algae can also be fed into the building's biomass plant to create methane as a power source.

"The system brings together different flows and cycles, such as water, carbon, heat and even food, if you want. So you can create an industrial symbiosis," explains Wurm. "For example, if you are creating CO_2 emissions on your site, you can take those emissions and feed them into the façade." It is this idea of the building being incorporated into the natural cycles of its environment, along with the opportunity to design with a living façade that changes throughout the day, that is exciting architects.

"What is interesting about it is the turbulence from the rising bubbles, but also the way that it changes color throughout the day and across seasons. You can use reflecting glass on the back so the bubbles create a glare effect, print interlayers, whatever you like," he says.

There is clearly no single silver bullet solution to our energy problems. The powerhouse of the future

The CasaE in São Paulo, Brazil, exhibits innovative products and technologies that can make significant energy savings possible.

CasaE

By 2050, around 75% of the world's population will live in cities. How do we meet rising demand for urban housing without it costing the earth? This is a challenge facing countries everywhere.

Built in the business district of São Paulo, the CasaE is Brazil's first energy efficient house. BASF and partners have built CasaE to showcase to architects, builders and the general public in Brazil innovative products and technologies that can make significant energy savings possible.

Covering 400 square meters of building area, the combination of smart building materials means that CasaE consumes up to 70% less energy than a conventional house. But the first thing that strikes visitors to the house is its design. It is a modern, elegant building, filled with light that creates bright, functional living spaces. And although it is situated in a busy part of São Paulo, thanks to acoustic insulation, the sounds of the outside world are completely shut out once the front door is closed.

Insulation plays a big role in producing the energy savings, protecting the interior from heat and cold alike. BASF's Neopor® expanded polystyrene insulation was used in the construction system, along with the rigid polyurethane foam Elastopor®. Inside the house, the walls contain Micronal® PCM (Phase Change Materials), a material that absorbs and releases heat depending on the temperature – providing a form of air conditioning without electricity.

Other new materials have helped to cut the amount of water used in the cement by 40%, while lowering CO_2 emissions during construction. Special paint pigments prevent solar radiation absorption, helping to keep the building's temperature low. Other specifically created paints protect the building from the ravages of the tropical climate, making it resistant to the effects of sun, rain and humidity and preventing the spread of algae and fungi.

The materials throughout the house have been chosen for their durability or reusability.

CasaE is open to all visitors wanting to learn about how sustainable homes can be developed affordably in Brazil and beyond.

To find out more, visit: www.casae.basf.com.br

will be a mixture of many technologies. The bioreactor façade is designed to work in harmony with other energy transformation techniques.

It is here that Wurm talks of the interconnected city, the city as an organism where different technologies exchange and provide usable energy in symbiotic networks. It is here that the living city starts to take shape, which is why bioreactor façades are generating so much interest.

Keeping heat in

But what about existing buildings? While transpired solar collectors and third generation photovoltaic could, in the future, be adapted for retrofitting, bioreactor façades are not the kind of thing that can be bolted to the front of your average home.

One cutting edge development that is being targeted at the domestic retrofit market is smart insulation. Increasing thermal efficiency without compromising aesthetics is the key goal. BASF has, for decades, developed insulation materials with different characteristics. Over the past seven years, it has been working on a new form of insulating material, called Slentite™, that contains pores on a nanoscale.

Now at the pilot production stage, it is a pure polyurethane aerogel that has all the necessary strength and provides high efficiency insulation, while being between 25 to 50% thinner than an equivalent insulation. Its unique quality is its ability to absorb and release water vapor, regulating moisture inside the building. "We see retrofit as well as new builds as its main application, both as an interior and exterior insulation," explains Dr. Marc Fricke, who heads the team at BASF that created the new material.

The Passive House in China

Insulation has been a driving force for one of the most significant recent developments in sustainable housing – the Passive House. A German concept, the Passive House provides an airtight, highly insulated shell that can reduce heat loss to the point where year-round comfort is achieved without a heating system.

It is a concept that has caught the attention of the Landsea Group, one of China's largest real estate companies, which opened the country's first Passive House, the Bruck project, in April this year.

Built in Changxing County, Zhejiang Province in Southern China, an area known for its cold winters, extremely warm summers and high humidity, the Bruck project is a hotel for delegates visiting a nearby research centre which showcases the Passive House concept. Landsea believes that if it can demonstrate that the Passive House works in Changxing's difficult climate, then it could be adopted in other parts of China. "These technologies could be widely applied in China, but we need to select the most suitable design and technologies according to local conditions in each different climate zone," explains Kai Zou, Civil and Sustainability Engineer at Landsea.

With the Chinese government placing more emphasis on the need for sustainable housing, China's construction industry is becoming more receptive to new ideas about reducing energy consumption. Landsea believes that now is the right time to champion the idea of the Passive House in one of the biggest housing markets in the world.

Algae façades, photovoltaic paints, smart walls and roofs, living buildings that do away with conventional energy sources – all this may still sound futuristic. But if the new breed of entrepreneurs and academics are successful, these cutting edge technologies will be appearing in buildings where we live sooner than we think. ▪

"For example, if you are creating CO_2 emissions on your site, you can take those emissions and feed them into the façade."

Associate Director Dr.-Ing. Jan Wurm, Arup's head of Europe research and lead on the BIQ (Bio Intelligent Quotient) house

To find out more, visit:
www.biq-wilhelmsburg.de
www.polyurethanes.basf.com
www.slentite.com

Cool Ideas

Al Bahar Towers

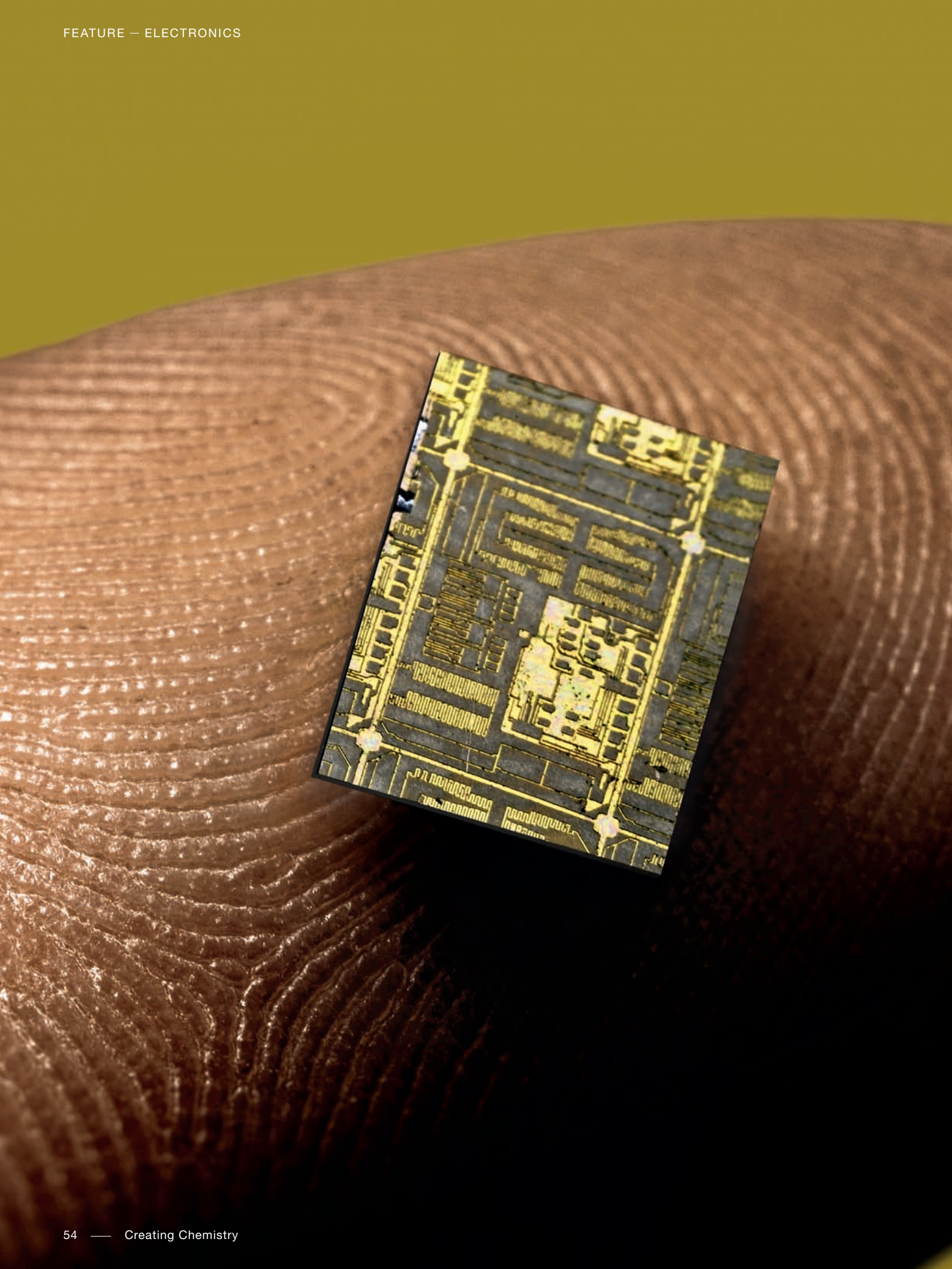
In Abu Dhabi, where intense sunshine and heat are the norm, keeping buildings cool is the priority. The two most recent buildings to emerge on the city's skyline, the Al Bahar Towers, have taken their inspiration from the mashrabiya, a lattice screen used in traditional Islamic architecture to provide shading. The towers are insulated and cooled by a dynamic intelligent façade. The outer screen of the building is programmed to respond to the sun's movement to provide those inside with shade.

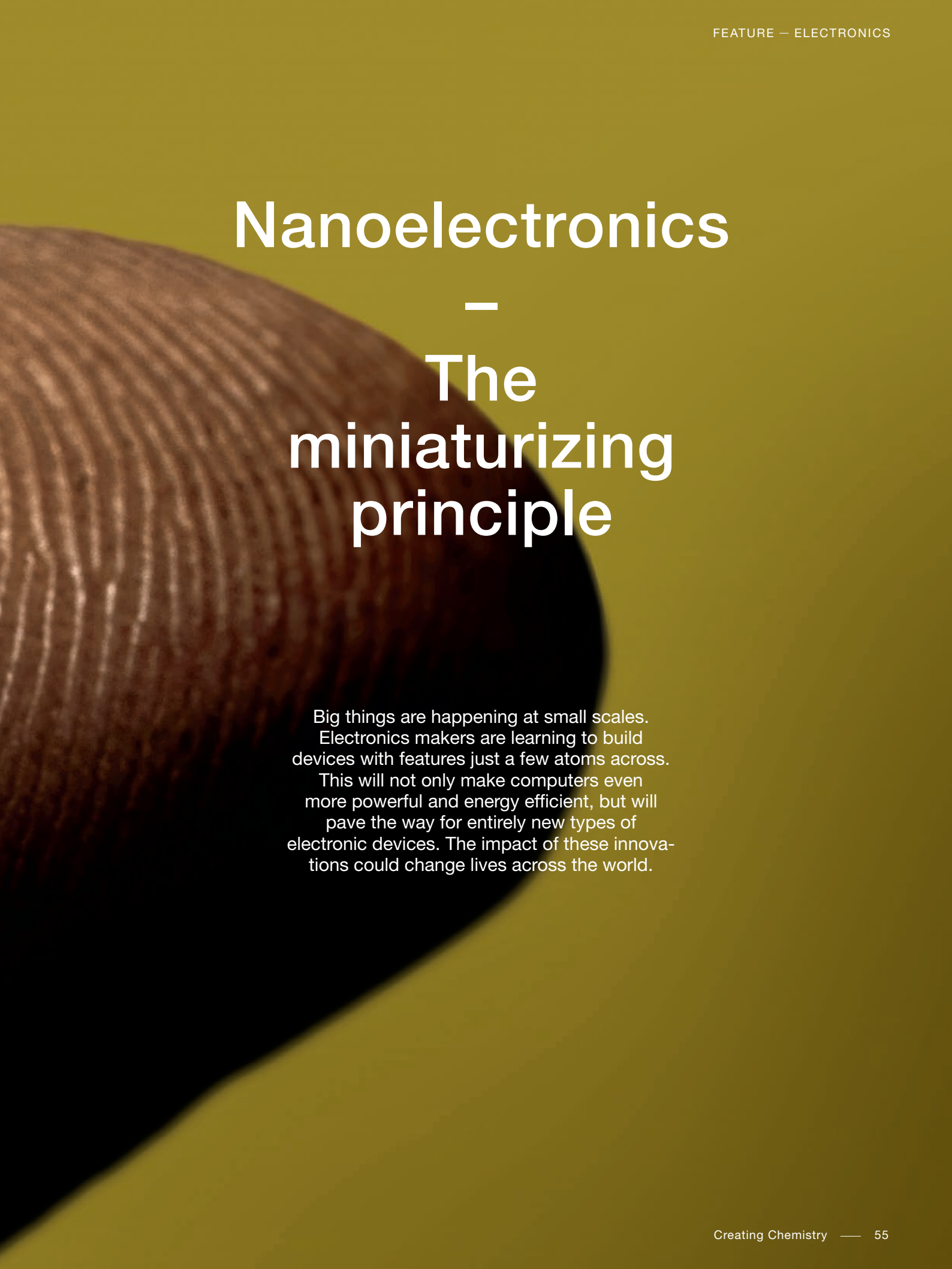
Onlookers have described the effect as like thousands of umbrellas opening and closing in response to the sun's movements. By incorporating this shade technology, the architects, Aedas, have done away with the use of dark tinted glass, which has the disadvantage of restricting the amount of natural light that enters the building. The 25-storey twin towers require less air conditioning and artificial light than an equivalent office space, and so energy consumption is reduced by 50%.

Harvesting electricity from running water

Researchers at Seoul National University have developed a way of using the motion of water as a sustainable source of energy. The new technique uses a characteristic of dielectric materials – substances, like porcelain, glass and plastics, that are poor conductors of electricity but can help support an electrostatic field to generate power.

The South Korean scientists have found that if a dielectric material is placed into water, an electrical layer forms around the outside of the material. It is the variation between the water and the dielectric layer that generates the electric charges on an electrode. Working with Korea Electronics Technology Institute, the team has adapted a simple dielectric transducer to harvest the power. They found that the movement of a single 30 microlitre water droplet generated enough power to light a green LED. The discovery opens up the possibility of harvesting energy from flushing toilets and rainwater running off buildings.





Nanoelectronics – The miniaturizing principle

Big things are happening at small scales. Electronics makers are learning to build devices with features just a few atoms across. This will not only make computers even more powerful and energy efficient, but will pave the way for entirely new types of electronic devices. The impact of these innovations could change lives across the world.

Imagine a complete clinical diagnostic testing laboratory in a disposable box the size of your thumb, or spectacle lenses that not only display tomorrow's weather forecast on demand but also charge your cell phone battery. Devices like these are just some of the possibilities enabled by nanoelectronics – an approach that exploits the unique properties that emerge when materials are shaped and combined at the tiniest of scales.

"Nanoelectronics involves devices which have features less than 100 nanometers in size, and where that feature size defines the functionality of the device," explains Professor Jo De Boeck, Ph.D., Chief Technology Officer and Executive Vice President of Imec, a Belgian nanoelectronics research center. 100 nanometers (nm) is very small indeed: one ten thousandth of a millimeter, around the size of a flu virus. "Down at that scale, you see dramatically different characteristics," continues De Boeck. "You see quantum effects. You can tweak the electrical properties of materials or shift the wavelengths of laser light."

Today's mainstream electronic devices sit firmly in the nanoelectronic space. The most advanced integrated circuits (IC), or computer chips, consist of billions of transistors with features 25 nm across or smaller. "Nanoelectronics has already changed our lives," says De Boeck. "It is the reason we don't burn our hands when we make a call on a modern cell phone, and that we have very high resolution displays on our mobile devices and laptops."

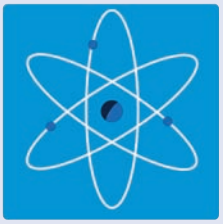
Indeed, our ability to engineer objects with features 1,000 times thinner than a human hair has arisen largely as a consequence of more than half a century of evolution in the power and efficiency of the integrated circuit. "Moore's law", proposed in 1965 by Gordon Moore, co-founder of Intel Company, stated that the number of transistors that could be squeezed onto a single integrated circuit would double roughly every two years.

Since then, the industry has continually found ways to meet Moore's predictions, by adopting new materials and new manufacturing techniques that allow it to cram ever more and smaller components onto a silicon wafer. Today's state-of-the-art integrated circuits have features only 22 nm across, and researchers are working on designs half that size again. As they start to include features just a handful of atoms in size, however, they are coming up against some hard physical limits.

Pushing the limits

"There are three ways that manufacturers can increase the performance of chips," says Claus Poppe, Vice President of Electronic Materials at BASF. "The first is shrinking the transistor size. This is what Moore's law is about. However, the industry accepts that 5 nm for the transistor gate length is as small as it can go, and it expects to get there in the next 10 years. The second way is to use new materials, like cobalt or germanium, to replace or augment the silicon used today. The third is in geometry, with the replacement of today's basically two dimensional designs with 3D ones."

The industry's ability to achieve its next evolutionary aims will depend in part on the right chemistry. The vast majority of steps in the 600 to 1,000 process cycles required to build a state of the art computer chip require chemical inputs (see graphic on page 57) and every evolution of the chip makes new demands on those chemicals. "As you get down to the nanoscale, our chemical know-how becomes a key success factor," says Lothar Laupichler, Senior Vice President, BASF Electronic Materials. One of his units – headquartered in South Korea – employs two thirds of the staff in the company's worldwide electronics business, an indication of the significance of Asia to today's global IC business, and of the importance of close collaboration in developing increasingly tailored materials for it. "In order to achieve innovation at this nanoscale, you have to understand interactions at a molecular level which also demands an extraordinary degree of purity", says Boris Jenniches, Vice President, Business Management BASF Electronic Materials Asia Pacific, and responsible for this unit.



Electron

The ancient Greeks observed that amber attracts dust when rubbed. When 19th century scientists discovered the existence of a fundamental particle with a negative charge, they named it after the Greek word for amber: ήλεκτρον (ēlektron).

Today, we understand that the electron is the glue that holds our world together. Electrons link atoms to create molecules: all of chemistry is based on the quantum characteristics of electrons.

Our ability to control the movement of electrons underpins much of modern life, from the energy we use to light our homes and power our factories to our information technology and communications infrastructure.

Scientists and engineers are recently finding new ways to exploit characteristics of electron behavior, like their ability to "tunnel" through thin layers of otherwise impassable material.

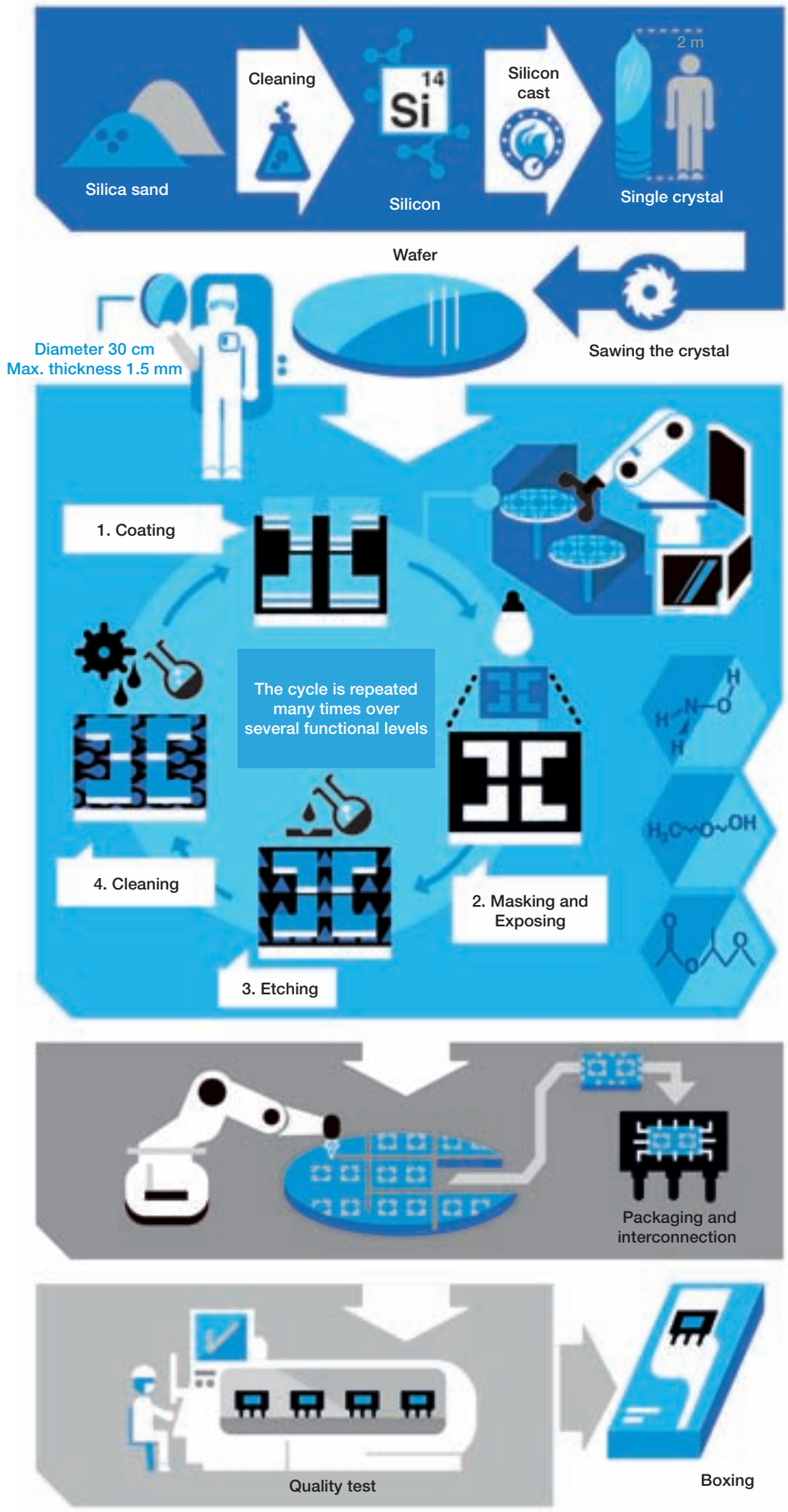
Purity matters because, at the nanoscale, even a few stray atoms of the wrong material can make the difference between a working circuit and a faulty one. Checking that BASF's electronic materials meet the cleanliness levels demanded by its customers is a key part of Jan Willmann's role. He is Operations Manager at the Competence Center Analytics Clean Room Lab at BASF in Germany. "We are trying to detect contamination at levels of between 10 and 100 parts per trillion," says Willmann. "That's a level where, if you showed the sample to somebody in the pharmaceutical industry, they would say 'we can't see anything at all, this is perfectly clean'." (See clean room report on page 59)

Faster, cheaper, energy efficient

The ability to shape and manipulate materials with extraordinary precision at the nanoscale is creating opportunities in a number of areas beyond conventional chip design. Many of the key limitations of conventional batteries come from their physical construction. To build better batteries, engineers want to increase the effective surface area of the anode and cathode to make it easier for electrons to flow between them. "Shaping the electrode surface in 3D at the nanoscale allows this to happen," explains Philip Pieters, Business Development Director, Energy Technologies at Imec.

Researchers hope that such batteries will not only store more energy than conventional designs, they'll also be much faster to charge, paving the way for electronic devices and even electric vehicles that can be recharged in minutes rather than hours. As well as nanoscale batteries, Pieters' research team is working on high precision printing technologies that can be used to apply ultra-thin layers of electronic materials in a range of other areas. Printable photovoltaics, for example, will eventually allow buildings to generate electricity from the sunlight falling on their façades and windows, or even from the otherwise wasted interior light hitting interior walls and ceilings.

How to make a chip



University of California Los Angeles' spin-off Aneeve Nanotechnologies has developed an approach that allows electronic circuits to be printed onto a wide variety of substrates. "The printing process isn't just cheap and energy efficient compared with conventional chip manufacture, it offers other environmental benefits too," says Aneeve CEO Kosmas Galatsis. He says, the carbon nanotubes used by Aneeve are "safe, sustainable and earth-abundant" compared to some of the rare-earth materials like tantalum and indium required in much of today's conventional electronics.

Aneeve's approach allows circuits to be applied to transparent materials in such a way as to be invisible to the naked eye. The company hopes that this will dramatically reduce the cost of manufacturing robust, flexible displays or wireless communication capabilities. This could enable new wearable technologies, like glasses with built in displays that could offer an "augmented reality" experience: floating direction arrows to help navigate an unfamiliar city, say, or customer reviews and opening hours next to nearby stores and restaurants.

Seattle-based Heapsylon, a start-up established by a group of former Microsoft employees, meanwhile, is taking a more intimate route, using nanoelectronics technologies to build sensors directly into clothing. Its products, which include pressure-sensing socks for runners and bras and t-shirts that can measure the wearer's heart rate, are claimed to be soft to the touch and completely machine washable.

The lab on a chip

As well as taking integrated circuit manufacturing technologies into wider applications, nanoelectronics is being used to build entirely new capabilities into chips themselves. The same technologies that allow chip-makers to etch shapes and apply different materials to make transistors can also build tiny pipelines, minuscule sensors and miniature machines. Earlier this year, Imec entered a partnership with Johns Hopkins University in Maryland, United States, to pursue the development of nanoelectronic medical diagnostic systems. "We envision a device the size of a USB stick that could conduct many of the diagnostic tests that currently take place in laboratories," explains Liesbet Lagae, manager of Imec's life sciences program.

A t-shirt that measures heart rate and socks that monitor pressure? It's not science fiction but possible today thanks to Heapsylon nanotechnology.

Using sensors embedded into chips, the Imec team hopes to be able to conduct an array of tasks, from pregnancy testing to the identification of antibodies for viruses like HIV and even the analysis of DNA. "We have all the basic building blocks in place," says Lagae. "We understand the microfluidics so we can build tiny capillary pumps into our circuits that mean the sample effectively sucks itself through the chip. We can do PCR (Polymerase Chain Reaction), used to amplify DNA prior to testing. And we know how to integrate biomarkers into our circuits that generate an electrical or photonic signal when they are exposed to particular enzymes or antibodies."

There is still work to do before the Imec Johns Hopkins team achieves its vision, however, and as with conventional chips, much of that depends on the development of the right chemistry. Integrating delicate biological molecules into chips remains extremely challenging. "We need to overcome issues of shelf-life," explains Lagae. "The biomarkers need to be stabilized so they don't break down before use, and that hasn't yet been done in the silicon environment." There are manufacturing challenges too; several of the steps used to produce a conventional chip require the application of high temperatures, which could destroy delicate biochemicals.

"A diagnostic test that takes less than 10 minutes and costs less than $10 could transform healthcare in many parts of the world."

Dr. Robert Bollinger, Johns Hopkins University

The long-term implication of nanoelectronics in biomedicine could be transformative, says Dr. Robert Bollinger, who leads the biomedical nanoelectronics program at Johns Hopkins University. "The ability to conduct testing at the point of care, wherever that is, will improve access to high-quality treatment and reduce the need for dedicated medical facilities."

But it is the electronics industry's ability to manufacture huge quantities of its tiny products cheaply that could really change the world. "Because nanoelectronics can make use of the manufacturing scale of the semiconductor industry, it creates the potential to deliver these capabilities at high volumes and very low cost," says Bollinger. "A diagnostic test that takes less than 10 minutes and costs less than $10 could transform healthcare in many parts of the world."

To find out more, visit:
www.heapsylon.com
www.basf.com/computer-electronics

Clean room supreme

Chemicals for semiconductor electronics manufacturing are tested for purity in BASF's cleanroom lab. The manufacture of microchips, which are found in nearly every electronic device from computers to single lens reflex cameras these days, would not be possible without them.

Melanie Bauer is dressed in light-colored coveralls, wears face-hugging safety goggles and has her hair up under a cap. She could be taken for a surgeon ready for an operation. As a matter of fact, her work at BASF takes place in a highly sensitive environment: the clean room lab of the Competence Center Analytics. Elemental analytics experts work closely with BASF's Electronic Materials unit. Samples of highly purified chemicals undergo final testing here before going out to customers all over the world.

Before Melanie Bauer enters her workplace, she passes through an airlock and is blasted in an air shower lasting about 30 seconds that removes the tiniest of contaminating particles from her clothes and hands. Things other people take for granted, like having a cup of coffee or visiting the bathroom, are a lot more complicated in her job than elsewhere. She has to change her outfit every single time and repeat the whole procedure – but that's no problem for the chemical laboratory assistant: "It's just routine in the meantime."

She and her similarly clad colleagues are well aware of the fine points of their job. Their task in the clean room lab is to analyze the special chemicals required in the meticulous microchip production process. The continuous reduction in the size of electronic components over the years has placed increased demands on the chemicals necessary for their production. The rapid pace of development in the electronics industry requires ever greater quality control. The input of chemistry has helped to make computers faster than ever before and to come up with increasingly smart mobile phones that can do just about anything you want.

Hundreds of production steps are involved in turning ordinary silica sand into millimeter-thick wafers and then going on to produce complex microchips. Even then, they won't work unless the most stringent cleanliness standards have been complied with during the production process. When a surface area of barely a single square centimeter is teeming with as many as a billion transistors, even the tiniest of particles that would be invisible to the naked eye could have disastrous consequences and result in entire production runs having to be discarded.

Any surface irregularities on microelectronic components must not exceed a tolerance of more than a few nanometers – if that. A nanometer is to a meter what a football is to planet Earth. "You wouldn't believe the absolutely miniscule levels of contamination we can detect here," Bauer says, sitting down at a flow box to prepare an ammonium hydroxide sample. The flow box is a lab workstation that looks like an open-bottom aquarium and meets the stringent clean room requirements. An inbuilt filter system draws in ambient air, removes dust particles from it and returns it to the circuit in the form of highly concentrated fresh air.

"Measurement precision is getting better all the time due to continuous improvements in the methods and equipment," says Alexander Honacker, who has worked in the lab since it first opened 15 years ago. To give an idea of the level of precision that applies when reviewing sample contents for compliance with the applicable limits, he has an example to offer: "We could detect a sugar cube in a mountain lake."

In addition to the rapid advances in analytical equipment and programs, the human factor is important, too. The skills of the dozen-or-so staff members and the care they exercise in the lab are crucial to the quality of the measurements obtained. For example, special devices are used for specific chemicals and samples are taken using high purity pipettes. Staff members wear gloves as a matter of routine and make sure not to brush against an experimental setup with a hand or arm. The standards of cleanliness in the lab sometimes cross over into everyday life. "I've developed a very special view when it comes to hygiene," Honacker admits. "After emptying the dishwasher, I sometimes rinse the dishes one more time."

To find out more, visit: www.basf.com/analytics

Even the tiniest specks of particulate matter are enough to ruin entire production runs. The picture shows Melanie Bauer concentrating hard as she works on samples in the flow box.

Pioneering thinker – then

Heinrich Caro

The German chemist first synthesized methylene blue in 1876.

Making dyes is one of the oldest human activities. Since ancient times, dye recipes have been handed down across generations. Until the mid-19th century, the basic ingredients came from plants. But with the advent of the industrial revolution and the rapid growth of the textile industry, natural dyes could no longer satisfy growing demand.

This was the world in which Heinrich Caro started his career. Chemistry was an exciting, fast-developing area. After the first synthetic coal tar dye, mauve, was obtained by William Perkin in England in 1856, chemists throughout Europe discovered a huge range of synthetic dyes, whose brilliant colors attracted high prices. Science and industry were at the beginning of their close and profitable cooperation.

Born in 1834 in Posen, Prussia (today, Poznań in Poland), Caro trained at the Gewerbeinstitut in Berlin as a textile colorist, at the same time attending chemistry lectures at the university. He got his first job in 1855 as a colorist at a calico printing company in Mülheim an der Ruhr, where natural dyes were still in use. The company sent him to England to learn the most up-to-date techniques, including advances in the use of steam. He eventually took up employment there for the Manchester chemical company Roberts, Dale & Co. Gradually he made the transition to becoming a fully-fledged industrial organic chemist, and made a series of discoveries, including a more efficient synthesis of mauve.

Caro was drawn back to Germany in 1866, where the new chemical firms provided exciting opportunities. He brought with him, from his time in England, an approach that fused academic, research-based science with an understanding of the commercial needs of industry. This proved highly fruitful in his position as the first head of research of the Badische Anilin- & Sodafabrik (BASF) in Ludwigshafen.

It was here, in 1876, that, while experimenting with a new intermediate product, he succeeded in synthesizing a pure blue dye for cotton, methylene blue. A year later, BASF was awarded Germany's first patent for a coal tar dye for methylene blue.

Caro went on to become a leading spokesman for the German chemical industry, helping to develop patent law to protect chemical inventions, and his groundbreaking work at BASF played a key role in the foundation of the German coal tar dye industry. He joined BASF's Board of Executive Directors in 1884 and, six years later, transferred to the company's Supervisory Board. He died at the age of 76 in Dresden in 1910.

And methylene blue has gone on from playing an important role as a dye to having a wide variety of uses in medicine and hygiene. ◘

Methylene blue:
a synthetic dye of many talents

Methylene blue revealed its medical talent in 1886 when the budding doctor Paul Ehrlich noticed a curious phenomenon during his experiments: methylene blue, a dye recently synthesized by BASF, turned live neurons blue – and had the same effect on plasmodium (the parasite that causes malaria) in human blood. Ehrlich concluded that the dye might be used for selective targeting of malaria in the human body. A few years later, he tested methylene blue as a remedy to treat swamp fever – with success. For the first time ever, Ehrlich cured an infectious disease with a synthetic substance. However, quinine was already established as an antimalarial and the dye vanished into oblivion. That's how things stayed until malaria started becoming increasingly resistant to the drugs currently in use. Then, several years ago, Professor Dr. Olaf Müller at the University of Heidelberg began looking into the blue dye. He found out that methylene blue is superior to all known antimalarial agents in important properties. In fact, it is probably the most effective drug to inhibit the transmission of infection. BASF is funding the project at the University of Heidelberg.

Pioneering thinker – now

Claude Wischik

The French-born scientist discovered methylene blue's potential as a treatment for Alzheimer's.

When Claude Wischik arrived at Cambridge University in 1980 to do a Ph.D. under Professor Sir Martin Roth, scientists around the world were trying to work out the cause of Alzheimer's – a disease that affects tens of millions, but for which no effective treatment exists.

Dr. Alois Alzheimer, who first described the disease in 1906, had identified thick fiber tangles in the brains of sufferers. Decades later, Roth established a correlation between the formation of tangles and the degree of dementia. He gave Wischik the task of finding out what the tangles were.

Wischik, born in France and raised in Australia, did not set out to play a pivotal role in Alzheimer's research. His first degree was in mathematics and philosophy. He only came to medicine, he says, because meeting his wife-to-be made it clear to him he "needed a proper job". "The trouble was," he says, "I found myself becoming increasingly interested".

Working in the lab at Cambridge, Wischik had to isolate the tangle before he could identify it. Colleagues suggested using the dyes alcian blue and dimethyl-methylene blue on the samples. To Wischik's surprise, they blew the tangle fibres apart. As unexpected as this was, it gave him the idea – if you could create a drug that would dissolve the tangle, could this be the basis of a treatment for Alzheimer's? "I was intrigued," he says. "I spent a night in the library looking up compounds. That's when I hit upon methylene blue. The key was, it also dissolved the tangles and had already been used psychiatrically – that meant it got into the brain."

Wischik discovered that the tangles are made of tau, a protein normally present in the brain but which, in Alzheimer's patients, folds back on itself and aggregates into oligomers which propagate themselves. His hope was that he had found a way to prevent tau aggregation. The theory now had to be put to the test.

Together with investors, he founded the company TauRx and set about launching a phase 2 clinical trial. By now, he had taken up the Chair of Mental Health at Aberdeen University, in Scotland. Here he met organic chemist, Professor John Storey. "Storey's role was crucial," explains Wischik. "Methylene blue is a fairly impure dye. Although it had been used as a pharmaceutical, it had not been manufactured to the standard required for long-term dosing. With Storey's help, we were able to create a suitably pure form, called rember®."

The phase 2 trial results were impressive: The drug arrested the progression of Alzheimer's for two years. The team is now carrying out a global phase 3 trial, this time using a novel stable, reduced form of the drug, called LMTX™, that is more easily absorbed and better tolerated.

"Methylene blue is the scaffolding we used to get to where we are," says Wischik. "Our hope is that LMTX™ will be the first disease-modifying treatment of Alzheimer's."

How do tabs make dishes shine?

Dishwashers make life easier, that's for sure – but without the right dishwashing tabs, dishes would still be pretty grimy after the final rinse. So how exactly does one small tab manage to get dirty dishes, cups and glasses sparkling clean?

Dishwashing tabs get dishes sparkling clean and remove even the toughest tea and coffee stains.

People expect a lot from dishwashing tabs: spotless dishes, gentle action, limescale prevention – and effective at low temperatures as well. To do all this, a variety of finely tuned interactive components are needed: surfactants to make grease soluble in water; enzymes to break down chain molecules like starch from flour and potatoes and proteins from meat and dairy products into their constituents ready for rinsing from plates and pots; and bleaching agents to remove tea and coffee stains.

About half of a conventional all-in-one tab consists of phosphates. Among other things, phosphates prevent the buildup of unsightly, white limescale marks by binding the responsible calcium and magnesium ions in the dishwater. Ecologically, though, phosphates have a bad reputation. As phosphorus is important in plant nutrition, phosphates can cause algal bloom in aquatic systems. The plants use up the oxygen in the water and may bring lakes and rivers to "tipping point." This problem has already been tackled through the introduction of stricter phosphate limits for detergents and modifications in sewage treatment plants. Tougher regulations are likely to come. The expectation is that phosphate will be banned as an ingredient in dishwashing tabs in Europe starting in 2017. Such a ban has already been in force in 16 US states since 2010.

A more ecological alternative with undiminished tab performance was needed. BASF stepped in to meet the need with a readily biodegradable chelating agent called Trilon® M. In combination with polymers and other excipients, the agent binds the water hardness ions (Ca^{2+} and Mg^{2+}) responsible for leaving chalky deposits on dishes and also removes persistent tea and coffee stains. Chelating agents literally "get to grips" with their target ions, and that is where the name comes from: "Chele" is Greek and means "pincers".

To find out more, visit:
www.basf.com/en/trilon-m

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