



The Chemical Company

Creating Chemistry

For a sustainable future

Issue two 2012

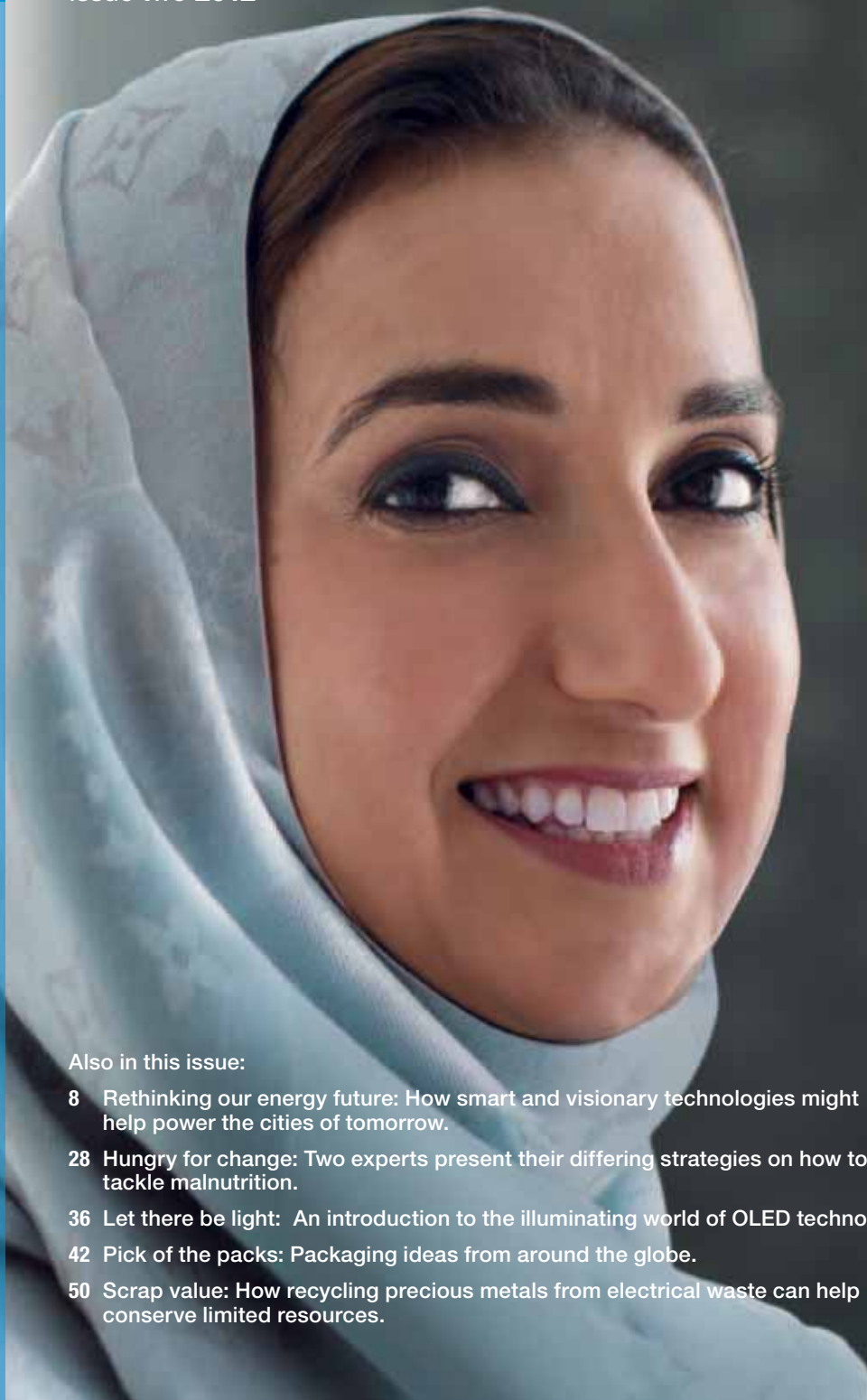
A role model for sustainable energy use?

Director of Sustainability
Dr. Nawal Al-Hosany (photo)
presents the ambitious Masdar
City energy-saving project.

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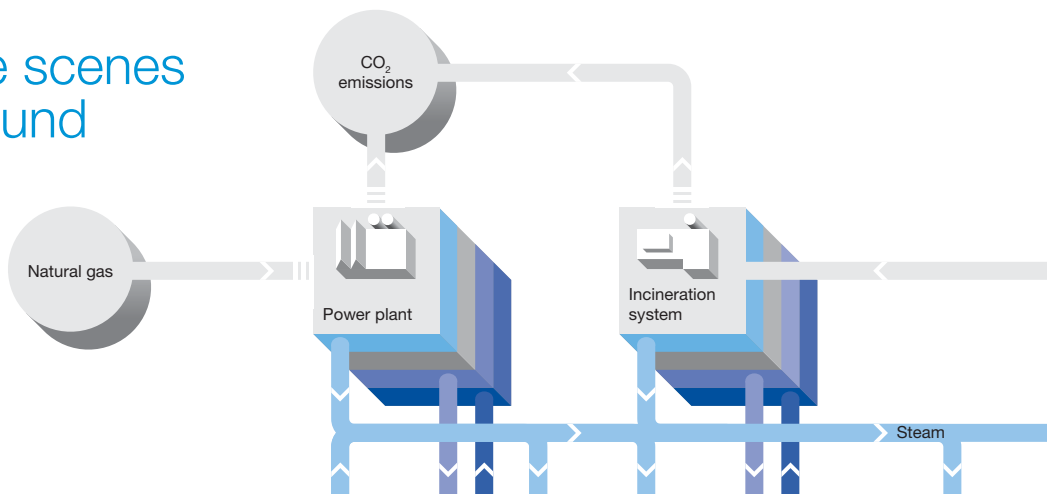
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Welcome



How can we use energy efficiently?

Everybody needs energy – to keep our homes cool in the summer and warm in the winter, to keep our economy going and to connect with each other worldwide. Our needs are growing daily: By 2050, humanity will consume two to three times more energy than it does today.

Energy efficiency is the focus of this issue of *Creating Chemistry*. This was the concern mentioned most frequently in our last reader survey. Of course, we are very keen to hear your views this time, too. Please let us know what you think of this issue at www.basf.com/creatingchemistry.

For BASF, energy efficiency is crucial. We require lots of energy, and it costs money. This is why we have been striving for decades to manage resources carefully. For example, we use the heat produced as a by-product from one plant to provide energy for another (page 20).

But energy efficiency has another dimension for us. We are working on solutions that help you save energy, too. For example, we are researching organic LEDs that are not only economical to use but also completely reinvent artificial light (page 36).

Renewable energy demands innovations from the chemical industry. Our products can be found in wind turbines (page 24) and solar installations. There are many other ideas and methods of producing energy, as well: In New York, for example, excess pressure in the drinking water system is being converted into electrical energy (page 10).

We need progress of this kind because our planet's resources are limited. The breakthroughs we are seeing now are just the beginning. I am convinced that in five or ten years, we will be able to find other answers and ways of doing things even better.

A handwritten signature in black ink, which appears to read "Kurt Bock".

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

The world in figures

50

The number of countries that require mandatory fortification of certain staple foods with specific nutrients to improve public health.¹
See **Better nourishment for all?** on page 28.



Food and nutrition

30%

Around one third of all the food produced worldwide – 1.3 billion metric tons – is lost or wasted every year.²



Resources, environment and climate

\$110*

The amount that the average household could save every year by turning off electrical devices and lights when leaving a room.³



\$4.4 billion

The estimated value of the global market for energy harvesting by 2021.⁴
See **Energy harvesting** on page 14.

*In this issue the conversion of euros to U.S. dollars is based on the average exchange rate on December 31, 2011, when €1 cost \$1.2939. The \$ symbol always refers to U.S. dollars.



\$1

The value of the gold typically found in a single cell phone.⁵
See **From trash to treasure** on page 50.

Resources, environment and climate

100

The number of vehicles that would cause as much pollution as just one vehicle produced prior to 1974, thanks to today's modern catalysts.⁶



20C

The reduction in average temperature in Masdar City (compared to outside of the city) possible through using traditional Arabic construction techniques.⁷
See **The diplomat for sustainability** on page 16.

Resources, environment and climate

20%

Masdar City's goal is to use just one-fifth of energy consumed by a similar sized city.⁸



Resources, environment and climate



40 million

The number of metric tons of electronic waste that are produced worldwide each year.⁹



90%

The percentage of the world's rare earth deposits that are found in China.¹⁰



252 meters

The predicted diameter of wind turbine rotor blades by 2020. In 1980, the average diameter of rotor blades was 15 meters.¹¹

Food and nutrition

25% of the world's population used iodized salt in 1990. Now it is more than 70%.¹²



1990 **25%** 2012 **70%**



2 billion

The number of people worldwide who suffer from malnutrition and other nutrition-related diseases.¹³



95 – 115 kg

The amount of edible food per person that is thrown away each year in industrialized countries.¹⁴

Quality of life



100

How many times thinner the diameter of the organic layer in organic light-emitting diodes (OLEDs) is compared to a human hair.¹⁵



20%

The percentage of the world's electricity consumption that is accounted for by generating light.¹⁶

1. www.foodinsight.org; 2. Food and Agriculture Organization of the United Nations (FAO): *Statistical Yearbook 2012*; 3. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; 4. IDTechEx: *Energy Harvesting and Storage for Electronic Devices 2011-2021*; 5. Jon Mooallem: *The Afterlife of Cellphones*, New York Times, 2008; 6. BASF Metals Recycling; 7. Masdar City; 8. Masdar City; 9. United Nations Environment Programme (UNEP); 10. European Commission; 11. European Wind Energy Association (EWEA); 12. Micronutrient Initiative; 13. World Health Organization (WHO); 14. Food and Agriculture Organization of the United Nations (FAO): *Statistical Yearbook 2012*; 15. www.oled-lights.org; 16. Dresden University of Technology

Staging a green revolution

November 26, 2010: Cate Blanchett stands on the roof of an old harbor building in Sydney known as “The Wharf,” the home of the Sydney Theatre Company. Immediately after becoming co-artistic directors of the theater, the Hollywood star and her husband set themselves the ambitious goal of transforming the heritage structure into a showcase for green building. Now, they are celebrating a major milestone with the installation of the second largest photovoltaic rooftop array in Australia. A lot has happened since then.

When Hollywood star Cate Blanchett and her husband, playwright and director Andrew Upton, became co-artistic directors of the Sydney Theatre Company (STC) four years ago, they not only focused on the repertoire, but also on the conversion of the heritage building housing the theater. With the “Greening the Wharf” project, they wanted to combine their two great passions: art and climate protection. “Theater is very much engaged in the time and place in which it is made,” says Cate Blanchett, explaining her motivation for the project (www.greeningthewharf.com). “And the greatest challenge facing us as a species at the moment is climate change. We felt that, as a theater company, if we did not engage with this incredible challenge we all face, then very quickly we would become irrelevant.”

Her goals are ambitious: to produce 70% of the electricity required by the theater and its restaurant onsite and to save 11.3 million liters of water each year – enough to fill four Olympic-size swimming pools. To achieve this, the Greening the Wharf project team focuses on measures such as an automated energy management system for heating, ventilation and air conditioning and energy-efficient stage lighting. “The project is ambitious and broad in scope,” explains Paul O’Byrne, STC’s Director

of Community Programs and the man in charge of implementing Greening the Wharf.

Shrinking the carbon footprint

In 2010, the building project marked its first major milestone: the rooftop installation of Australia’s second largest photovoltaic rooftop array. The 1,906 solar panels now produce about 427,000 kilowatt hours of electricity annually. To meet its water conservation targets, the theater installed a sophisticated rainwater recycling system. A gigantic tank under the pier supplies all the non-drinkable water used by the STC and its restaurant “The Bar at the End of the Wharf”. Now, drinking water is no longer flushed down the toilet.

These easy-to-implement measures have been highly effective, reducing the STC’s carbon footprint by 80%. With these results, the theater’s management has demonstrated that older heritage buildings can be ecologically transformed. “We believe that change is possible without a correlating loss of quality,” Blanchett said at a recent panel discussion called “Creating a Climate for Change”.

Waste is turned into biogas

Their drive for innovation did not end with the theater; Blanchett and Upton also investigated how to make the restaurant more environmentally friendly. Today, organic waste from the restaurant kitchen is converted into energy and fertilizer, while other waste is turned into biogas. “We are thrilled that the level of waste sent

directly to the landfill by the theater is being reduced,” says Patrick McIntyre, General Manager of the STC. The system had a positive impact almost as soon as it was installed, with a significant reduction in the amount of waste thrown away.

Promoting real changes in behavior and attitude is one of the more challenging goals of Greening the Wharf. As Blanchett explains: “One of the key roles of theater and the arts more broadly is to stimulate social change by bringing vision to action through forum, experimentation and debate.” The STC has developed a model that resonates far beyond the walls of the old harbor building: Not only does it aim to engage the neighboring district of Barangaroo and create a modern wharf area here, it also wants to inspire other art and cultural organizations around the world.

Green Award

To make these goals possible, around \$5.6 million (€4.3 million) has been invested in Greening the Wharf,



Above *The Histrionic* by Thomas Bernhard is just one of many plays on the theater’s 2012 program.

BASF’s new North American headquarters

Lowering the energy consumption of buildings is also an important goal for BASF. Its new North American Headquarters in Florham Park, New Jersey, which opened in May 2012 and provides room for 1,400 employees, is one example of BASF’s commitment in this regard. More than 30 BASF products were used during the construction of this 30,200 square meter (325,000 square foot) building. It meets the highest environmental standards and was designed to fulfill the requirements of the United States’ Green Building Council’s Platinum LEED® certification (Leadership in Energy and Environmental Design), which promotes sustainable construction techniques.

One of the special features of the headquarters is the efficient use of natural resources through intelligent systems. In comparison to conventional buildings, this reduces water usage by at least 40% and energy consumption by more than 20%. Furthermore, at least 20% of the materials used come from recycled components. This is even true for the furniture: chairs were partly crafted from old plastic bottles, with each seat containing 111 recycled items of packaging.



Left On the roof of Sydney Theatre Company in Walsh Bay: Cate Blanchett (right) and her husband, Andrew Upton (left), together with the chairman of Suntech, Dr. Zhengrong Shi, and his wife, Vivienne, inaugurate one of the largest solar rooftop arrays in Australia. This project was enabled by a donation from the chairman's family foundation.

All images courtesy of Sydney Theatre Company

provided by private donors as well as partners from politics, business and academia. The project was also supported by the Australian government's "Green Precincts Program". For project manager O'Byrne, the money is well invested: "The full project impact will require a few more years' data, but we know that the investment is already significantly reducing the financial burden that increasing utility costs add to our annual budget."

Greening the Wharf has provided the theater with an even more promising future ecologically, economically and socially. This achievement has recently been publicly recognized: Greening the Wharf has seen Cate Blanchett – already the recipient of an Oscar and two Golden Globes – honored further. Along with Andrew Upton, she was awarded two Green Globe Awards in 2010, one for Sustainability Excellence and one for Community Sustainability. ■

Cate Blanchett

Hollywood star and Academy Award winner Cate Blanchett takes a hands-on role in climate protection. Her declared goal is to reduce her personal carbon footprint by 13,300 kilograms. To that end, she and her husband Andrew Upton have not only carried out green renovations at the Sydney Theatre Company, but also at their home near Sydney. To promote climate protection more widely, the Australian actress has taken to the political stage. As a prominent advocate, she got involved in the emotional 2011 debate about the introduction of a carbon tax in Australia. Since 2007, she has also been Patron of SolarAid, an international NGO bringing solar power to developing countries.



To find out more, visit:
www.greeningthewharf.com

Towards a new future for sustainable energy use

Experts worldwide are developing innovative and visionary energy concepts for the future. Their aims are to find ways to use existing energy sources more efficiently and to improve the viability of alternative sources of power. The desired outcome is to take the pressure off more conventional means of producing energy while still meeting growing global demand. Some cities are beginning to establish themselves as pioneers of this new approach, but how successful are they?

A special train transports these rotor blades to their destination – a new wind power station in Australia.





The highways of California may soon be known not just for their endless distances. A bill recently adopted in the U.S. state will transform roads into small power stations that will harness the vibrations from moving cars. This phenomenon is called *piezoelectricity*; certain minerals are deformed and become electrically charged in response to applied mechanical stress. Sensors in the road convert this mechanical energy into electrical energy. On a two-lane, half-mile section of road, up to 44 megawatts can be produced, according to the proponents of this technology. The total energy generated from roads could be sufficient to supply 30,000 households with electricity. Although it is questionable whether these values can actually be achieved, the basic idea of harnessing small energy packets in our everyday lives is widely accepted.

Energy harvesting in everyday life

Using roads as mini power stations is a prime example of how new ways of producing energy are being sought, even in familiar areas of life. Energy harvesting, as it is known, describes the notion of producing small amounts of energy and electricity from our immediate environment in order to ultimately produce a significant quantity of energy. From hybrid cars, to watches that charge themselves through motion, and electronic tea lights that convert heat into electricity using a thermoelectric effect, there are opportunities to harvest energy everywhere. Although these methods are ridiculed by some as misguided, others see this as a viable means of producing energy in the future.

The equipment used to harvest energy works on a small scale in exactly the same way as large solar installations and wind turbines – even though it is not yet as efficient. It harnesses ambient energy that would otherwise be lost.

An alternative market is emerging; U.S. market research companies estimate global revenues from energy harvesting at \$663 million (€512 million) a year. By 2021, this should rise to \$4.4 billion (€3.4 billion). But many of the novel devices used to harvest energy have a problem: Compared to the cost of a conventional battery with the same power, they are still too expensive.

Water pipes producing energy

The search for economic and intelligent approaches to alternative forms of energy production is an important concern worldwide. Countries and cities have long sought to work out where new energy infrastructure might be created – but there is also new potential being discovered in existing systems. In the area's 'green lung' around 200 kilometers (125 miles) north of Manhattan, the reservoirs of the Catskill Mountains store the water supply for the whole of New York

City. A system of pipelines allows water to flow into the center moved by gravity alone, at a pressure that enables it to reach the upper floors of the city's highest skyscrapers without a pump. However, this high pressure becomes too much for pipes to withstand once they reach people's homes. A pressure regulator is therefore used to reduce the pressure in the urban water pipelines from more than 40 to just over 4 bars.

In the future, the New York company Rentricity wants to replace the pressure regulators with a flow-to-wire element – a turbine that will convert the excess pressure into electrical energy. Similar to wind and solar power, this process does not produce any emissions. In the U.S. state of New Hampshire, Rentricity has already installed the first such generator unit in the water treatment plant for the city of Keene. This mini power station has an output of 62 kilowatts and supplies the plant with electricity.



Cities such as New York are focusing on innovative energy concepts. It is planning to use the excess pressure in its water pipes to produce energy.

Innovative urban planning

While cities such as New York are optimizing their existing structures, the planning of new housing developments often focuses on efficient energy use from the outset. This is demonstrated by an example from Asia, where a new wave of enthusiasm for saving energy has been building for some time.

In 2007, the Prime Ministers of China and Singapore signed a framework agreement for the construction of the “Tianjin Eco-city” covering an area of 31 square kilometers (12 square miles). Several companies from China and Singapore have equal shares in this \$9.7 billion (€7.5 billion) joint venture. The city is being built 40 kilometers (25 miles) outside the port of Tianjin in Northern China. With an integrated overall design, as well as the latest technology and incentives for environmentally friendly behavior, the aim is to keep the energy consumption of the city’s inhabitants to a minimum.

Developers are building the city entirely according to the tenets of efficient energy systems. Intelligent town planning ensures that distances are kept short, and a sophisticated recycling system and environmentally friendly local transport system are being developed. Desalinated seawater and recycled water are fed into the water supply chain, covering half of the city’s water needs. On roofs, solar panels and rainwater utilization systems ensure the supply of warm water. The energy for the planned 240,000 square meters (about 2,600,000 square feet) of residential and office space is produced by a small power station using solar cells and geothermal facilities. These renewable energy sources will account for one-fifth of the urban energy mix. The rest will be generated by coal, which is still used widely in China, but here too the focus will be on efficiency. Thanks to modern technology, the power stations outside the city will reduce

their annual coal consumption by 17,000 metric tons. In around 15 years, the city will be complete and will house a population of 350,000.

On a much smaller scale, but with similar environmental ambitions, Masdar City in the United Arab Emirates is also taking shape. The energy supply for this model city will come entirely from local, renewable sources (see interview on pages 16-19).

Clever grids

Cities and countries are also seeking innovative ways of securing their energy supply through measures involving their electricity grids. The city-state of Singapore, which does not have any raw material reserves of its own and is promoting

a self-sufficient energy supply based on alternative energy sources, is focusing on microgrids. These low-voltage grids are to be trialled on the small island of Pulau Ubin, which will be a test site for green energy technologies.

Microgrids are closed regional energy systems integrating decentralized energy producers, consumers, and sometimes storage facilities. These relatively small grids operate intelligently. They can be linked up to the higher-level grid or run separately from it, whereby the connection can be opened or closed according to needs.

Even if the central transmission or distribution grid fails, the microgrid continues to operate. The consumer can then take electricity directly from the decentralized generation units. >>



As far as renewable energy sources are concerned, a clear strategy toward economic viability is needed – even if this requires a continued commitment to state aid over a number of years in order to achieve it.

Maria van der Hoeven, Executive Director of the International Energy Agency



Above Maria van der Hoeven has been Executive Director of the International Energy Agency since 2011. In this role, she represents the major industrialized countries on energy matters on the international stage.



To find out more, visit:
www.iea.org
www.tianjinecocity.gov.sg

Energy-saving tips

Turn down the heating:

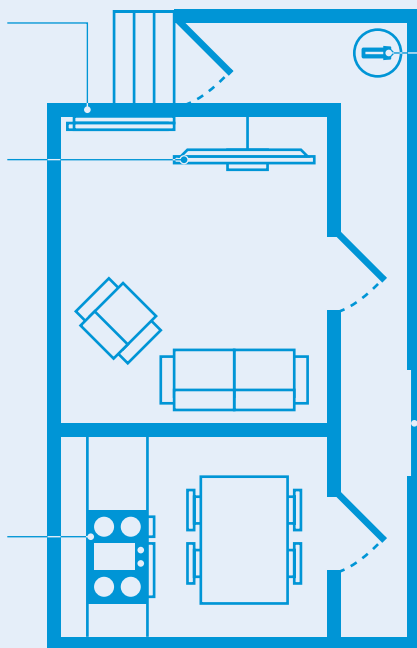
Lowering the temperature in the home by just 1.8F (1C) reduces energy costs by 6%.

Unplug appliances and switch off lights:

Don't leave electronic devices such as TVs, computers and stereos in stand-by mode, and turn lights off when leaving the room. This can save the average household around \$110 (€85) per year.

Get economical in the kitchen:

The kitchen offers numerous ways to save energy. Only fill your kettle with as much water as you need to boil, and place a lid over saucepans to conserve energy while cooking. Use the right-sized hob or burner, and regularly defrost the fridge-freezer – ideally twice a year.



Replace traditional bulbs:

Fluorescent tubes and energy-saving lamps use around a quarter of the energy of traditional bulbs. The U.S. Department of Energy claims that simply changing every bulb in the United States to an energy-saving model would cut CO₂ emissions by 400 million metric tons a year.

Insulate wherever possible:

Ensure that windows and doors around the home are fully sealed. Use a lit candle to test for drafts by observing whether the flame is blown out or flutters when close to window or door frames. Check how walls and roofs can be better insulated – infrared thermal imaging shows where energy is being lost. According to the German Energy Agency, the right insulation can lead to savings of up to 80%.

Source: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

Although they are less efficient in producing electricity than central installations, they ensure that a local energy supply is guaranteed in the event of disruptions to the central grid. These decentralized microgrids situated close to consumers enable the electricity grid to be stabilized when electricity needs rise. Together with a further expansion of central grids, microgrids can help in achieving the transition to a new energy era.

Corporate energy sustainability

In the past few years, more and more companies have started meeting their energy demands with their own wind parks and photovoltaic and biogas installations. In addition, many firms are attempting to increase their efficiency by producing more energy from fewer resources, and saving both money and energy by keeping heat losses to a minimum. One example is the LED factory of Siemens subsidiary Osram in Regensburg, Germany. Its design enables incidental heat produced by machinery to be captured and fed into other production equipment. According to Siemens, this saves the company around \$1.2 million (€900,000) in energy costs each year. The BASF Verbund system also shows how energy can be kept within

the cycle and reused, thus saving resources (see diagram on pages 22 and 23).

"By increasing energy efficiency, it might be possible to ensure that demand for energy does not rise at the same pace as economic growth," says Maria van der Hoeven, Executive Director of the International Energy Agency (IEA).

Van der Hoeven is also convinced that "we must not only try to use less and less in the way of old energy sources, but also guarantee that the costs of new energy sources reflect the true costs." This means boosting efficiency, but also phasing out fossil fuel subsidies and pricing in externalities (such as through carbon pricing) to make renewable energy sources marketable and competitive.

The political vision

According to van der Hoeven, governments can make a major contribution to the development and deployment of clean energy technologies and new energy sources "by giving greater support to research in this area and creating attractive underlying conditions for innovation and private investment." She sees the optimal energy mix of the future as a more efficient and cleaner use of fossil fuels in combination with renewable energy

sources and nuclear power. "As far as renewable energy sources are concerned, a clear strategy toward economic viability is needed – even if this requires a continued commitment to state aid over a number of years in order to achieve it," she stresses.

If politics and business work effectively together, a growing share of renewable energy sources in overall supply can become more than just a nice-sounding idea. That said, experts are divided on how quickly and to what extent this vision can become reality. For example, the German Advisory Council on the Environment is convinced, according to a 2010 report, that Germany will be able to supply all its energy needs from renewable sources by 2050. However, this report uses model calculations and working hypotheses based on technologies that are currently not ready for the market, such as geothermal energy and compressed air storage. Critics therefore doubt whether this scenario will truly be realistic by 2050.

Fossil fuels are still an essential source right now and will continue to play an important role in energy supply in the future. New potential is offered by unconventional deposits, such as shale gas stored in porous rocks up to 4,000 meters (2.5 miles) below the Earth's surface, which can

Shale gas is mixing up the energy market

Renewable energy sources alone will not be able to secure our energy supply in the foreseeable future. Fossil fuels will also still be required to provide the base load – the amount of energy that must be available around the clock to supply all homes, businesses and public institutions with electricity. But resources are limited. Alongside the development of new energy concepts, major efforts are being made to find unconventional deposits and innovative extraction methods for raw materials.

Shale gas is a particularly hot topic at present. In the United States, it's undergoing a real boom; the widespread extraction of shale gas has led natural gas prices to fall by up to 80% over the last few years. Shale gas is found in thick clay and shale formations at depths of up to 4,000 meters (2.5 miles), where it is trapped in small pores. Special techniques are required for extraction, such as hydraulic fracturing – or "fracking". Here, a mixture of water and quartz sand, containing 0.5% to 2% chemical additives, is pumped into the rock at high pressure, to create fissures. The gas can then escape via these fissures, and funnel through the borehole at the surface. The quartz sand remains in the rock, and acts as a support material to keep the cracks open. The additives prevent the fissures from becoming blocked, and thus increase the gas output. Critics claim the technology could be harmful to the environment; however, it has been used without any problems in oil and gas extraction for decades. The American shale gas boom has had a big impact on the U.S. economy. As a result, energy-intensive industries can operate at lower costs due to reduced energy prices, and thus enjoy competitive advantages.

be extracted by means of a complex technical process (see box on the right).

Intelligent electricity and steam energy storage

Energy production is only one side of the coin; storage methods are crucial too. Solar and wind energy output fluctuates, but electricity is used on a continuous basis. Shortfalls in production or peaks in electricity consumption must therefore be evened out using efficient storage technology. This is the only way in which goals such as those agreed to in Germany can be achieved; with its reform package adopted in 2011, the country has set itself big targets to bring about a shift in its energy supply. It is aiming, by 2020, to produce more than 35% of the electricity in its grid from renewable energy sources, but for that it needs the right storage facilities. Professor Dr. Ulrich Wagner, Head of Energy and Transport at the German Aerospace Center in Cologne, expects the need for such storage facilities to become increasingly apparent in future and grow constantly over time. He stresses that “we must therefore come up with something new as far as storage technology is concerned.”

Yet storing energy in the form of electricity is not easy. Storage requires conversion, which always leads to some energy loss.

Pumped storage achieves a high efficiency. It enables energy to be stored by pumping water into a vessel situated at a height. To produce electricity, the water is released to flow down to a lower vessel and thus drive a turbine. However, this system can only be used in geographically suitable locations, and many sites have already been in service for a long time. There is therefore very little expansion potential in Germany and the rest of Europe.

Besides pumped storage power stations, experts have identified particular potential in electrochemical storage devices in the form of batteries. These are able to store electricity temporarily and make it available to the grid quickly and very efficiently when needed. Private households using solar energy might soon be able to use such battery systems themselves. This would allow self-generated electricity to be used directly in one's own home more often than is currently the

case – and it would no longer be fed from the solar installation on the roof into the grid.

Many experts consider power-to-gas to be another promising option for long-term electricity storage. The power-to-gas concept involves converting excess energy into methane, which is then fed into the natural gas network.

Cost effectiveness

Energy storage continues to face a number of challenges. “All the new storage solutions under discussion are still a long way from crossing the threshold of cost effectiveness – plus, efficiency is still too low and the conversion losses too high,” says former head of the German Federal Network Agency Matthias Kurth, who is now a lecturer in energy issues at the University of Bonn. “Things might improve in the coming years, of course, but even then hardly anybody will get involved in major projects unless funding is available once more.”

So when will the vision of U.S. economist Jeremy Rifkin become reality? The influential thinker whose ideas have inspired energy reform is not only demanding a complete shift to renewable energy but the dismantling of hierarchies between producers and consumers as well: “This Third Industrial Revolution will be driven by millions of people worldwide who produce electricity in their own homes and share surpluses via an intelligent network.” Rifkin is now 67. He still hopes to see his vision come to fruition. ■



A question of motivation

Dr. Florian G. Kaiser, professor of social psychology at the University of Magdeburg, Germany, on social pressure to save energy and the impact of one's own experience of nature.

Creating Chemistry: Switching off lights, pulling out plugs, avoiding waste – we know how to save resources. Why then do we often fail to do it?

Professor Dr. Florian G. Kaiser:

Because we are occupied with other things. The goal of saving electricity and resources is not a primary concern like eating, drinking, and sleeping; it is, at best, a secondary, learned one. Not to mention that saving energy ultimately means each of us will have to give up some personal benefits. The easiest way out for some is currently to buy an energy-efficient fridge, an energy-efficient car, or a house that uses minimal energy. We should begin broaching the subject of doing without in the debate about what form energy should take, the shift to alternative energy sources, and energy consumption. Without forgoing things, it will not be possible in the long term to achieve any political targets relating to the reduction of energy consumption.

Why do some pay attention to resource-efficient behavior and others do not?

There has barely been any empirical research on this subject yet. One thing we know is that it

“Without forgoing things, it will not be possible in the long term to achieve any political targets relating to the reduction of energy consumption.”

does not help just to live closer to nature. You also have to use it for your personal recreation. In Sweden and Norway, this use of nature is truly impressive. A relatively high proportion of leisure time is spent on activities in a natural environment. There are also indications from several research groups that those who use nature for their active recreation tend to be more motivated to behave in a resource-efficient and environmentally friendly manner.

How can a person with only limited environmental awareness be encouraged to save energy?

To get somebody to save energy, it is of course possible to raise the price of energy or apply social pressure to save energy. If, for example, penalties are imposed for throwing away paper in a public space, then less paper will be thrown away. Energy savings could also be achieved by each of us being a little more motivated to consume a bit less. Looking at the unchanged figures for per capita energy consumption in Germany over the last 20 years, one unfortunately has to wonder whether personal motivation or attitudes toward doing without are changing at all. This means that political energy-saving targets – irrespective of where they are – must convince people to reduce consumption through personal conviction rather than only focusing on the question of which are the most efficient technologies.

Energy harvesting

Energy harvesting taps ambient energy by generating electricity from movement, pressure and air streams. Developers from all around the world are working on innovative pilot projects: In Israel, for instance, streets are producing electricity, while in the french city Toulouse as well as in Tokyo sidewalks are harvesting energy and in London subway stairways are generating power. The yield from each individual initiative may indeed be small, but the overall potential of the technology is anything but – American market research firms estimate the global market will be worth \$4.4 billion (€3.4 billion) by 2021, and even more in the years beyond.

Nightclubs

When miniature dynamos are fitted to nightclub dance floors, the energy generated by dance movement can be converted to power the club's lighting. Each reveler can generate up to 20 watts per hour in this way.

Roads

Sensors allow roads to act as mini power plants. When fitted into the surfacing, they convert vibrations from cars into electricity for road signals and street lighting. The technology is known as *piezoelectricity*.

Sidewalks and subway steps

Energy plates featuring piezoelectric (see above) fibers in sidewalks and steps convert the pressure from pedestrians' footsteps and movement into power.

Clothing

Energy harvesting means cell phones can be powered via a T-shirt – special films placed under the fabric transform sound waves into electricity. The louder the ambient noise gets, the faster the battery recharges.

Shoes

Scientists have developed a micro-generator made up of metal droplets, which convert energy from walking and jogging into electricity. When the foot touches the ground, the pressure moves the droplets, generating electricity that can be used for mobile devices.

Bags and backpacks

With the help of a dynamo-like energy converter attached to a bag or backpack, every step taken by the wearer is transformed into electricity. One minute of walking is enough to power a smartphone for the same amount of time.

This intersection in Tokyo's Ginza district illustrates numerous possibilities for energy harvesting.

Electric airplanes

With the push of a button, the propeller transforms into an electric generator for the on-board battery either during the plane's descent or a sharp ascent. This would enable the plane to fly for the entire day.

Exhaust pipes

The waste heat produced by cars is also suitable for energy harvesting. Electric generators can produce up to 1 kilowatt hour of power in this way – almost enough to replace the alternator completely, and cut fuel requirements by 5%.

Shock absorbers

The vibrations from shock absorbers on buses or trucks can be harvested by power generators. Up to 400 watts per hour can be produced in this way.

Brakes

In hybrid vehicles, the brakes are connected to a power generator. Simply bringing the vehicle to a halt at traffic lights is enough to power the car electrically for several hundred meters.

Cars and buses

The air streams generated by vehicles can be captured by small wind turbines and converted into electricity to power illuminated information panels or weather stations on the side of the road.

Tires

Special generators are able to produce electricity using the rotations of tires; this powers the sensors that measure tire pressure.

The diplomat for sustainability

Situated in the desert of Abu Dhabi in the United Arab Emirates (UAE), Masdar City aspires to be one of the most sustainable cities in the world. As it takes shape, Dr. Nawal Al-Hosany, Director of Sustainability at Masdar, explains this ambitious energy-saving project, and how it could serve as a role model all over the globe.

Dr. Nawal Al-Hosany

As the Director of Sustainability at Masdar, Dr. Nawal Al-Hosany oversees the company's corporate sustainability programs. One of the company's projects, Masdar City, is a new development being built in Abu Dhabi, United Arab Emirates (UAE). Al-Hosany leads a team responsible for developing sustainability standards and policies in the area, which is intended to provide housing and business opportunities for 40,000 residents and 50,000 commuters, and generate minimal waste and CO₂ emissions. Al-Hosany grew up in the UAE, where she also completed her engineering degree. She obtained her doctorate from the University of Newcastle upon Tyne, United Kingdom, and attended Harvard Business School in Cambridge, Massachusetts. Before her role at Masdar, she was the deputy director for planning at the Abu Dhabi Police Force – the first woman to hold this position – and in 2008, received the Emirates Business Woman Award. Al-Hosany tackles challenges in her private life as readily as she does in her work: Along with a friend, she was the first woman from the UAE to climb Mount Kilimanjaro.

Creating Chemistry: Masdar City is growing fast. Your goal is to become a nearly zero-emissions city over the coming decades.

Can you give us a short update on how successful your efforts have been so far?

Dr. Nawal Al-Hosany: Masdar City, an integrated unit of Masdar, is being built as the world's most sustainable urban development. Several measures are being taken to ensure that it remains a low-carbon, low-waste city that can serve as a commercially viable role model for cities across the world. Masdar takes a multifaceted approach to the entire value chain of renewable energy and sustainability. Besides implementing energy efficiency measures, such as the use of recycled concrete in the construction of Masdar City, we are developing smart grids on several levels in partnership with global cleantech leaders.

Do such systems offer an opportunity for energy and cost savings?

They do in an enormous way, through an integrated grid that tracks and influences energy consumption all the way from the utility down to the consumer level. Smart appliances, meters, sensors, dashboards, building management systems and distribution management systems are all part of the integrated network. For example, Siemens' Middle East headquarters, currently under construction in Masdar City, will meet the highest architectural and energy efficiency requirements – potentially resulting in a 45% reduction in energy consumption compared with the internationally acknowledged ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) standard and a 50% reduction in water consumption.

Is construction inside Masdar City progressing well?

Yes, it is. The first completed neighborhood comprises the Masdar Institute and retail outlets including a bank, a grocery store and restaurants. The City also has a number of ongoing pilot projects. Some of the projects, for instance, encourage sustainable transportation and test the efficiency of electric vehicles, including the driverless electrical personal rapid transport system.

Can you tell us more about the energy requirements of Masdar City?

The entire demand of Masdar City is met by power generated through the 10-megawatt photovoltaic solar power plant – the Middle East's largest grid-connected solar power plant – and the rooftop photovoltaic panels inside the city. Any excess power is fed back into the Abu Dhabi national grid. Masdar, the company that initiated the Masdar City project, has also developed other large-scale commercial renewable energy projects, both domestically and internationally. In Abu Dhabi, the company is developing the 100-megawatt Shams One plant, one of the world's largest concentrated solar power (CSP) plants, which is set for completion by the end of 2012. When in operation, the plant will help save approximately 175,000 metric tons of CO₂ every year, equivalent to planting 1.5 million trees or taking 15,000 cars off city roads. Internationally, Masdar has developed the first commercial-scale 19.9-megawatt CSP plant in Southern Spain, Gemasolar, the world's first solar power plant capable of 24-hour electricity generation. Masdar is now developing the twin 50-megawatt CSP plants Valle 1 and 2 in partnership with the Spanish >>

“

Masdar City
can serve as
a commercially
viable role
model for
cities across
the world.

Dr. Nawal Al-Hosany,
Director of Sustainability at Masdar City

”



20%

Masdar City's goal is to use just one-fifth of energy consumed by a similar sized city.

54%

The reduction in water use in Masdar City compared to Abu Dhabi.

0

The number of cars with combustion engines that will be allowed in Masdar City.

2025

The year when Masdar City is due to be completed and ready to provide space for its 40,000 inhabitants.



development and technology group SENER. Besides solar power projects, Masdar is also developing one of the world's largest planned offshore wind farms, London Array, in a partnership with DONG Energy and E.ON. It is also spearheading several renewable energy projects in developing countries such as Seychelles, Tonga and Afghanistan.

Solar energy is only one side of the story. How about other alternative energy concepts in Masdar City?

Masdar does not only develop renewable energy projects; it is a commercially-driven enterprise that operates across the full spectrum of the renewable energy and sustainable technology industry. As you know, the most sustainable option depends on each country's resources and

how abundant they are. Let us take Masdar City: We have capitalized on the plentiful solar energy available in Abu Dhabi by building a 10-megawatt solar power plant and rooftop photovoltaic panels. We also pursue an urban development approach with as little wastage and CO₂ emissions as possible. The cleantech cluster embodies Abu Dhabi's commitment to a sustainable future by pioneering the best practices in sustainable urban planning, design and construction, as well as educating residents about efficient energy usage.

How much energy does Masdar City consume compared to other cities?

Compared to the 2011 average figures in Abu Dhabi, Masdar City has managed to cut water consumption by 54%, electricity consumption by approximately 70% and cooling requirements by 50%. Waste is sorted and recycled, and organic waste will be used for compost. Masdar City also has a geothermal test site – a pilot project that involves exploratory drilling deep underground to test the availability of sufficiently hot geothermal water to be used in thermal cooling.

Early on, there was a lot of attention focused on Masdar City, but this has since died down. Is construction still on schedule?

First of all, I do not feel that it has become quieter around Masdar City: Whether locally or abroad, the

interest in Masdar City's progress has steadily increased over the years. And we have already achieved many milestones: Construction continues inside Masdar City with the expansion of the Masdar Institute campus expected to reach completion by year-end. Extension of the campus will more than double the university's area and include additional laboratories, dormitories and retail outlets. Masdar's first commercial building is also due for completion by the end of 2012 and is expected to house more than 50 companies. Siemens' Middle East headquarters is scheduled for completion in 2013. Construction will begin soon on the Masdar headquarters building and the International Renewable Energy Agency (IRENA) headquarters. When it is fully built by 2025, the city is expected to have 40,000 residents and welcome 50,000 commuters.

What places around the world do you consider to be the most inspiring with regard to sustainability and carbon-neutral living? Can you tell us how they influence you at Masdar?

First of all, every country has its own environmental context, but we learn from many experiences around the world, especially in regions that offer similar climatic conditions. The design elements used in Masdar were inspired by traditional Arabic architecture. For example, the wind tower inside Masdar Institute's campus – which captures wind with its flexible flaps, directs it downwards and uses it for cooling – is a modern

Above The cityscape of Masdar City is greatly influenced by traditional Arabic architecture. Thanks to the refined architecture of the city, the buildings provide shade for each other. This enables streets and houses to remain cool without the use of air conditioning.

Below left The Masdar Institute of Science and Technology is focusing on renewable energy research and sustainable technologies. The number of students is expected to grow to 600 over the next five years.

interpretation of one of the region's most iconic traditional architectural features, the Al Barjeel. This was prominent in many Gulf Cooperation Council (GCC) homes. Cities that inspired Masdar City's master plan include Shibam in Yemen, Aleppo in Syria and Marrakesh in Morocco, as well as traditional districts within Abu Dhabi and other cities in the UAE and Gulf region.

Generally speaking, what can cities do to drive climate protection?

We can all agree that climate change is a threat that the global community shares. Rising temperatures and sea levels will have a major impact on our region and it is in our interest to find solutions. Our country is already gaining global visibility as a sustainability champion with an active role in international climate negotiations such as Rio+20. Inside Masdar City, we continue to improve energy efficiency standards in our



buildings, invest in sustainable public transport and support public awareness campaigns to inform our society about how we can reduce emissions. And yes, there is no doubt that people can have a higher impact on saving energy when they have intrinsic motivation.

How important is it for you to exchange information with experts from all over the world?

Working in Masdar City – a test bed for research, development and creation of scalable innovations in renewable energy and clean technologies for sustainable development – means that information exchange and knowledge sharing is part of our daily routine.

On a personal level, I was appointed Sherpa (chief negotiator) to the U.N. Secretary General in the 'The Sustainable Energy for All' initiative to support the appointed principal, Dr. Sultan Ahmed Al Jaber, the Chief Executive Officer of Masdar. I also serve on the boards of several regional and international initiatives and organizations: I'm a Co-Chairperson of Women for Sustainable Growth and I was part of the Sustainable Development Dialogue panel in Rio. I am now looking forward to our annual flagship events, the World Future Energy Summit (WFES) and the Zayed Future Energy Prize awards ceremony, which will be held during the Abu Dhabi Sustainability Week in January 2013. These are all platforms for knowledge exchange that directly add to my experience and understanding of industry's best practice.

Do you also aim to establish platforms for knowledge exchange in Masdar City itself?

On a wider scale, Masdar City and Masdar Institute of Science and Technology are attracting leading academics, researchers and businesses eager to situate themselves in an environment that

will promote and adopt research, development and technological innovation. The new headquarters of the International Renewable Energy Agency will be based in this thriving environment, underscoring Masdar's aim to become a global cooperative platform in the search for solutions to the pressing issues of energy security, climate change and the development of human expertise in sustainability.

Saving energy is a very important goal. How can we successfully rise to this challenge?

In theory, development that is sustainable and not damaging to the planet is achievable. In reality, there are challenges at every step, and so far, global efforts of moving towards sustainability in a collective manner, with a common framework, appear to have been quite feeble. Around the world, a large part of the population still lives without access to basic necessities. In the most fragile environmental conditions, the population typically has limited financial means and the least adequate resources to address these challenges. Integrating these societies into the economic and development programs can speed up the pace of sustainable development and contribute to improving their quality of life because it builds an entrepreneurial platform that has tremendous positive impact and yields long-term benefits for the communities engaged.

Does sustainability also play an important role in your private life?

On a personal level, I'm currently building my own home in a sustainable way which will reduce its impact on the environment and ultimately lower carbon emissions. I'm hoping it will serve as a case study for all Abu Dhabi community members to identify ways in which they can implement sustainability measures in their own homes. ■



I'm hoping my house will serve as a case study for all Abu Dhabi community members to identify ways in which they can implement sustainability measures in their own homes.

Dr. Nawal Al-Hosany, Director of Sustainability at Masdar City



Masdar City – Cleantech cluster on the Persian Gulf

The United Arab Emirates (UAE) has ambitious aims when it comes to developing technologies for renewable energy and climate protection: Located 17 kilometers from the capital Abu Dhabi, Masdar City will be a showcase for sustainable urban development. The buildings completed so far are already using 100% renewable energy.

Masdar is the Arabic word for "source" or "origin". The pioneering project Masdar City is in fact a large-scale experiment: It embodies the vision of a city that is nearly carbon neutral and barely produces any waste. Masdar City also serves as a think tank, where new solutions for climate protection and renewable energy can be developed. The project was initiated in 2006 by Masdar, a company from the United Arab Emirates which takes a multifaceted approach to research, development and commercialization of technologies in the renewable energy and cleantech sector. Masdar is a subsidiary of the state-owned joint stock company Mubadala and explores new economic and energy diversification plans for Abu Dhabi.

The developers of Masdar City are employing best-practice benchmarks, sustainable building materials and energy-efficient technologies. As a result, the city's energy consumption was 55% lower and water consumption was reduced by 54% compared to the 2011 average figures in Abu Dhabi. The energy used in the buildings completed thus far comes entirely from renewable sources. It is generated by a 10 megawatt solar power plant and 1 megawatt of rooftop photovoltaic panels. Masdar City is also implementing environmentally friendly

transportation concepts: Cars with combustion engines have to be parked at the edge of town. In their place, electric vehicles ply the city's streets and there are a well-developed public transport system and shady sidewalks.

The city was designed by the team of legendary British architect Sir Norman Foster and also incorporates traditional Arabic urban construction techniques. The buildings are laid out in such a way that they provide shade for the public roads and other buildings. This reduces the average temperature in Masdar City by up to 20C (68F) compared to outside the city. The coolness of the lower layers of earth is used for air-conditioning in the buildings.

Masdar City not only integrates environmentally friendly technologies, it also wants to promote their development. For example, it is home to Masdar Institute of Science and Technology, a university with a focus on renewable energy research. The International Renewable Energy Agency (IRENA) is also going to set up its headquarters in Masdar City.

In order to live up to its pioneering role, Masdar has partnered with leading names, including BASF. The strategic partnership between BASF and Masdar began in 2009 and has resulted in BASF being named a "preferred supplier." As a leading supplier of raw materials, formulations and systems for the construction industry, BASF has provided a range of products for the first building phase in Masdar City, including the Masdar Institute of Science and Technology. Some of the products used in its construction were grouts and mortars, joint sealants, coatings, tile adhesives and concrete additives.



To find out more, visit:
www.masdar.ae

The BASF Verbund



Dr. Bernhard Nick is responsible for BASF's European Verbund sites in Antwerp, Belgium, and Ludwigshafen, Germany, which employ around 37,000 people. In a conversation with *Creating Chemistry*, Nick explains how the BASF Verbund saves resources while also achieving profitable growth.

Above The photo shows some of the facilities in the northern part of BASF's largest Verbund site in Ludwigshafen/Germany. From here, the Verbund has expanded worldwide. BASF currently operates six Verbund sites.

Creating Chemistry: According to the International Energy Agency (IEA), industry accounts for slightly more than half of global energy consumption. The chemical industry in particular requires a lot of energy and steam for its production processes. How can BASF credibly advocate energy efficiency?

Dr. Bernhard Nick: Chemistry is vital to ensuring that the needs of a growing world population continue to be met in the future. BASF's products help to save resources and protect the climate and environment. Let us look, for example, at the housing and construction sector; by using the products that BASF sold worldwide in 2011, more than

280 million metric tons of CO₂ emissions are avoided. This is more than a quarter of Germany's annual CO₂ emissions. A big contribution towards this achievement came from the use of BASF's concrete additives and insulating materials in renovating old buildings and in the construction of new ones. Of course, emissions do occur during production, but we are constantly working on keeping them as low as possible. This is why we have set ourselves ambitious energy and climate protection goals: By 2020, we want to reduce greenhouse gas emissions by 40% per metric ton of sales product compared with 2002 levels, and we want to increase our energy efficiency in production processes by 35%. Our Verbund is crucial to achieving this.



How does the Verbund work?

The Verbund is based on the idea of maximum resource efficiency. We aim to produce as much as possible with as few resources as possible, and in doing so keep our emissions to a minimum. To this end, we link up plants, energy flows, logistics and infrastructure. We are therefore not focusing solely on individual processes, but on the interplay between all plants and the infrastructure at any given site. BASF currently operates six Verbund sites: in Germany, Belgium, China, Malaysia, and two in the United States. The Verbund system is also influencing thinking at all of our other sites. It already extends well beyond production. For example, we are linking up the knowledge of our employees and our broad technology base worldwide in order to provide our customers with innovations in all relevant sectors. The methods of the Verbund system permeate throughout BASF's entire business.

How, for instance, are you increasing energy efficiency in production?

To begin with, we are focusing on capturing and reusing energy and resources released at our Verbund sites. When surplus heat is generated in one factory, it is used for production in another plant rather than being wasted. Additional energy is being produced at Verbund sites by our own combined heat and power plants using gas and steam turbine technology. They produce steam and electricity at the same time and, with a fuel-efficiency rating of up to 90%, are highly efficient. Natural gas – the greenest fossil fuel – is used as a raw material. At large sites such as Ludwigshafen, water supply systems have also been optimized in such a way that drinking water is only used for washing and drinking. Toilets are flushed using the river water supply.

Who benefits most from this system?

The Verbund helps BASF achieve profitable and sustainable growth. It enables more than €200 million to be saved in energy costs each year in Ludwigshafen. At the same time, the environment benefits: In 2011, BASF's energy consumption was lower by 2.6 million metric tons of crude oil equivalent thanks to the Verbund system and the use of combined heat and power technology. This corresponds to a reduced environmental load of 6.2 million metric tons of CO₂ emissions. This is where ecology and economy go hand in hand.

Could other companies or towns also copy BASF's Energy Verbund?

There is good reason why our Verbund sites are constantly being compared with small towns. If you examine the sites in detail, there are many similarities (see diagram on pages 22 and 23). In my opinion, the recovery of energy from waste heat and residues, and the supply of energy using combined heat and power plants – which meet over 70% of BASF's electricity needs worldwide – serve as good role models. We are also transferring many of our transport needs from road to rail based on innovative logistics concepts. Other companies or towns could use these solutions to save resources and reduce emissions too.

Finally, we want to uncover a secret: Who actually founded the Verbund?

The Verbund has been part of BASF from the outset. BASF founder, Friedrich Engelhorn, owned a coal-gas factory in Mannheim in the 1860s. It produced an annoying waste product: tar. Nobody in the factory could use it until Engelhorn came up with the idea of using it to manufacture tar dyes and selling them at a profit. Together with others, he founded a chemical company called Badische Anilin- und Sodafabrik, or BASF for short. Efficient handling of resources is therefore in our DNA. ■

280 million

The avoidance in the number of metric tons of CO₂ emissions achieved in the housing and construction sector through the use of products which BASF sold worldwide in 2011.

35%

The targeted increase in energy efficiency in BASF's production processes by 2020.

€200 million

The reduction in energy costs achieved through the BASF Verbund in Ludwigshafen alone.



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



The Verbund is based on the idea of maximum resource efficiency. We aim to produce as much as possible with as few resources as possible, and in doing so keep our emissions to a minimum. To this end, we link up plants, energy flows, logistics and infrastructure.

Dr. Bernhard Nick, President Verbund Site Management Europe, BASF



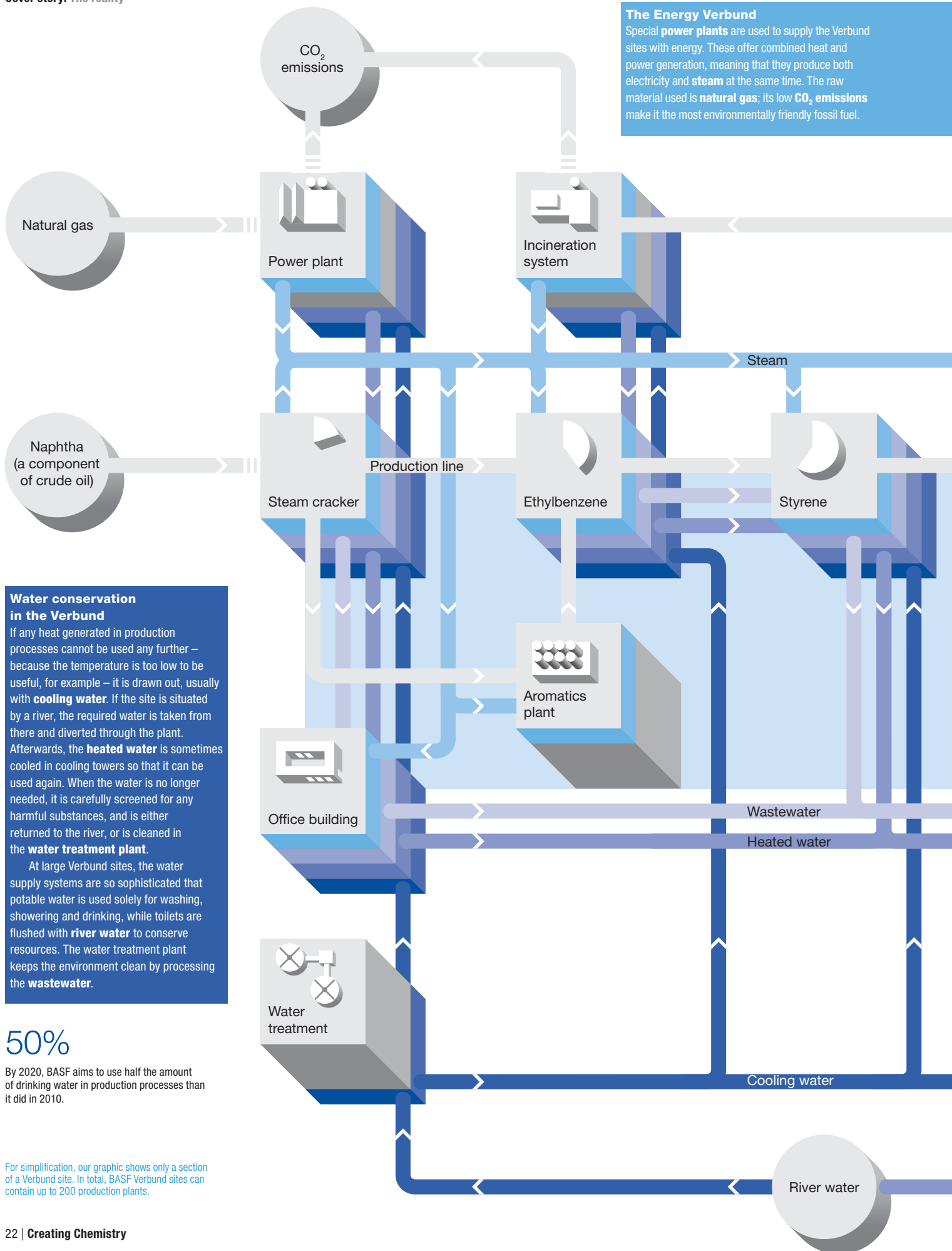
Dr. Bernhard Nick

Dr. Bernhard Nick has been head of BASF's Verbund Site Management Europe since January 2008 and is responsible for the large BASF production sites in Europe. The career of this chemistry doctorate holder and businessman has included setting up the BASF Verbund site at Kuantan/Malaysia, and working as head of the Financial Evaluation and Strategic Planning units.



The Energy Verbund

Special **power plants** are used to supply the Verbund sites with energy. These offer combined heat and power generation, meaning that they produce both electricity and **steam** at the same time. The raw material used is **natural gas**; its low **CO₂ emissions** make it the most environmentally friendly fossil fuel.



Water conservation in the Verbund

If any heat generated in production processes cannot be used any further – because the temperature is too low to be useful, for example – it is drawn out, usually with **cooling water**. If the site is situated by a river, the required water is taken from there and diverted through the plant. Afterwards, the **heated water** is sometimes cooled in cooling towers so that it can be used again. When the water is no longer needed, it is carefully screened for any harmful substances, and is either returned to the river, or is cleaned in the **water treatment plant**.

At large Verbund sites, the water supply systems are so sophisticated that potable water is used solely for washing, showering and drinking, while toilets are flushed with **river water** to conserve resources. The water treatment plant keeps the environment clean by processing the **wastewater**.

50%

By 2020, BASF aims to use half the amount of drinking water in production processes than it did in 2010.

For simplification, our graphic shows only a section of a Verbund site. In total, BASF Verbund sites can contain up to 200 production plants.

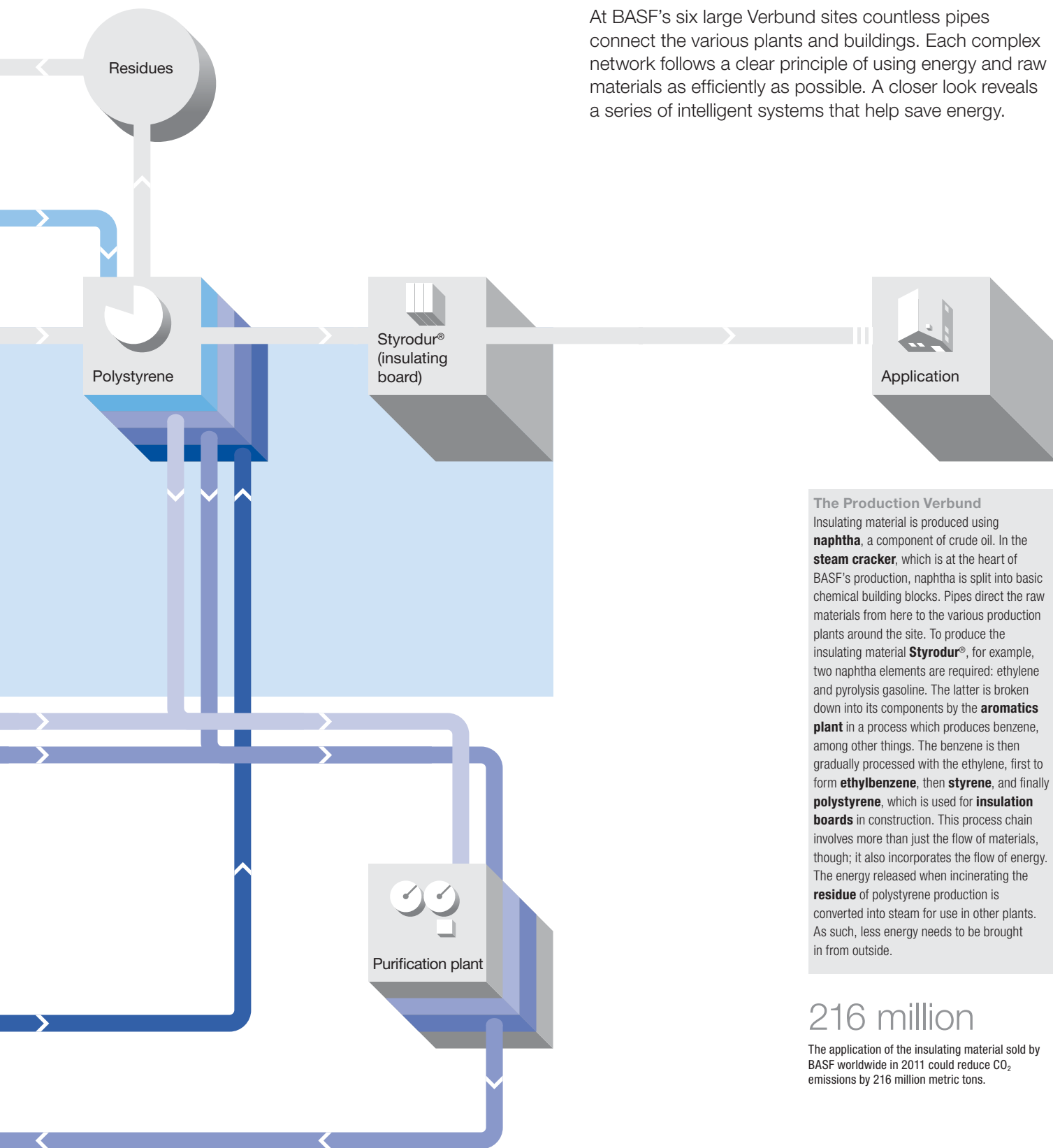
As electricity and steam are produced together, the rate of gas utilization can be as high as 90%. Another way in which CO₂ emissions are kept as low as possible is that whenever a plant generates excess heat during production, it is not lost. A steam network diverts the heat to another plant, where it is used in production.

2.6 million

BASF's use of the Verbund system and combined heat and power generation saved the equivalent of 2.6 million metric tons of crude oil in 2011.

Understanding the Verbund

At BASF's six large Verbund sites countless pipes connect the various plants and buildings. Each complex network follows a clear principle of using energy and raw materials as efficiently as possible. A closer look reveals a series of intelligent systems that help save energy.



The Production Verbund

Insulating material is produced using **naphtha**, a component of crude oil. In the **steam cracker**, which is at the heart of BASF's production, naphtha is split into basic chemical building blocks. Pipes direct the raw materials from here to the various production plants around the site. To produce the insulating material **Styrodur®**, for example, two naphtha elements are required: ethylene and pyrolysis gasoline. The latter is broken down into its components by the **aromatics plant** in a process which produces benzene, among other things. The benzene is then gradually processed with the ethylene, first to form **ethylbenzene**, then **styrene**, and finally **polystyrene**, which is used for **insulation boards** in construction. This process chain involves more than just the flow of materials, though; it also incorporates the flow of energy. The energy released when incinerating the **residue** of polystyrene production is converted into steam for use in other plants. As such, less energy needs to be brought in from outside.

216 million

The application of the insulating material sold by BASF worldwide in 2011 could reduce CO₂ emissions by 216 million metric tons.

Winds of change

Often seen as a modern technology, electricity has actually been generated from wind power for 125 years.

Among the various alternative energy sources, wind power is seen by many as the most promising route to a cleaner future. Prices for electricity generated by wind energy are dropping, while the number of wind farms is growing rapidly. Today, the global wind power market is worth billions, yet few people realize that the technology was first introduced 125 years ago.



The drive to convert wind into energy was initially private in nature: Scottish engineer Professor James Blyth wanted to have electricity at his remote holiday home. In the summer of 1887, he built a simple wind turbine with fabric sails, which produced enough power for ten light bulbs. Before his invention, windmills were used almost exclusively to grind grain or pump water.

Shortly after Blyth's innovation, U.S. inventor Charles F. Brush followed with an automatic wind turbine.

At the same time, he developed a process for storing excess energy in lead batteries.

Then, in 1900, Danish scientist Poul la Cour made a decisive breakthrough. He carried out the very first wind tunnel tests, and established the aerodynamic principles for the ideal rotor blade. He proved that rotors with a lower number of blades actually produced more electricity. With this knowledge, he was able to develop fast-moving wind turbines capable of supplying small villages with direct-current power.

1887

Professor James Blyth designed the first known electricity generating wind turbine.

1900

The first wind turbine incorporating aerodynamics was designed by Poul la Cour.

1991

The world's first commercial offshore wind park began operating in Lolland, a Danish island located in the Baltic Sea.

2020

Wind energy is expected to provide more than 9% of global power supply. The current figure is around 2.3%.

Source: BTM Consult, *International Wind Energy Development*.

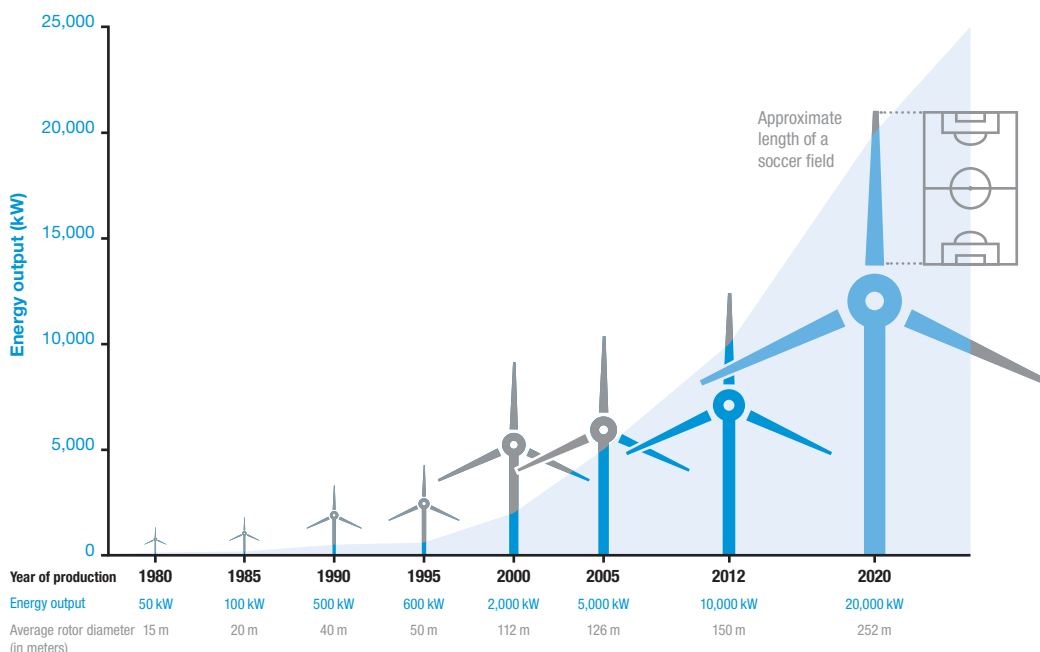


Above In 1887, Scotsman Professor James Blyth built the first ever wind turbine for power generation. Eight years later came a second, improved design, which provided emergency power for 30 years to the psychiatric clinic in Montrose/Scotland.

Above right American Charles F. Brush looked to windmill technology in 1888 when constructing his 65-foot high turbine.

Growing Giants

Turbines are getting increasingly larger in order to improve their energy output





But soon progress began to slow significantly as increasing numbers of central coal power stations pushed wind turbines out of the picture.

This situation was exacerbated in the 1950s with the introduction of nuclear power and the excitement that surrounded the discovery. However, the oil crisis and increased skepticism about nuclear technology prompted a wind renaissance that has continued to this day. Once more, the key driver was Denmark – the Danish government at the time encouraged investors to build efficient wind farms. This policy powered the development of today's well-known three-blade turbines. In the 1980s, Danish rotors with a diameter of approximately 20 meters (65 feet), produced energy yields between 35 and 95 megawatt hours per year for the first time, with a nominal output of between

30 and 80 kilowatts. Combined with progressive legislation regarding power input, this created a profitable market.

From its humble beginnings, wind energy has become a global industry with major markets in China, the United States and Germany. Two trends are shaping the sector: Turbines are increasing in size in order to improve output and wind power is gradually moving out to sea. The first systems with a maximum output of 5 or 6 megawatts are already on the market, while rotor diameters of over 110 meters (360 feet) are nothing short of gigantic. There is constant progress in terms of size, yield, and innovation – ideas are already under development to harness the power of wind above the clouds. In the future, kites, light aircraft and balloons might be used for energy generation. ■

Above Spanning an area of 110,000 m², the American Wind Power Center in Lubbock, Texas, is a museum of gigantic proportions. Visitors can marvel at one of the largest collections of American wind turbines. Some of the machines date back to the early 1920s.



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

BASF contributes to making wind power profitable

The forces exerted on modern wind turbines are immense. Winds can howl at speeds of up to 300 kilometers (186 miles) per hour, which causes the blades to bend by more than a meter (about 3 feet). In addition, the systems must be able to withstand weathering caused by prolonged exposure to UV rays, rain and the salty climate of the sea.

Chemical solutions help ensure these giants can endure such challenging conditions for at least 20 years. This makes the turbines far more profitable: The longer they can operate, and the fewer maintenance shutdowns they require, the more electricity they can produce. In addition, BASF enables the turbines to be manufactured and installed in a cost-efficient way. Chemical innovations play an important role in many turbine components, including the foundations, towers, gears and rotor blades.

Special BASF grouts secure the towers to the foundations for long-term operation and are quick to use, cost-efficient and utterly dependable under harsh weather conditions. Concrete additives help to make sure that both towers and foundations are efficiently manufactured to be long-lasting, while lubricants from BASF keep turbine gears running smoothly. Rotor blades benefit in three ways from chemical solutions: Firstly, today many blades are manufactured with special fiber-reinforced epoxy resin systems from BASF, which ensure that the highly resilient components can be produced up to 30% faster and thus more cost-effectively. Secondly, BASF's PET (polyethylene terephthalate) foam will increasingly be used inside blades longer than 60 meters (197 feet) to help stabilize them. Finally, multi-layered BASF coating systems protect the outside of blades against weathering and wear and tear.

BASF aims to offer wind turbine manufacturers innovative, tailored solutions by leveraging its multi-disciplinary expertise. BASF works with its customers to continually develop its product range.

New discoveries

Inventiveness is in demand: Innovations make our everyday lives easier in a host of ways, and help improve sustainability. In this section, we present a selection of inspiring examples.



Sustainability measurement

A successfully managed process must be measurable and comprehensible. With this in mind, BASF developed a method for holistically assessing sustainability in agriculture called AgBalance™. It evaluates 69 indicators from the three dimensions – environment, society and economy. AgBalance considers, for example, the nutrient balance of soil, the biodiversity of species inhabiting farmland, plus residues in food and feed as well as fixed and variable costs. The method has received independent assurance by the global expert agencies NSF International, DNV Business Assurance and TÜV SÜD. Recently, AgBalance was ranked first in the 2012 ideas competition of the German Council for Sustainable Development.

www.agbalance.agro.basf.com

Liters of light

The idea is simple, the impact immense: Ilac Diaz, a former actor from the Philippines, is bringing light to the slums of his home country's capital Manila just by using humble discarded plastic bottles. An old bottle is filled with water and a small quantity of bleach is added to sterilize the liquid and keep it clear. The bottle is then vertically wedged into a hole cut in the corrugated iron of a hut roof, secured to stop it from falling down and sealed with a bit of rubber. The makeshift bulb is ready. When the sun outside shines on the bottle, the water inside it refracts the light and illuminates the interior of the hut without the use of electricity.

www.isanglitrongliwanag.org



Digital plant care

There are people who talk to their plants. Now, plants are able to talk to their owners. This is thanks to Koubachi, a spin-off from the Swiss Federal Institute of Technology Zurich (ETH) that gives plants their own 'voice'. The company has developed a sensor that alerts plant lovers when it is time to water again. It measures humidity, temperature and exposure to light. This data is then transmitted via Wi-Fi directly to Koubachi's own system for assessment. The application analyzes all the collected data and, based on the type of plant, determines whether watering is necessary. If action is required, the user is immediately informed via smartphone or computer.

www.koubachi.com

Decoration from nature

Cornstarch, potato and tapioca are everyday ingredients for chefs in different countries, but Lili Giacobino does something different: She transforms these ingredients into bioplastic. With this very pliable material she is able to create colorful necklaces, earrings and bracelets. The designer developed her special formula following months of experimentation in her own kitchen; the results are beautiful creations produced from natural ingredients. Giacobino does not ignore other everyday items; she even integrates materials such as yogurt containers and tin cans into her collections, pursuing her own distinctive form of upcycling, finding a new valuable use for used items.

www.creativelili.com



Above Earrings made of biodegradable plastics.

Intelligent temperature control

Thermostats were not noted for their design or learning capacity until the former head of development for Apple's iPod and iPhone got involved. That involvement led to Nest, the intelligent thermostat with a sleek and stylish appearance that is similar to Apple designs. The thermostat is a mini computer for the home which recognizes the occupants' habits after a short learning phase. It is then able to control room temperature independently to ensure that the heating and cooling of the home is as energy efficient as possible.

www.nest.com





Efficient solar tree

New Yorker Aidan Dwyer is just 14 years old, but has already created a stir in the solar industry. While walking in the woods, Dwyer wondered how trees manage to capture sunlight so efficiently. The young researcher worked out the exact spacing of tree branches using the famous Fibonacci sequence first published in the 13th century, and then incorporated these calculations into his solar module design. His invention looks like a tree trunk with solar panels facing in all directions on the branches. This allows sunlight to be more efficiently collected and transformed into energy. Although scientists have since noticed that Dwyer made some mistakes when calculating the yield, his solar tree still achieves better results than traditional roof-mounted solar panels. His idea of following nature's example has now made it all the way to Abu Dhabi, where the teen inventor opened the World Future Energy Summit 2012.

www.amnh.org/yna



Above Young researcher Aidan Dwyer discovered that when solar panels are arranged like the leaves of a tree, they collect more light.

Left Dwyer's invention takes inspiration from nature to produce solar energy more effectively.



Illuminating power usage

Power consumption can be made visible: The Power Aware Cord functions as a type of detector. This illuminated cord glows and pulses more intensely as more power flows through it. Even appliances that consume power without your knowledge are very quickly exposed with the help of this product. The Power Aware Cord's two Scandinavian designers, from the Interactive Institute in Stockholm, want their invention to encourage consumers to save energy.

www.tii.se

Biotech oral care

Now there is an easy way to wash out the pathogens that cause dental cavities: pro-t-action®, developed by BASF in cooperation with Organobalance, makes daily toothbrushing more effective with the help of micro-organisms. The patented, all-natural and safe bacteria in pro-t-action sticks to the troublesome bacteria *Streptococcus mutans* that cause cavities, and forms clumps that are more easily rinsed away from the mouth. The first brand of toothpaste containing pro-t-action is now available on the Eastern European market.

www.pro-t-action.com





Non-identical twins: Even when foodstuffs look the same, there can still be fundamental differences between them. Food fortification is a method that reinforces staple foods, such as rice, with nutrients in order to fight malnutrition. From the outside, nothing appears to be different.

Better nourishment for all?

When we do not eat enough protein or carbohydrates, we feel hungry. It's different with vitamins and minerals. Even though these micronutrients orchestrate vital body functions such as growth, immune response and vision, their absence is harder to detect. Food fortification is a potential solution to the problem of malnutrition, but is it the right one?

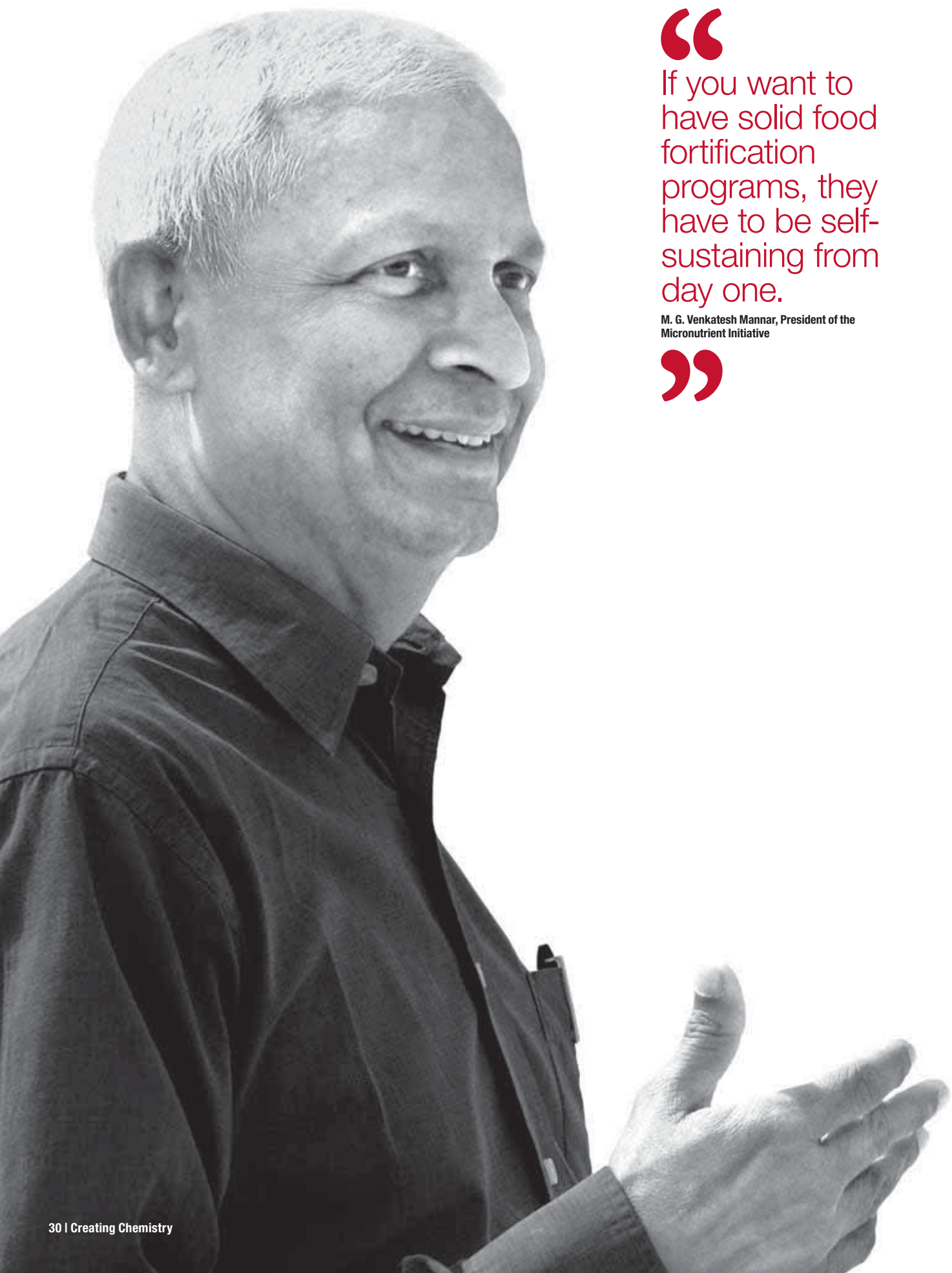
Malnutrition, or "hidden hunger", affects the world's poorest people, especially mothers and children under five years of age. The micronutrient most lacking in the world's diets today is vitamin A, which is important for healthy skin, wound healing and eyesight. Vitamin A deficiency (VAD) is responsible for a million child deaths every year. It can lead to blindness and makes children more susceptible to other diseases such as tuberculosis and pneumonia. In addition, each year 18 million babies are born with mental impairments due to iodine deficiency. UNICEF estimates that more than 2 billion people – almost a third of the world's population – suffer from some kind of micronutrient deficiency.

In the past two decades, fundamental efforts have been made to fight malnutrition. Starting at the 1990 U.N. World Summit for Children, leaders from around the world agreed to combat three

major micronutrient deficiencies: the lack of iodine, vitamin A or iron. One emerging intervention against malnutrition is food fortification, a method by which staple foods are enriched with vitamins and minerals they do not naturally contain or are only present in small amounts. Some fortified foods such as iodized salt have been used for almost a century.

Proponents of food fortification argue that it is an economical and effective way to combat malnutrition. But do fortified foods really reach the world's poorest? Or are detractors right to argue that only promoting better dietary habits and improved local farming can lead to long-term solutions? We asked M. G. Venkatesh Mannar, President of the Micronutrient Initiative, and Frank Braßel, Deputy Leader for Campaigns and Lobbying at Oxfam Germany, to share their views.





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If you want to have solid food fortification programs, they have to be self-sustaining from day one.

M. G. Venkatesh Mannar, President of the Micronutrient Initiative

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M. G. Venkatesh Mannar

Since 1994, M. G. Venkatesh Mannar has served as President of the Micronutrient Initiative (MI). The Canadian NGO develops, sets up and controls cost-effective, sustainable solutions for vitamin and mineral deficiencies. MI is the longest-standing organization of its kind. It was formed in 1992 as a secretariat at the International Development Research Centre, a member of Canada's foreign aid program, and became independent in 2000. Every year, 500 million people benefit from MI's work.

Mannar was born in Chennai/India. He studied chemical engineering at universities in India and the United States and managed an Indian salt company for 17 years. He has worked for different U.N. and aid agencies since 1973. In 2010, Mannar received the Tech Award for innovators who are finding technological solutions to benefit humanity.



To find out more, visit:
www.micronutrient.org

Creating Chemistry: Malnutrition is a serious problem in more than a hundred countries. It especially affects the poorest people of this world. Proponents of food fortification see it as a cost-effective and sustainable way of fighting malnutrition. What do you say?

M. G. Venkatesh Mannar: There are three proven ways to close deficiency gaps. You can change people's diets, which is a long-term approach. In the long and medium term, you can enrich food with essential nutrients. And when you want to help vulnerable populations quickly, we recommend supplementation.

What are the advantages of food fortification programs compared to the other approaches?

Approaches to reducing vitamin and mineral deficiencies must be complementary. They serve different needs and work in different situations. Supplementation helps highly deficient people, especially pregnant women and children during the first two years of life. With food fortification, you can address the whole population across the board. Food fortification is not a miracle cure. Changing dietary habits remains the goal of every long-term health policy, but it is difficult to achieve. Even in industrialized countries, where food is abundant, fortified foods ensure that people receive important micronutrients like iodine and vitamin A. I can't imagine how you could achieve this in less developed countries solely by changing dietary habits.

How can you make sure that food fortification is effective and reaches the world's poorest, who generally suffer most from micronutrient deficits?

That's the key question. Critics say fortified foods don't reach the poor, and it's true that it's hard to reach the bottom 20% – poor people in remote areas. These people often do not eat foods that are centrally processed in mills or factories – and it's these foods that can be easily fortified. A year ago, I visited a rural market in Ethiopia, and the only processed food I found was salt. Everything else was locally produced. So you need to find other vehicles for such regions. Food fortification works best when addressing populations that can access processed foods.

In what way should food fortification programs take different approaches in different countries?

The programs have to be country-specific. First, you have to identify staple foods that are widely consumed on a regular basis and then work out how to fortify them. In the Middle East, we have advocated fortifying wheat flour, but in Southeast Asia or China, condiments like oil, fish or soy sauce are better vehicles. In Central America, sugar is widely grown and consumed. While I don't advocate eating lots of sugar, it has helped to provide vitamin A in many countries in the region.

What role should governments play in the fight against malnutrition?

Governments play a key role. They set the policies and guidelines for fortified foods, but also monitor these policies and enforce regulations. If all this is in place, the private sector will make sure that fortified foods are economically viable.

What are the Micronutrient Initiative's goals for addressing malnutrition within the next three years?

We want to continue to help the most vulnerable: women and children in the most impoverished parts of the world. This is the case for large parts of Southeast Asia, Sub-Saharan Africa and some parts of Latin America and the Caribbean. Micronutrient deficiencies can be addressed at low costs and very quickly.

What is the rationale behind an NGO like the Micronutrient Initiative working with the private sector in the area of food fortification?

Most multinational corporations have huge teams of experts and don't need much guidance. But we can make a difference with small national and local producers that are often not aware of all the norms and guidelines on fortification. In addition, we can interface between companies and governments because we are seen as a neutral body that doesn't favor particular companies or products.

What has been the international nutrition community's biggest achievement so far in the fight against malnutrition?

Our biggest success has been in the area of salt iodization. In 1990, 25% of the world population used iodized salt. Now, it's more than 70%. We'd like to see this same success with a range of staple foods and condiments. We've made similar progress in vitamin A supplementation, especially for young children. In 1999, only 16% of children worldwide were fully protected with two annual doses of vitamin A; by 2010, 66% of children were receiving two doses, not including China. But I would say that there is still huge potential to reduce malnutrition around the world. We continue to work in the areas of supplementation and fortification. More recently, we have been working to scale up the use of zinc, along with oral rehydration salts, for the treatment of diarrhea in children under the age of five. This will help us reduce child mortality.

What's the biggest mistake you see when analyzing past food fortification programs?

There have been a number of failures in the past 20 years. What often happens is that, initially, a donor shows interest and a program is set up only to buy fortificants or equipment. But if the donor withdraws, the program often stalls. It's a classic mistake, and I've seen it happen in countries where a good fortification program has virtually come to a halt because there was no transition plan in place for when external funding ends. We have to adequately plan the programs and make sure they deliver long-term, sustainable results.

At the U.N. Rio+20 conference, BASF committed to reducing the vitamin and mineral deficiencies of 60 million people with fortified staple foods each year. What are your specific demands on the private sector in terms of addressing malnutrition?

The private sector should work actively with local governments to understand the issues and regulations related to food fortification and comply with them in an economically viable manner that is not dependent on external subsidies. If you want to have solid food fortification programs, they have to be self-sustaining from day one. ■

Creating Chemistry: Malnutrition is a serious problem in more than a hundred countries. It especially affects the poorest people of this world. Proponents of food fortification see it as a cost-effective and sustainable way of fighting malnutrition. What do you say?

Frank Braßel: We are not in principle opposed to food fortification, but do not see it as a long-term solution to global hunger. We see the problem as being one of unfair distribution. It is a scandal that, in an ever richer world, one in seven people go to bed hungry. Food fortification does not therefore tackle the cause of the problem but rather the consequences. We at Oxfam believe that all people are able to feed themselves as long as they have access to land, water, markets and fair working conditions.

What, in your opinion, is driving the private sector to get involved in food fortification programs?

You can probably assume that a company does not develop products unless it is also able to do good business with them. With food fortification programs, firms can hope for government support.

What strategy do you propose instead to combat malnutrition?

We think in terms of long-term and short-term measures. In the short term, it is necessary, for example, to put a stop to food speculation and abolish the blending rates for agro-fuels. It is crazy that food is increasingly being used to fill gas tanks and not to feed hungry mouths. This increases prices, and causes many people to be driven from their land. In the long term, we advocate a food system focusing on small farmers who are able to feed themselves and their communities. This is more secure than obtaining supplies via the world market, on which prices fluctuate widely. And it is also better for the environment because it saves resources. Even the

World Bank has published a study which comes to the conclusion that agriculture based on smallholdings is more effective than large-scale plantation farming.

What do you consider to be the main challenges to putting your ideas for combating malnutrition into practice?

Firstly, we should stop viewing agricultural land and food as purely commercial commodities because they form part of the basis of human coexistence. Various instruments can be used to encourage small farmers. For example, we can provide microcredit or open up local markets, as Oxfam has helped to do in Bogotá. These do not cost much and open up important new sales channels for small farmers.

What role should the private sector play in combating malnutrition?

Large corporate groups should, first and foremost, ensure that they comply with national legislation and global human rights and environmental standards. This would already represent considerable progress. In poor countries where state control is weak, companies should also think in a more preventative way and make an effort not to cause harm. For example, in recent years, 5% of the arable farmland in Africa has been taken over by foreign investors, meaning it cannot be used for vital local food production. This is absurd.

What should politicians do to help?

Politics has a decisive role to play. Governments are best placed to act in the public interest. In this case, this means preventing malnutrition and enforcing the right to food. For industrialized countries, this entails rethinking their own failed agricultural policy, reducing subsidies, and opening up their agricultural markets. There is also much to do in

developing countries. They must again shape their agricultural policies more actively; women should play an important role in this.

Should those facing hunger and malnutrition first help themselves? How can you make that happen?

Those affected do try to help themselves, but do not always have the opportunity to do so. Oxfam is funding hundreds of projects aimed at helping people to help themselves. For example, we are making it possible for people to exchange information on farming methods – because we believe that small farmers can best learn from other small farmers.

Can these approaches really ensure that people everywhere have adequate food supply?

There is already enough food today, but almost a third of it ends up rotting. Instead of creating ever more food and thereby destroying nature, we propose that the food available should be better distributed and used.

And you do not see food fortification playing an important role in combating hunger?

In emergencies it may make sense, but there is also the risk of making people dependent on charity and not taking their right to food seriously. ■

Frank Braßel

Frank Braßel has worked for Oxfam Germany since 2011 and is head of its “Mahlzeit!” campaign. The international aid organization Oxfam was founded in the United Kingdom in 1942 and today has branches in 17 countries. The “Mahlzeit!” campaign advocates a shift toward ecological and socially fair agriculture. Braßel was born in 1958 in Herne, Germany, and studied German and History at the Ruhr-Universität in Bochum. In 1986, he co-founded the human rights organization FIAN (FoodFirst Information and Action Network), which advocates a right to food for everyone. From 2005 to 2011, Braßel worked for the Church Development Service (EED) at the independent SIPAE agricultural research center in Ecuador.



To find out more, visit:

www.oxfam.org

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In emergencies, food fortification may make sense, but there is also the risk of making people dependent on charity and not taking their right to food seriously.

Frank Braßel, Head of the “Mahlzeit!” campaign at Oxfam/Germany

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The best investment in human development

“Providing micronutrients to the undernourished is the best investment in human development,” believes the Copenhagen Consensus, a group of leading economists that includes five Nobel Laureates.

We at BASF's Nutrition & Health division took up this call for action. It quickly became evident to us that the benefits of micronutrient fortification are huge: Consumption of fortified foods improves health, which directly leads to better educational opportunities and improved productivity. At the same time, it prevents costs accrued by treating illnesses that are caused or aggravated by micronutrient deficiencies. The benefits are even more evident when one considers how small the costs can be to help those in need, in particular low income groups in developing countries: A bottle of cooking oil enriched with vitamin A, for example, costs only 0.2 euro cents more than a conventional one.

This is why we started our food fortification program, which combines social responsibility with financial self-sufficiency. With such a dual bottom line, food fortification is an approach to Corporate Social Responsibility that is sustainable and scalable.

Taking center stage in all our food fortification efforts is the 'inclusive

business ecosystem': We partner with highly complementary stakeholders, including the United Nations, civil society, academia, development agencies and local food producers in more than 30 developing countries. The diverse strengths of these partners are key for effective food fortification programs. For instance, our partners advise governments on national policies, regulation, and quality control for micronutrient fortification, whereas we enable local food producers to fortify staple food by providing them with technical nutrition expertise.

One example of a very successful multi-stakeholder partnership is SAFO (Strategic Alliance for the Fortification of Oil and Other Staple Foods), an initiative supported by the German government which promotes the local production of affordable fortified staple foods in six developing countries. BASF contributed technical assistance and developed portable mini laboratories for analyzing the vitamin A content in



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We are driven by a desire to make real, sustainable improvements to people's lives.

Walter Dissinger,
President Nutrition & Health at BASF

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fortified foods. The result: SAFO has improved the diet of more than 150 million people.

The success story of food fortification was decisive for BASF's public commitment at the United Nations Conference on Sustainable Development, Rio+20: BASF will strive to reduce vitamin and mineral deficiencies in people suffering from or at risk of malnutrition – each year 60 million additional people shall benefit from fortified staple foods.

We believe that micronutrient fortification is one possible answer to the question of how to fight 'hidden hunger' in the world. Yet food fortification alone is not capable of solving the problem of hunger. Through engaging in the long-term approaches of improving agricultural production and dietary diversification, BASF makes a vital contribution to the easing of these problems. In our Samruddhi business model, for instance, BASF agronomists advise Indian farmers throughout the growing season. Not only does this ensure our customers' success – we

are helping around 225,000 farmers secure good harvests – but our business with crop protection products for soybeans in India also grew.

'We create chemistry for a sustainable future' – that is BASF's purpose. Social responsibility is a core element of our strategy. Within BASF's Nutrition & Health division, we want to contribute to the improvement of the nutrition, health and wellbeing of consumers all over the world. We are driven by a desire to make real, sustainable improvements to people's lives. Micronutrient fortification is one of the ways we hope to achieve this. This is why we will continue to move forward with the best investment in human development. ■



To find out more, visit:

www.food-fortification.com
www.wbcd.org/rio-20/membercommitments.aspx

Above Food fortification enriches staple foods with vitamins and minerals to address the nutrient deficiencies prevalent in a particular country.



Walter Dissinger

Since 2010, Walter Dissinger has been President of the Nutrition & Health division at BASF, which works to support and improve the diet, health and wellbeing of people around the world. Prior to this, the industrial engineer worked at BASF's Styrenics and Performance Chemicals divisions, and was head of the crop protection business in Latin America.

The reinvention of light



Organic light-emitting diodes (OLEDs) create a world in which illuminated wallpaper and windowpanes that turn into a source of light at night are possible. Experts are convinced that in the next few years, these promising energy savers could revolutionize the lighting sector.

The centuries-old door is three meters high, dark and heavy, allowing no light to pass through. But behind this door, the future of lighting is being developed. This is where Professor Dr. Karl Leo has his office at the Dresden University of Technology, Germany.

Together with his team, he is developing a very special lighting panel. The 52-year-old works at the university's Institute of Applied Photophysics. At the same time, he manages the Fraunhofer Research Institution for Organics, Materials and Electronic Devices (COMEDD) in Dresden and is internationally recognized as a pioneer in the field of organic light-emitting diodes (OLEDs). He and his team are aiming to realize the potential of OLEDs to imitate natural light as accurately as possible. "OLEDs are a technological sensation that enables us to completely rethink artificial lighting," enthuses Leo.

The competition for efficiencies

The expectations placed on OLEDs are high; they are expected to become more efficient than all existing light sources and, someday, to be able to convert nearly 100% of their energy supply into light. These weighty ambitions place demands on materials developers and lighting manufacturers alike. With electric light bulbs, halogen lamps, and energy-saving lamps, a large proportion of the energy is converted into heat instead of light – the surface of a 100-watt electric bulb, for example, reaches a temperature of more than 200C (392F) when lit. By contrast, the OLEDs being developed in Dresden remain at around 30C (86F), so they're always safely cooler than body temperature.

The luminous efficiency of commercial OLEDs is currently between 45 and 60 lumen per watt. In the laboratory, values of more than 90 lumen per watt have already been achieved. For the purposes of comparison: A standard fluorescent tube achieves 45 to 75 lumen per watt. At 10,000 hours, the lifespan of OLEDs is also promising, even at this stage. Leo and his team are working on

making these values better still. Before major lighting manufacturers incorporate OLEDs into large-scale production, they must reach a lifespan of several tens of thousands of hours and achieve an efficiency that is approximately twice that of existing fluorescent tubes.

Light for wellbeing

It is not only because of their efficiency that OLEDs are the light source of the future. "Their light is more flattering, softer and more forgiving than any other light source, which is why I call it the 'light for wellbeing,'" says Rogier van der Heide, head designer at Philips Lighting (see interview on page 41). The secret to their 'feel-good' factor lies in the way they emanate light. In contrast to all other past and present artificial light sources, OLEDs do not emit light from a point; they are a flat light source. "With OLEDs, it is also possible to regulate the color temperature and adapt the light to the time of day," explains Leo. So, it is possible to have a warm white light for the morning and evening hours and a cool white for daytime. "This is something which has hardly been seen before with lighting," he says.

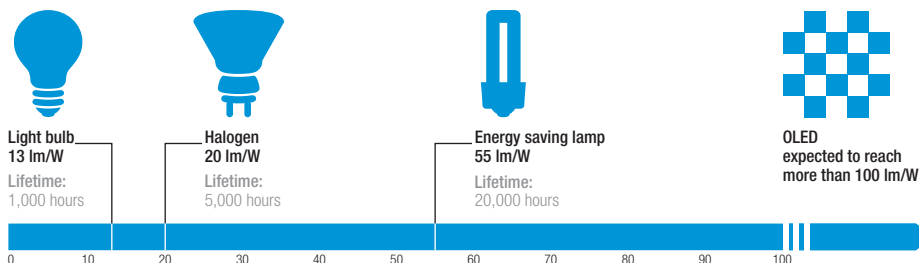
Another property of OLEDs is inspiring lighting designers as well. They are made of wafer-thin organic materials, and in the foreseeable future it may be possible to place them like a second skin over wallpaper, ceilings, or windows. This would enable a ceiling to create the perfect illusion of a summer sky, or a wall to become a virtual spring meadow. When switched off, OLEDs are white, reflective, or transparent – so they could be used to help create windowpanes that let in sunlight during the day, then transform into flat lamps in the dark. The rooms of the future might be able to do away entirely with lamps as we know them today.

Carbon molecules create light

OLEDs function according to the same principles as LEDs. With both types, light is produced using semiconductors. These are solids that conduct electricity under certain conditions. When >>

Increasing efficacy

Luminous efficacy shows the amount of light produced per watt of electricity. It is measured in lumens per watt (lm/W).



Organic light-emitting diodes (OLEDs) may soon revolutionize the lighting market. Their light output promises to break all records.

Source: U.S. Department of Energy: *Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030*, Elektrizitätswerke des Kantons Zurich (EKZ).



electricity flows through semi-conductors, they start to glow. The difference between LEDs and OLEDs is the “o,” which stands for “organic.” While LEDs use tiny inorganic crystals based, for example, on gallium nitride, OLEDs are made from pigment-like organic compounds that are normally used to coat a base material by means of vapor deposition.

The structure of an OLED is a bit like a sandwich (see graphic on page 39). The organic layers are positioned between two flat electrodes, which are around a hundred times thinner than a human hair and are invisible to the naked eye. When an electrical current is passed through them, the molecules in the organic layers start to glow. If red, green and blue substances are combined, white light is created. “We have so far used only glass as a base, but flexible materials are likely to be used in the medium term,” says Leo. The organic semiconductors must be well protected against steam and air and be properly encapsulated. It is still difficult to achieve this on pliable materials.

Glowworms – nature’s OLEDs

The beginnings of OLEDs go back

to 1979 when the Chinese-American chemist Professor Dr. Ching W. Tang discovered a blue glowing phenomenon in organic matter when working on solar cells at Kodak’s research department in the United States. Eight years later, he and his colleague Steven Van Slyke presented the first light-emitting diodes made from organic layers. In the animal kingdom, the principle is age-old: Glowworms are like nature’s OLEDs. Their bodies contain a natural substance called luciferin that reacts with oxygen thanks to an enzyme. The energy produced is almost entirely emitted as light; but while the luminous molecules in glowworms disintegrate, in OLEDs they revert to their original state.

Companies such as BASF are working on making the molecules produce light for longer and more efficiently than has been the case so far. BASF is a leader in the development of blue luminous substances – the biggest challenge that these organic materials present. As Dr. Karl Hahn explains, “blue light has much more energy than green and red. This means that the molecules can disintegrate and lose their effect.” Hahn is in charge

of research in the field of organic electronics at BASF. BASF’s researchers achieved their first breakthrough with highly efficient molecules a few years ago. Now they are working on extending their lifespan and on developing the robust lighting systems we call diodes.

Practical applications

Well-known lighting manufacturers have already made use of the new technologies. Two of the leading companies are Osram and Philips. Almost four years ago, Osram, a subsidiary of Siemens, introduced the first OLED light sculpture – known as Early Future – onto the market. Since then, Osram has expanded this business and created entire conference rooms for its customers with a combination of OLED and LED lighting. In 2011, the company opened its first OLED pilot production line in Regensburg to enable such applications to be available on a larger scale in the near future. Here, Osram is researching how these sensitive light panels can be processed on an industrial scale.

The Dutch company Philips has christened its first OLED lighting module Lumiblade, presenting it in

2010 as the world’s largest OLED light installation: The wall is made up of more than 1,000 small panels. A camera records every movement made in front of it and translates them into electrical impulses that light up individual panels. The natural ‘feel-good’ light could also be used in hospitals and doctors’ surgeries in the future. Enquiries are also coming from museums interested in a gentle light source without UV rays and strong heat emission. Japan is already a step ahead; the first exhibition halls here have already been equipped with OLEDs.

The start of mass production

The new technology is inspiring Asian manufacturers in particular. In Japan, following the Fukushima nuclear disaster and the temporary closure of most nuclear power stations, almost everybody is trying to save electricity wherever possible, according to Dr. Takuya Komoda, Research Director in the organic lighting division at Panasonic. Lighting accounts for 16% of Japan’s total energy consumption. “In order to reduce the power consumption of lighting, it is urgently necessary to introduce next-generation lighting

5–10

How many times longer an OLED lasts compared to a light bulb.

40,000

The number of hours that an LED lasts for.

10,000

The number of hours that an OLED currently lasts for.

Source: Dresden University of Technology



To find out more, visit:

www.oled-research.com

www.basf-futurebusiness.com/en/projects/organic-electronics/oled

Top left The organic light-emitting diodes (OLED) lamps made by the Franco-Italian company Blackbody are simultaneously stylish and energy-saving.

Below This display made from organic light-emitting diodes (OLEDs) is only a few millimeters thick. It impresses thanks to its flat design as well as its sharp picture.

devices. OLEDs will be a very important lighting source in the future because they are able to provide both high energy savings and an excellent lighting atmosphere," says Komoda. Although energy-saving lamps are more efficient right now, this will change. "We are planning to raise the power efficiency of OLEDs up to 100 lumen per watt by 2018."

In 2011, the Japanese company Lumitech, which specializes in OLEDs, gave the market new momentum by launching affordable hanging light panels and OLED desk lamps at a unit price of \$410 (€315) and \$650 (€500) respectively. Additionally, Konica Minolta is taking part in the lighting revolution of the future with its Symfos light panels. The company has also made headlines with a type of print head for OLEDs. Instead of ink, this device, the first of its kind, applies electronic functional materials and is thus able to 'print' organic lights.

Governments embrace OLEDs

Policymakers have also recognized the potential of these energy-efficient miracle lights and has been promoting their development for years. In the United States, the Department of Energy has been supporting research, development and the manufacture of efficient light sources such as LEDs and OLEDs since 2003 with its "Solid State Lighting Program". The government's aim is to reduce electricity consumption for lighting purposes.

In the European Union (E.U.), the aim is to achieve a 20% reduction in greenhouse gas emissions by 2020. To achieve this, the E.U. is promoting research in the energy sector,

including OLEDs as an energy-saving and environmentally friendly technology of the future. Several million euros are flowing into European research projects in which the scientific community and industry are working together to develop OLEDs that are more efficient. In Germany, the Federal Government is supporting research and development through its OLED 2015 program. Together with business partners, it has invested more than \$1 billion (€800 million) since 2006. This initiative includes follow-up ventures like the Kobalt Project, launched in the spring of 2012 and involving partners such as Philips and BASF, where the focus is on developing cost-efficient OLED components for applications in the lighting market.

OLEDs in displays

OLEDs are already widespread in the display industry. For example, Korean company Samsung is already using mass-produced flat light panels in its latest cell phones and tablets. This is a chance for OLEDs to truly show what they are capable of. They emit light themselves and do not require any background lighting – this saves electricity. The sharp, high-contrast images load quickly. The design is equally captivating: the first 55-inch OLED TV sets presented by Samsung and Korean electronics group LG are only a few millimeters thick. Browsing the web for information on OLEDs, it's possible to glimpse the future: Images show prototypes with flexible displays; examples include e-books, that can be folded like handkerchiefs and cell phones that can be rolled up.

Good business prospects

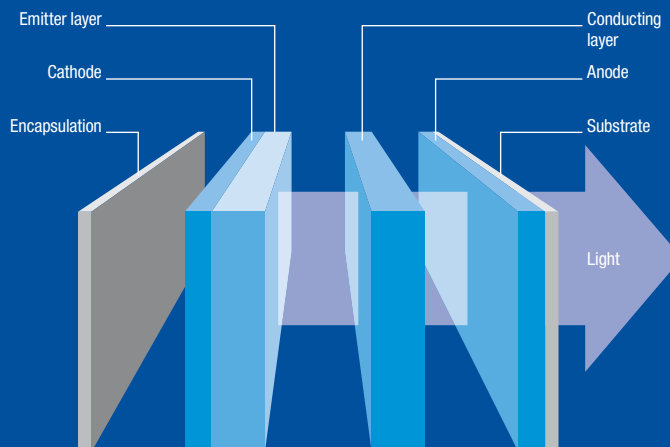
"Annual sales of small OLED displays already amount to around \$4 billion," says Professor Dr. Leo in Dresden. In a few years, this figure will have risen to double digits. If costs fall and efficiency increases, experts believe that nothing will stand in the way of an OLED revolution.

"LEDs have been under research for 40 years longer and thus have an edge today. But provided OLEDs reach an energy efficiency comparable to that of LEDs, both solutions will each take their own share of the lighting market – precisely because they represent complementary alternatives," says Dr. Felix Christian Görth of BASF Future Business. The organic light panels will therefore not entirely monopolize the market, even in the future. For certain applications, such as car headlights, point light sources are still in demand. LEDs might therefore be the future of point light sources and OLEDs the future of flat lamps. For Görth it is no longer a question of whether OLED technology will be commercially successful. "OLEDs have, after all, played an important role in cell phone displays since 2011," the BASF expert points out. "The only thing still open to debate is how big the market will ultimately be," he adds.

The fact that the big breakthrough is still to come for OLEDs is apparent from Professor Leo's office in Dresden. He still has a conventional reading lamp on his desk, and the room is still lit by traditional fluorescent lamps on the ceiling, yet he is convinced: "It may not be long before OLEDs become commonplace in many offices like mine." ■



How OLEDs work:



OLEDs are built like a sandwich, with a filling made up of wafer-thin layers of organic material. These layers are placed between a positively charged anode and a negatively charged cathode. When an electrical current is passed through them, electrons and positive charges flow into the middle of the sandwich and coalesce. In so doing, they cause the embedded molecules to glow. Because the organic layers are very sensitive to water and oxygen, they must be encapsulated for their protection.

BASF researchers are taming blue light

Having the blues is not always a bad thing, at least not for BASF's researchers. In 1897, they produced the first ever artificial indigo-colored pigment. This dye, which had previously been an expensive luxury imported from India, was suddenly affordable, and can today be found in virtually every pair of jeans. The company now wants to create another innovation involving the color blue, but this time on the lighting market.



Only the right mixture of red, green, and blue light produces the white light of an organic light-emitting diode (OLED). But until now, manufacturers have had to make do with a blue dye that is relatively inefficient. The fluorescent emitters currently on the market convert no more than a quarter of the energy into light, with the rest being converted into heat. "What we want, however, are lamps and not hotplates," says Dr. Karl Hahn who is in charge of BASF's research in the field of organic electronics. BASF chemists therefore started looking for a solution to the 'blue problem' a few years ago. They discovered molecules that shine blue and are able to convert the energy almost entirely into light. These molecules belong to the highly efficient phosphorescent emitters used in OLEDs. There was just one snag, however: they only lasted a few minutes.

While long-lasting red and green variants of the highly efficient OLEDs are already available, there is still no corresponding blue in the palette. The reason for this is that blue light is particularly aggressive. "It is very short-waved and thus highly charged with energy. Blue light is therefore able to destroy molecular bonds like no other light can," Hahn explains. The challenge for BASF researchers is to find molecules able to withstand this strong energy over a long period. An OLED must be long-lasting in order to be suited to applications such as lamps, cell phone displays, and TV sets. However, finding the right dye is not the end of the story. The other materials in the blue OLED sandwich (see diagram on page 39) must be robust in order to enable OLEDs to shine brightly and over a long period. BASF is therefore working on the entire materials system for blue diodes and aims to be the leading supplier worldwide for these active components.

BASF has already managed to extend the few minutes of life of its early molecules to several thousands of hours. "But lamp manufacturers

want several tens of thousands of hours," says Hahn. BASF's researchers are working to achieve this goal in the company's chemistry laboratories. Day after day, lab assistants are using vapor deposition techniques to coat small glass plates with dye molecules and materials that make them shine. Countless diodes have been produced in this way. "We constantly test new combinations," says chemist Dr.-Ing. Soichi Watanabe, originally from Japan.

Watanabe is completely covered in protective clothing. "The wafer-thin layers on the diode must not, under any circumstances, be contaminated with dust particles," he explains. Even a single speck of dust would act like a mountain on the much smaller molecular layers and destroy the lamps. Steam and oxygen are also poison to the organic molecules. They would quickly spoil. "It's like with sushi. I would prefer to eat it fresh rather than a couple of days later," says Watanabe. The lab assistants must immediately seal each individual glass plate with another glass plate once all the molecules are in place.

The finished diodes are tested in two chambers. In the first, trials are run on light intensity and other parameters. In the second, which looks like a small recording studio, the durability test is carried out. A large number of switchboards are attached to electrical cabinets and computers. On the black cabinets, 360 diodes shine for days on end. The series of figures on the screens show which lamps are worth continuing to work on. Watanabe and his colleagues continually assess these data.

In 2014, BASF hopes that the blue dye and the associated system components will be ready for the mass lighting market. By 2016, the BASF blue should have the necessary depth of color for the display industry. The researchers are aware that they will have to fight hard for every inch of progress until then. "We are working on a pioneering development, and every day this rekindles the team's spirit of discovery," says Hahn. ■

Left With their efficient blue OLEDs, BASF researchers want to revolutionize the lighting market.



Taking lighting to a new dimension

Rogier van der Heide, Philips Vice President and Chief Design Officer, talks about fascinating new organic lighting concepts and his personal visions for the future.

Above left The design of this chandelier, made of OLED lighting tiles, is the work of Tommy Voeten from 1212-Studio, and was inspired by the structure of DNA.

Above right Rogier van der Heide.

Creating Chemistry: Luminous wallpaper, windows and doors as flat sources of light – organic light-emitting diodes (OLEDs) are revolutionizing the lighting market. What new opportunities do OLEDs offer with regard to lighting design?

Rogier van der Heide: OLEDs offer much greater integration of light into objects, furniture, cars, buildings, architecture... even fashion. Suddenly, illumination can go where it has never been before. With OLEDs, designers have unparalleled possibilities to use light in new and unexpected ways.

Can you tell us what organic lighting concepts you are currently working on?

We are working on many concepts based on OLEDs. We're looking into integration in car interiors, and we recently launched a mirror that radiates light just around your face. The OLED lighting it uses is incredibly natural, flattering and soft – the perfect light by which to see your features! I love such concepts; they truly draw from the unique properties of OLEDs as a new art of light.

What is your favorite piece of design using organic diodes and what makes it so fascinating?

I really love the OLED chandelier designed by Tommy Voeten of 1212-Studio, which was further detailed and engineered by Philips. It was inspired by DNA, and expresses the idea that groundbreaking OLED technology adds new, fundamentally different possibilities to the way we light our environments.

That sounds sensational, but also fairly upmarket. When will luminous wallpaper be stocked at my local home improvement store?

It would be fantastic to have luminous wallpaper, and of course we are looking into ways of making light flexible and uniform. Any new form of light that expands the freedom of designers is interesting and relevant. For a long time, light was limited to the light bulb and the tube light, but now new concepts are constantly being developed. Will luminous wallpaper become widely available in future? We'll see. Check back with us in two years!

How will the new OLED lighting concept change our living and working environment?

OLED is more flattering, softer and more forgiving than any other light source. It renders human skin beautifully. We all look better in OLED light, which is why I call it the "light for wellbeing." With OLEDs, we can create environments that are more pleasant, better for our wellbeing and more inspiring than we could before.

Which lighting vision would you like to implement in your own home?

For my home I love the concept of "the human scale." That means avoiding light sources above eye level and having a number of small lamps scattered around the space, instead of one strong lamp in the middle on the ceiling. It dramatically improves the atmosphere of any room. ■

A glimpse around the globe: packaging

Minimalist, playful, sustainable or uniquely regional – a look at diverse examples of packaging from around the world shows just how inventive this industry can be.



Refined and inviting

The design for these Japanese sushi rolls was produced by a laser cutting into paper-thin sheets of seaweed.

Practical and functional

The lid of this Korean butter packaging also serves as a spreader for when customers are on the move.



Economical and useful

With this unique Chilean lamp made of thermoformed plastic, the packaging and product are one and the same.



Ecological and clever

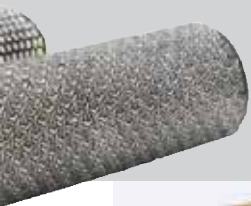
A simple piece of folded card is used to make this Philippine snack packaging, with no glue involved at all.



Fruity and functional

This Japanese banana juice packaging looks and feels like a banana.





Round and sound

Packaging for a good cause: Children in developing African countries can assemble their own soccer ball using the cardboard from aid packages.



Innovative and environmentally friendly

This Dutch packaging actually forms part of the contents – it is used to create a child's chair made of corrugated cardboard.



Compact and minimalist

This shoe box from the United States is made of recycled papier-mâché and takes up very little space when stacked.



Playful and traditional

These Ukrainian containers are used for sour cream and play on local culture and traditional milk jugs.



Evocative and exquisite

This family pack of tea from Singapore recalls traditional regional architecture.



Boxing clever

These days, nearly as much research and development goes into how we package our food as goes into the food itself. Innovations and high-tech solutions mean that the cartons, films and bottles ensure that food is kept fresh and safe, helping food production to become more efficient and safe.

In Austin, Texas, there is a supermarket where customers are advised not to come empty handed to do their weekly shopping: fabric bags are the order of the day. Shoppers who fail to bring these must buy compostable containers to take home their purchases of fruit and vegetables, which are largely locally grown. Known as the first precycling supermarket in the United States, it does not offer any packaging at all.

What may work on a small scale, however, is simply inconceivable at a larger level, with food packaging now an essential part of our everyday lives. "Packaging is key when it comes to protecting our products, guaranteeing our high quality standards, preventing food waste and informing consumers," says Dr. Anne Roulin, Global Head of Packaging and Design at Swiss food conglomerate Nestlé. There are many reasons for the growing need for food packaging. More than half of the world's population lives in cities, where there are few options for growing food independently. The planet's 3.5 billion city-dwellers thus buy their products outside of the home – and they usually come packaged. In addition, the rising number of single-person households, which prefer smaller portion sizes, and the growing trend of eating on the move between appointments are giving rise to an increasing amount of packaged food.

Freshness is imperative

The demands made of packaging are high. Guaranteeing freshness and hygiene is a particular challenge, as foods must often cover great distances when travelling from their place of origin to supermarket shelves. Further time passes before they find their way into a shopping basket, and then again before they ultimately end up on the dining room table. Highly developed technology ensures packaging can keep products impeccably fresh and hygienic. A quick glance in the refrigerated section shows the complexity of what is involved – the packaging for cheese and sausages, for example, is made of a wide range of plastics. The differing characteristics of these composite materials are combined to ensure the packaging is ideally suited to the food. The base of the packaging, for example, can be produced to have different characteristics than the lid or wrapping film.

Hard-wearing composites made of various materials are also well suited for use in what is known as **Modified Atmosphere Packaging** ¹ or MAP. With this technology, the air surrounding an edible product is replaced with a protective atmosphere specially tailored to the food. One example is a mixture of nitrogen and carbon dioxide. These slow-reacting gases replace oxygen, and slow the growth of germs, all without using any preservatives. To ensure the solution works >>

1 Modified Atmosphere Packaging

"Depending on the food, packaging has to be firm, flexible, transparent, printable, or impermeable to aromas, oxygen or carbon dioxide," explains Dr. Rolf-Egbert Grütznert from polyamide market development at BASF. There is no such thing as a universal material that can do it all. The bottom section of the packaging is made of plastic, such as polypropylene. Polypropylene provides flexibility, protects against moisture, and can act as a seal. The flexible, removable, and often resealable lid is made of a five- or seven-layer film. The uppermost layer contains polyamide like BASF's Ultramid® which is particularly stable and pliable, keeps out oxygen and carbon dioxide, and retains its shape at higher temperatures. The lid ensures an extremely high puncture resistance; it prevents oxygen from entering the packaging and any fat contained within the food from going rancid, or harmful microorganisms developing.

Left Today, there is more to packaging materials than meets the eye. Consumers rarely realize how much sophisticated technology is hidden in these high-tech containers.

1.3 billion

The number of metric tons of food production – around one-third of the total – lost or wasted every year worldwide.

95 – 115 kg

The amount of edible food per person that is lost or wasted each year in industrialized countries.

Source: Food and Agriculture Organization, *Statistical Yearbook 2012*.

properly, the packaging material must form an effective gas barrier. Otherwise, the valuable protective atmosphere would quickly be lost.

Regional preferences

In Japan, the development of sophisticated packaging systems is also driven by regional eating preferences. Japanese consumers react very negatively to packaging that no longer appears perfectly intact from the outside; even harmless creases or folds in packets can cause perfectly fine food to be left on the supermarket shelf. Fish and seafood are often on the menu, and it is particularly important that they are kept fresh and protected against spoiling. It is popular to package foods accompanied by small sachets filled with substances that bind moisture, such as silica gel and starch polymers. "For Japanese consumers, the presence of sachets indicates that the product is very well protected," explains Sven Sänglerlaub from the Fraunhofer Institute for Process Engineering and Packaging (IVV). In contrast, many Europeans view such tiny sachets of moisture-binders with suspicion, and their presence inside a package can prompt skepticism about the food it contains.

Minimizing waste

How can consumers accurately assess the condition of products? Uncertainty in this area often leads to waste: "Too many consumers see the best before date as an absolute cut-off point, although many foods can still be eaten after this time," explains psychologist Stephan Grünewald, from rheingold, a German market and media analysis institute. Every year, in industrialized countries, 95 to 115 kilograms of perfectly good food is lost or wasted by each person, according to a study by the Food and Agriculture Organization of the United Nations (FAO).

In years to come, 'intelligent' or 'active' packaging could help reduce food waste. This is a response to experts' efforts around the world to come up with new ways to inform consumers about the perishability of food and to protect against spoiling. The new systems could display the state of a product, and at the same time increase its lifespan with oxygen

absorbers or special acids. As an example, American firm Sonoco is currently developing packaging with integrated microchips that collect information about the condition of a product, such as moisture and temperature. It raises the alarm when preprogrammed thresholds are exceeded or fall below target. "In the future, I expect to see a shift in business models towards direct contact with consumers," predicts Dr. Anne Roulin from Nestlé.

Environmental awareness

Alongside freshness, increasing numbers of consumers want packaging that can be recycled. According to a survey of 6,000 consumers in ten different countries, carried out by Swedish carton manufacturer Tetra Pak, recyclable packaging is one of the public's key priorities, as it is seen as kinder to the environment.

Consumers and legislative regulators are becoming increasingly concerned with packaging. The aim here is primarily to encourage the efficient use of resources. This trend is particularly noticeable in Europe. In the Netherlands, for example, a tax is applied to packaging manufacturers according to the average CO₂ emissions of the materials used – 36 to 57 euro cents per kilogram for aluminum packaging, 6 euro cents for cardboard.

Sustainable packaging can be worthwhile for packaging manufacturers and food companies. In Europe in particular, demand is on the rise for paper and cardboard packaging with environmentally friendly recyclable fibers, which are also cost-effective. In addition, companies are working to come up with solutions that simplify packaging designs so that **recycling** ² rates rise.

Biodegradable materials

Recycling is one thing; there is growing demand for renewable materials that are biodegradable too. ³ Drinks cartons or food containers, for instance, can be made of **biodegradable plastics** ⁴ formed partly of renewable raw materials. After use they can be disposed of and composted with the rest of the food waste.

Reducing the weight

⁵

of packaging is another way of protecting the environment while protecting companies' bottom lines. As well as cutting the CO₂ emissions generated during transportation, making packaging lighter can reduce costs too. Corrugated cardboard, frequently used in transport packaging for food, can be reduced in weight with the help of fluid synthetic dry strength agents. These mean that fewer paper fibers are needed to construct the cardboard, without compromising its strength.

Focusing on health

In many countries around the world, the trend towards greater sustainability goes hand-in-hand with an enhanced awareness of personal health. As well as **information** ⁶ about the contents, food packaging should also provide details relating to nutrition, calories, and possible allergy triggers.

Potentially dangerous substances are not limited to the food, however – they can also be found at times in the packaging material itself. In 2010, researchers at the Zurich Food Safety Authority in Switzerland found that mineral oil residue contained in cardboard packaging was being transferred to foods. The main source of the problem was deemed to be ink used in newspaper printing, which found its way into the packaging via recycled paper. The residue traces detected also occasionally came from inks used to print the food packaging. These oil residues evaporate at room temperature, and can then be transferred to dry foods, such as pasta, semolina, rice, or cornflakes. This is even possible merely when the transportation packaging of the food contains recycled paper. Certain components of mineral oil are suspected of being carcinogens, according to the World Health Organization's Joint Expert Committee on Food Additives, and the FAO. >>

2 Increasing recycling rates, reducing material requirements

BASF products that contribute to reaching the goals of reducing material requirements and increasing recycling rates include additives, which make plastics more elastic and resistant to ageing and tearing. They are used in processes such as recycling PET beverage bottles. Additives belonging to BASF's Joncryl[®] family ensure that the recycled material obtains the quality of new PET. Moreover, paper chemicals from BASF enable the production of new paper and board from recycled fibers.

3 Water-based adhesives

Water-based adhesives offer an alternative to traditional adhesives. They do not contain potentially harmful ingredients like solvents or aromatic amines which could migrate into the food. In addition, they help optimize production processes, as laminates made with these adhesives can be processed quickly, cutting costs and increasing flexibility. BASF recently launched the first water-based compostable adhesive, Epotal® ECO, which can be used for fully biodegradable packaging.



4 Biodegradable plastics

There can be plenty of garbage left over after sports events, music concerts, and busy days at the zoo. To turn disposable cutlery and food packaging into valuable compost, BASF has developed biodegradable plastics based on renewable materials. The product ecovio® has been available since 2006, and is made of ecoflex®, a biodegradable plastic, and polylactic acid derived from the renewable raw material corn (maize). Due to its molecular structure, ecovio breaks down in a similar way to organic waste, as microorganisms decompose the plastic with the help of enzymes.

The material ecovio can be used, for example, in biodegradable garbage can liners, shopping bags, cup coatings, and food containers made of foam. It is particularly well

suited for use in what are known as closed-loop systems – closed waste systems that can be set up in stadiums, hotels and businesses. Here, the operator will exclusively provide visitors with compostable food serving items. After use, this packaging is mixed with leftover food and collected in organic waste disposal units. A special waste disposal firm then empties these units, and transports the garbage to a composting facility. This ensures far fewer extraneous materials make it into the facility, which would otherwise have to be carefully removed. The Seattle Mariners baseball club is one of the first organizations to apply this system. Around 80% of waste generated during one of the team's home games is sent for composting.

Above Additives ensure that recycled PET boasts the same quality as new plastic.

Below Composite materials help to keep food fresh.



5 Reducing weight

BASF has managed to develop a system, based upon the innovative product class polyvinyl amine, which enables paper producers to respond to the fluctuating quality of their raw materials. The trick is to combine an anionic and a cationic polyvinyl amine. This improves the mechanical strength of the packaging paper, allowing its weight to be reduced while maintaining the same stability. BASF markets this dry strengthening system under the name Carrier System.

6 Adhesive information

Labels with the required information are applied to food packaging with the help of specifically formulated adhesives. Pressure-sensitive adhesives, which are used to produce self-adhesive labels, pose special challenges. On frozen products for example, the label must stay in place at sub-zero temperatures.

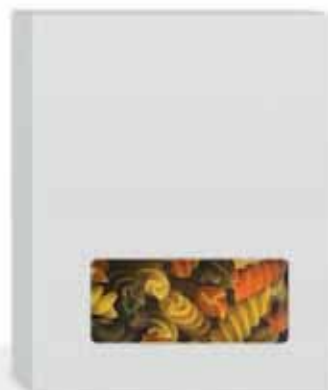
When used in the food sector, adhesives also have to comply with a range of strict regulations. "That's why we have our raw materials for pressure-sensitive adhesives regularly tested and certified by an independent institute," states Michael Gutschmann, who is responsible for pressure-sensitive adhesives marketing at BASF.

Mineral oil barrier in packaging

Going forward, one way of reducing or even entirely eradicating mineral oil residue in paper and cardboard packaging is to use water-based binders for **mineral oil-free printing** ⁷ of newspapers. In addition, food can be protected against the migration of unwanted substances through functional barriers. **Functional barrier solutions** ⁸ are currently available for practically all types of packaging and standard manufacturing processes. In this way, our food is reliably protected from mineral oil and other potentially critical substances.

Over the last few years, research into the best, most secure types of food packaging has made major advances. Guaranteeing safety, providing freshness, and delivering information, our food's containers are increasingly sophisticated and play an important role in our everyday lives. ■

Right Packaging made of recycled paper fibers may contain mineral oil residues that can migrate into food.

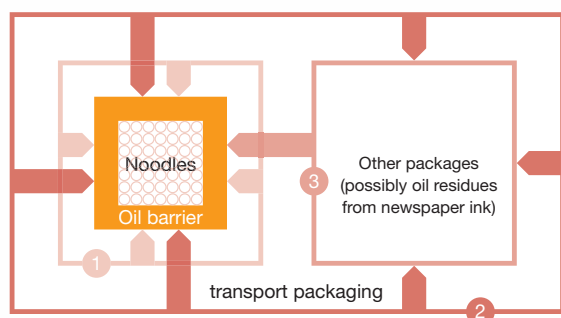


7 Mineral oil-free printing

Under the Joncryl® brand name, BASF has developed aqueous binders that national newspapers in the United Kingdom and Italy already use for mineral oil-free flexo printing. Joncryl is also ideal for printing food packaging.

The mineral oil barrier protects food

Food packaging is often made of recycled paper fibers. This recycled paper packaging can contain newspaper ink, which researchers have identified as the main source of potentially harmful mineral oil residues in cartons. These oil residues evaporate at room temperature and can thus be transferred to dry foods that contain fats, such as noodles.



Mineral oil residues can migrate from:

1. the inner side of contaminated primary packaging
2. contaminated outer packaging, for example, corrugated board packaging used to hold products during transportation
3. contaminated packages in close proximity, for example, on the supermarket shelf or in delivery trucks

8 Functional barrier solutions

The water-based dispersion **Epotal® A 816** can be used to coat films. It creates the desired barrier effect in liner bags, which are often used to package foods like cereal. Three further BASF solutions are available for the protection of food packed into cardboard.

BASF's polyamide **Ultramid®**, can be applied to the inside of cartons to provide functional barrier properties. Moreover, it is suitable for usage in protective inner pouches. In addition, the biodegradable plastic **ecovio® FS Paper** can be used to create the functional barrier for cartons. The barrier made of ecovio FS Paper can either be applied directly to the cardboard or be added to a hybrid material along with paper or plastic, which is then used for liner bags and lamination. The product also shows improvement in cardboard stiffness and provides sealing properties.

Similarly, food packed into paper and cardboard can be protected with newly developed water-based **dispersions** applied onto the board. "This innovative water-based functional barrier solution will give packaging producers more flexibility in creating their end products, whether they want to print the barrier or coat the paper or cardboard," explains Lauren Ritacco from BASF's Paper Chemicals division in Europe. A series of tests, carried out by the Zurich Food Safety Authority, Fraunhofer IVV and Innoform, among others, have proven the effectiveness of the four functional barrier solutions.

Well packaged

Today, packaging must do more than protect food. Nicolas Eilken, 3D Design Director at design and branding agency Lothar Böhm and lecturer in packaging at the Brand Academy of Hamburg/Germany, explains the many roles it fulfills.



Above Nicolas Eilken, 3D Design Director at Lothar Böhm

Above right Different kinds of cheese require different kinds of packaging.



Creating Chemistry: Industry is constantly developing new materials for packaging and protecting foods as well as reducing environmental impact. With such diversity, how do you choose the right packaging for your designs – to pack cheese, for example?

Nicolas Eilken: That would depend on the type of cheese. Some types of cheese ripen in their packaging and need air to circulate, while others require a barrier against oxygen. Consumers' needs also play a role, as does presentation – things like a viewing window, the cheese's appearance on the shelf, and differentiation from the competition. And of course, the material needs to be sustainable.

Many consumers decide which products to buy when browsing the supermarket shelves. How can packaging encourage them to make a purchase?

Freshness, for example, is primarily expressed through graphic design, while the material itself can convey a sense of sustainability or premium quality. If consumers pick up the product, they might see that the packaging is easy to open and resealable, which makes it convenient to use. All these factors can persuade them to purchase, and furthermore, to return to the brand the next time they shop.

Your design agency Lothar Böhm has offices in Hamburg, London and Warsaw. Do Polish people prefer different things to the British or the Germans when it comes to food packaging?

Comparatively speaking, the Germans are less willing to experiment and are very rational. Packaging should convey a sense of quality; customers look for high quality at a good price. They also want to see what they are buying. British people are a step ahead in terms of design – they are even happy with pink packaging for cheese! In Poland, meanwhile, packaging must be authentic and playful, with even brighter colors. As each nation has different habits and customs, it is difficult in the food industry to produce packaging that can be employed globally.

Rising levels of packaging waste continue to be a problem. What are you doing to counteract this?

We are looking at ways of reducing volumes, to cut the burden on transport and logistics. In addition, we are working to save materials by minimizing the thickness of packaging.

Are there any food packaging functions that you would like to see developed?

Most functions can already be carried out, such as cooling or self-heating packaging. Scientists are currently working on how to add moving images or changing messages to packaging. This would allow us to communicate far more engagingly with smaller packaging units. It remains prohibitively expensive, but I think it's on its way.

From trash to treasure

In developed countries, primary supplies of raw materials for high-tech industries are beginning to dwindle, but there are still large untapped reserves to be found in both household and industrial waste. The recycling of rare metals is in its infancy, but it already has some influential supporters – including a Japanese virtual singer.



Three years ago Japanese authorities recruited Hatsune Miku for a recycling campaign. The virtual character, who is popular among young people in Japan, invited her fans to return their old cell phones for recycling. In addition, a competition encouraged the public to take part in the phone recycling scheme. It was a resounding success: In a hundred days, more than 570,000 phones were collected at almost 2,000 shops. With the campaign, the government wanted to tap an often overlooked source of raw materials: electronic waste.

According to experts' estimates, 20 kilograms of cell phones contain as much as one metric ton of gold ore. And gold is not the only resource in cell phones: A typical mobile phone contains about 40 raw materials, including rare special metals such as indium, palladium, cobalt, and tantalum. While the names of some of these elements may not be familiar to us, they are extremely important for the production of future technologies. This is why companies and governments are increasingly trying to recycle old cell phones and other high-tech scrap.

The matter is even being discussed at the highest political levels. Last year the European Commission presented a "roadmap to a resource-efficient Europe", which outlined ways for industry and business to increase resource efficiency by 2020, with one of the proposed strategies being metal recycling. And two years ago, Rainer Brüderle, then German Minister of Economics and Technology, stated at a raw materials congress of the Federation of German Industries (BDI): "Recycling is the most important domestic source of raw materials."

Recycling is now recognized as an important contribution to meeting future demand for rare metals. This is particularly the case for industrial nations with few natural resources, such as Germany and Japan, which

are often dependent on imports to meet their demand, because it allows them to develop their own local sources of supply.

Shortage of resources

The main reason for the growing demand in special metals is the success of microelectronics. These days, almost every Western household uses smartphones, video game consoles and laptops. At the same time, the consumption of these goods in emerging markets like China and India is likely to rise dramatically. In addition, the semiconductor industry uses an increasing variety of raw materials. Today, semiconductors contain about 60 different chemical elements – compared to just 12 in the 1980s.

The fact that many different technologies use the same materials complicates the matter further. Alongside microelectronics, other advanced technologies like fiber-optic cables for telecommunications networks, fuel cells, wind turbines and catalysts are driving up the demand for rare metals. A 2011 E.U. study concluded that the development of alternative energies might suffer if member states ran short of special metals. The heavy metal indium, for example, is not only a basic component of modern flat screens and lasers, but also of solar panels. As the market for new technology will grow in the long term, so too will the demand for rare special metals, which the production of so many cutting edge products relies upon.

Small quantities, huge impact

Depending on the metal, the amounts being used can be surprisingly small. Whereas in 2011 the world production of copper amounted to a total of 17 million metric tons, in contrast, the yearly output of indium could be pressed into a cube with an edge length of just 56 centimeters (1.8 feet).

Although the quantities consumed seem small, the scarcity of special metals – especially the rare earths –

is a key topic in the media these days. These metals are rarely found in concentrated form in the Earth's crust, which makes it hard for companies to mine them. There are 17 rare earth elements, and they are used in catalysts, LEDs, magnets and other products. The most important rare earths mines are located in China, which today meets more than 90% of the world's demand. The largest rare earths mine in the western world, the Mountain Pass Mine in California, was closed in 2002 because it was not profitable.

There are several reasons for the scarcity of certain metals. Some naturally only occur in small amounts, while reserves of others have not been developed yet; worldwide supply of the metalloid germanium, for example, could be exhausted in 17 years. But sometimes raw materials are scarce because they come from politically unstable regions. For example, a major mining area for minerals like coltan, which contains tantalum, is located in the Democratic Republic of the Congo where civil wars have been raging for years. In other cases, government policies can artificially limit supply. For instance, in recent years China has reduced the export of rare earths. "Among other reasons, the Chinese government did this in an attempt to force companies to shift production into their country," explains Dr. Hubertus Bardt, an expert on natural resources at the Cologne Institute for Economic Research, a non-governmental think tank in Germany.

Limited supply of rare metals has pushed companies and researchers to look for solutions. Australia will soon begin producing rare earths from local mines. In California, the Mountain Pass Mine is reopening. Many industrial companies are revising their processes to make better use of their stock of scarce materials. Japanese universities are looking for materials that could replace rare metals. >>

“ Recycling is the most important domestic source of raw materials.

Rainer Brüderle, former German Minister of Economics and Technology

”

Hatsune Miku is a virtual character that performs songs created by users of a music software package.

The secret value of landfill

Another valuable strategy is, of course, recycling. The extraction of materials from high-tech waste is referred to as “urban mining.” Whereas mass metals like lead or aluminium are already recycled in large quantities, rare metal recycling is a nascent industry. “At the moment, almost no rare metals are recycled, but this is the goal we have to set ourselves,” says Dr. Stefan Gäth, Professor of waste management and environmental research at the University of Giessen, Germany. A report published last year by the United Nations Environment Programme (UNEP) confirms Gäth’s assessment. Among 37 special metals analyzed in the report, 32 had recycling rates close to zero.

There are various reasons why these kinds of metals are not yet being widely recycled. Sometimes, recycling companies face technological problems. Whereas precious metal recycling is relatively easy, rare earths are hard to extract from electronic scrap. Cost is another factor – and not just for rare earths: The energy required to recycle indium from screens, for example, is enormous. And in the case of metals like wolfram, beryllium or gallium, the amount of metal being used in high-tech products is so small that recycling it would only make sense if combined with the recycling of other metals like copper or gold. In this situation, rare metals are mere by-products of an extremely complex recycling chain. Worldwide, there are only a few recycling plants that are able to recycle rare metals this way (see feature on pages 54 and 55). “The industry is only just beginning to realize the full potential of rare metal recycling – it’s a step by step process,” says Bardt.

There are logistical challenges, too. Scrap needs to be taken to a modern recycling plant for the maximum levels

of valuable metals to be extracted from it – but this seldom happens. According to UNEP, every year 40 billion metric tons of electronic scrap are thrown away. Only a tiny amount is recycled – in the case of cell phones, it is only 2% or 3%. The rest ends up in the waste stream; is combined with other metals – a process called downcycling – or shipped to developing countries, where the regulations for disposing of electronic waste are less strict. According to experts, between 50% and 80% of E.U. electrical scrap is exported to developing countries although the Basel Convention of 1989 forbids this practice.

The perils of backyard recycling

The illegal international electronic scrap trade is responsible for environmental pollution and can cause health hazards for people in developing countries who dispose of the waste. In addition, when recycling is unregulated, it is often inefficient, and metals are not recovered at optimum rates. Experts estimate that, on average, developing world recyclers retrieve only 25% of the gold in old mobile phones. Modern recycling processes increase the rate to 95%. This is why, at the moment, experts are discussing the introduction of a cell phone deposit system. “This way, society would put a value on e-scrap and create an incentive to bring mobile phones back to official collection points,” says Gäth.

At the same time, some companies are developing their own systems to recover the treasures hidden in high-tech waste. Japanese car maker Honda has started cooperating with partners to retrieve rare metals from car batteries, while electronics manufacturer Hitachi has announced plans to recycle rare earths from hard drive magnets. Furthermore, German technology



Electrical waste is sorted before recycling.

company Siemens recycles indium from old X-ray machines.

Maybe, one day, it could even be profitable to mine old landfill sites. German waste management expert Gäth has already carried out test drills in three closed trash dumps in Germany. He found a wealth of scrap metal, including old vacuum cleaners and disused cars. A garbage dump in Hechingen, a small town in the south-west of the country, contains raw materials worth \$84 million

(€65 million) to \$155 million (€120 million), according to Gäth’s estimates. At the moment, mining landfill sites would still be too costly to make it worthwhile, but Gäth believes that will change as raw material prices continue to increase: “I think this could be the case sometime between 2025 and 2040.” ■

Rare metals in modern technologies

Rechargeable batteries: Both electric cars and laptops need powerful batteries. In order to produce these batteries, lithium and the heavy metal **cobalt** are often used. 40% of cobalt originates from the Democratic Republic of the Congo, where civil wars have been raging for years.

Turbines: High-tech turbines are not only used for airplanes, but also for power stations. The rare element **rhenium** helps to make them resistant to heat and corrosion. Rhenium is a mining by-product, and the major exporter is Chile. The metal is easy to recycle.

Flat panel displays: Indium-based alloys are an ideal transparent conducting material for flat panel displays. **Indium** is one of the rarest raw materials on Earth. Reserves could run out in 2020 – especially because this metal is difficult to replace and its recycling quota is low. Zinc, copper and lead mines produce small amounts of indium.

Thin-film photovoltaic cells: Many rare metals are needed for producing these photovoltaic cells, including cadmium, germanium, indium and **gallium**. Gallium is also used in other semiconductor products. It is a by-product of refining bauxite and about 75% of worldwide

production currently comes from China. Its recyclability is limited.

Fiber-optic cables: Manufacturers of fiber-optic cables are dependent on the supply of **germanium**, which is also used in infrared devices. The metal is a by-product in copper, lead and zinc mining. Demand in Europe could rise by 250% by 2030. However, germanium reserves are expected to last just 17 years at current rates of production.



Municipal recycling concepts

In 2009, each citizen of the European Union (E.U.) produced an average of 510 kilograms of household waste. However, in the United States this figure was even higher, with every citizen producing 720 kilograms on average. Given the growing mountains of trash, many municipalities have to come up with solutions for how to deal with household waste.

Several E.U. member states have introduced waste separation systems since the 1990s, becoming role models for municipalities around the world. A number of E.U. directives have also led to increasing recycling rates across Europe, although statistics still vary widely between countries.

A European model of how to deal with household trash is found in Amsterdam, the Netherlands. The city burns 99% of its household and industrial waste and uses the energy produced to generate electricity for the local public transport system, street lights and for 75% of all households. In addition, the residual heat from incineration is used to provide heat for 12,000 households. Metals like iron, copper and aluminium are collected and sold, while the rest of the waste is used as construction materials for roads.

Communities in emerging markets often cannot afford this kind of investment in recycling technology, but some have come up with innovations of their own. The Brazilian city of Curitiba, for example, introduced a revolutionary

waste disposal program in 1991. Because garbage trucks were not able to access the small lanes of local favelas, the city started a barter program: garbage for food. Every two weeks at 61 designated places in the city, locals can exchange four kilograms of recyclable materials for one kilogram of food. Depending on the season, citizens are also able to swap their garbage for school materials or plants.

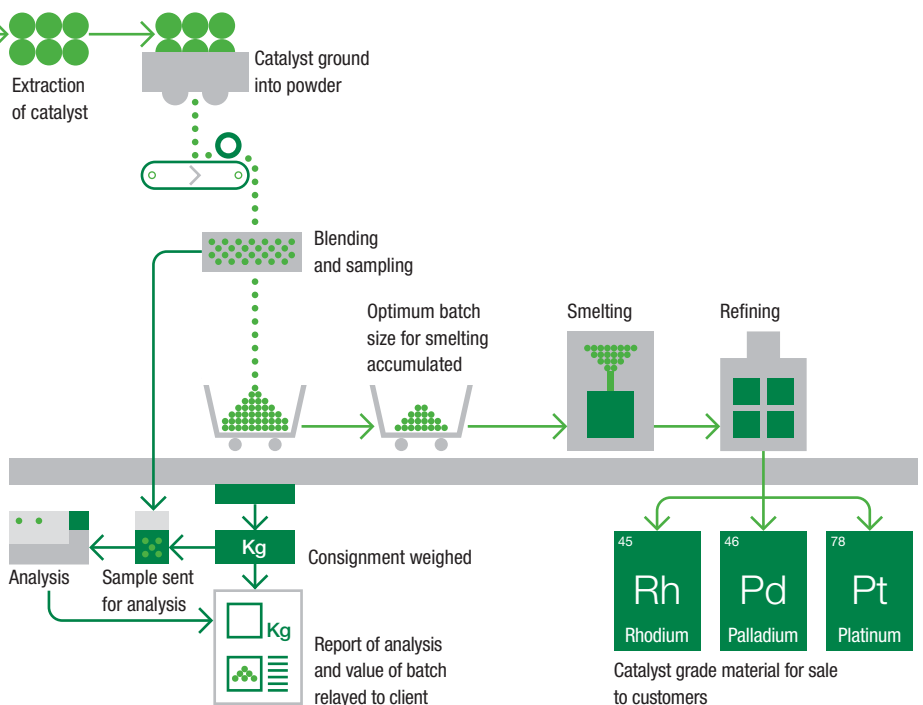
In the United States, San Francisco leads the way in terms of recycling. In 2009, the mayor started a waste separation system similar to those found in Europe. Now, only 22% of household waste ends up in the landfill – one of the lowest rates in the country. The city plans to recover all its household waste by 2020.

In 2009, each citizen of the United States produced an average of 720 kilograms of household waste.

Precious metals from ceramic auto catalysts

Processing and refining

There are currently more than half a billion cars on the roads worldwide, plus around 200 million trucks. Their catalysts contain valuable precious metals like platinum, palladium and rhodium. They help to eliminate engine emissions such as carbon monoxide. The recycling of spent automotive catalysts is a complex process that enables the re-use of their precious metals. BASF operates a plant that can recycle these catalysts in Cinderford, in the United Kingdom (see story on pages 54-55).



Garbage is good

Supplies of precious metals are dwindling, while both prices and demand for them are expected to continue to rise over time. BASF relies on an environmentally friendly process to recycle precious metals from 'end-of-life' materials – mostly spent automotive catalytic converters and electronic scrap materials. These 'throw-away' items contain significant amounts of recoverable, valuable metals. Recently BASF invested approximately \$4.9 million in building a state-of-the-art recycling operation for the recovery of precious metals from industrial scrap materials in the United Kingdom.

A well established tradition of recycling precious metals can be found in the small English town of Cinderford, located in Gloucestershire on the border of Wales and England. The recycling of valuable metals from a variety of sources has been going on here since the 1960s. The BASF Metals Recycling plant, part of the company's global network of precious metals recycling and refining operations, now serves as its European hub for recycling catalytic converters.

The future of the plant can be found in a factory hall behind the main building. Since last year, the space has been occupied by a highly efficient industrial shredding machine that looks like a giant slide connected to a huge metallic silo. Sitting next to the machine is a truckload of raw material: ceramic substrates recovered from spent catalytic converters. The substrates are fed into the machine, which grinds them into a fine white powder that is loaded into large white sacks that are subsequently stacked on nearby shelves. "The powder is later fed into a high-temperature furnace, which breaks down the metals it contains," explains Dr. John Setchfield, site manager. The heaviest materials of the mixture are the platinum-group metals, which concentrate at the bottom. These melted precious metals can then be removed by tapping into the base of the furnace.



Above Dr. John Setchfield has worked at the Cinderford site for half of his life.

“ We want to considerably expand our catalyst recycling operations in Europe, which is why we have made such a significant investment here.

Dr. John Setchfield, site manager of the BASF Metals Recycling plant in Cinderford, U.K.

”



The melts operator is making flux additions during the melting of sampled material. The melting serves to ascertain the precious metal content of a scrap metal delivery.



Left Too valuable for the garbage: There are many hidden precious metals in electrical waste.

Below These copper collection discs are prepared for the precious metal analysis. The laboratory in Cinderford evaluates thousands of samples every year.



To find out more, visit:

www.catalysts.basf.com

Beneficial metals

Catalysts, especially automotive catalysts like those being processed in Cinderford, contain valuable precious metals which help to eliminate engine emissions such as carbon monoxide. Most of the metals recycled in the plant will ultimately be used to support BASF's mobile emissions catalysts business. The business develops and markets a wide range of emissions reduction technology for motor vehicles.

BASF Metals Recycling is a service provider for other businesses whose scrap is bought by the company at world market prices and then processed. It buys scrap from other businesses at world market prices and then processes it. A majority of its customers are industrial scrap dealers that disassemble old cars or collect household electronic waste such as personal computers and TVs.

The facility's brain

"One of the specialties of our plant is that we not only process industrial scrap, we analyze it at the same time," says Setchfield as he enters the laboratory, which is located on the second floor of the main building. It is here that employees test batches of precious metals ranging from platinum, palladium and rhodium to gold and silver. Given its role, the laboratory is considered the 'brain' of the Cinderford facility.

When scrap is delivered to the facility, Cinderford site employees weigh it and take a small sample to ascertain the precious metal content and to estimate the value of the load. Each sample is melted and melded with liquid copper, cooled and then cut into small solid discs, ready for analysis in the laboratory. "Every sample is tested a number of times to avoid deviations," explains Laboratory Supervisor Ben Hillary. Each year the laboratory evaluates thousands of samples.

The Cinderford site is part of a global network of multiple BASF sites that engage in the recycling and refining of industrial scrap materials, including sister plants in Rome/Italia,

Shanghai/China, Lincoln Park/ Michigan and Seneca/South Carolina. The refining of materials primarily takes place in Seneca, where BASF operates a large furnace designed for precious metals recycling.

"We want to considerably expand our catalyst recycling operations in Europe, which is why we have made such a significant investment here," says Setchfield.

This year, the plant in Cinderford will celebrate its 50th anniversary. Setchfield has seen how the recycling business has changed over the years: from the manual melting down of old jewelry to the state-of-the-art recycling of catalysts and electronic scrap materials. Before Cinderford became part of BASF, the site was owned by the U.S. chemical company Engelhard.

In 2011, BASF more than doubled the local operating footprint and manufacturing capacity to enhance the existing Cinderford site.

Successful pioneers

"Engelhard, which was acquired by BASF in 2006, invented the automotive catalytic converter nearly 40 years ago. Since that time, the emissions control solutions of Engelhard and BASF have prevented more than one billion metric tons of pollutants from being released into

the air," says Setchfield. "In fact, it would take 100 modern vehicles, equipped with BASF emissions control solutions, to equal the pollution put out by just one vehicle produced prior to 1974. Platinum, palladium and rhodium are the key components that make catalytic emissions control systems work – so those are the metals we are focused on recovering here in Cinderford."

As global automotive production continues to grow, and emissions regulations become increasingly stringent, the need for these valuable precious metals will increase. By recycling these limited resources, BASF is helping to ensure a reliable, secondary source of precious metal supply, leveraging the already mined and recoverable reserves that exist in scrap materials.

At present, Cinderford's facility for the ceramic catalyst process does not even cover half of the 5,000 square meter (about 54,000 square foot) factory hall. But there is a reason Setchfield has left all this space unoccupied: "Next year we want to install a new process here for the recycling of electrical waste," he says. He still has a lot in store for the plant to ensure that it continues to make history. ■

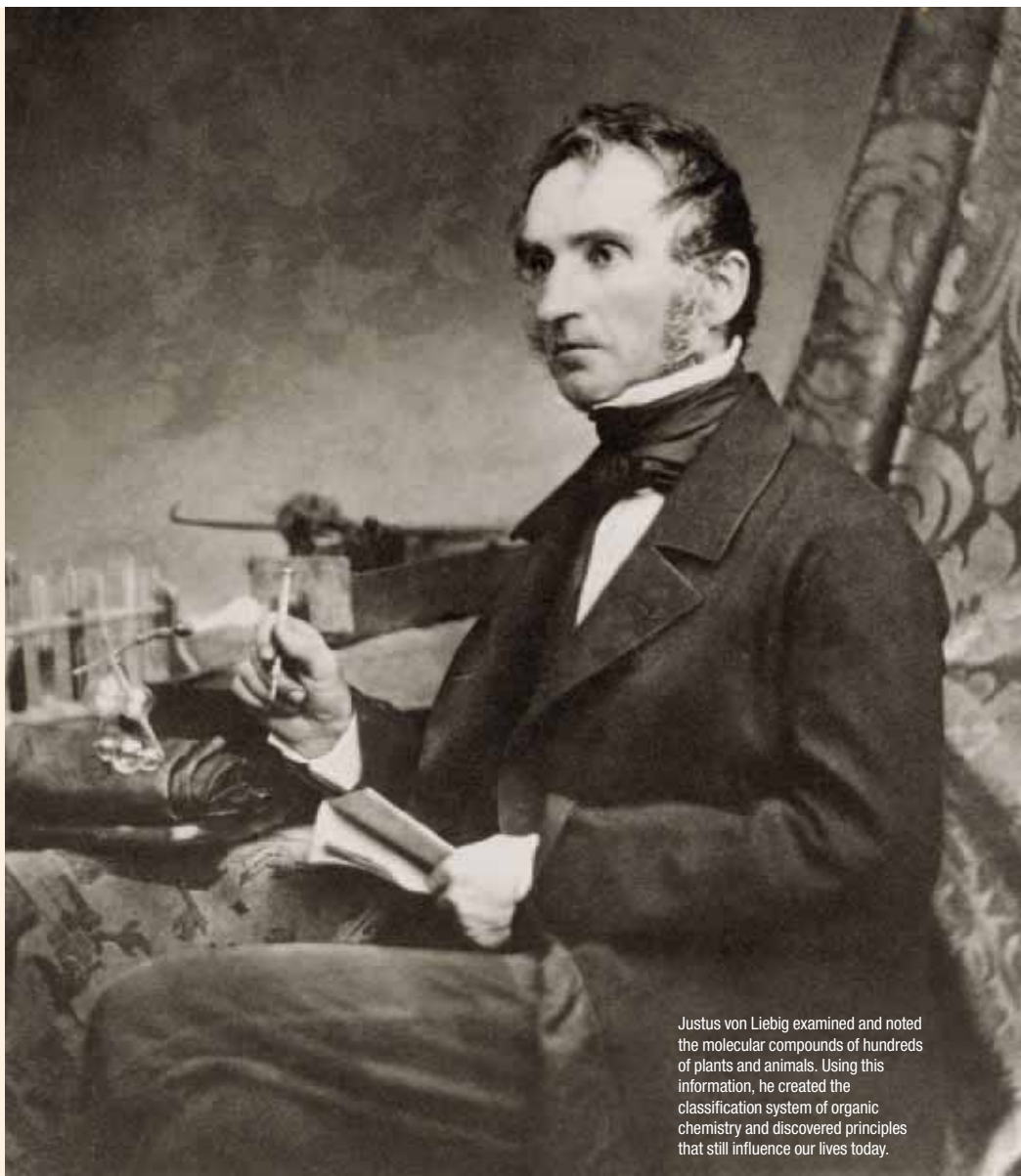


Pioneering thinker – Then

Justus von Liebig

Today he is known as the founder of organic chemistry (see box on page 57), but initially it did not seem like Justus von Liebig – born in Darmstadt, Germany, in 1803 – would have such a remarkable career. Due to poor grades, he was thrown out of school without graduating. He then began an apprenticeship as a pharmacist, but this also ended quickly when an experiment with silver fulminate nearly blew the roof off the laboratory and Liebig was let go. Nevertheless, chemistry remained his passion, and became his life. He studied the subject in Bonn, Erlangen and Paris, and his work on fulminic acid brought him such acclaim that renowned natural scientist Alexander von Humboldt expressly recommended him for a professorship to the Grand Duke of Hesse. At 21 years of age, he was appointed as a professor of chemistry in Giessen. He went on to become the greatest chemist of his era and his laboratory became the birthplace of modern chemistry.

In this laboratory, Liebig laid the foundations of knowledge crucial to chemistry today with the development of elementary analysis and the identification of carbon and hydrogen in organic compounds. His inventive nature was a huge help in this work; he used a glass “five-bulb apparatus” to enable the rapid and reliable capture and weighing of carbon dioxide. Liebig and his students employed the device to examine the molecular composition of hundreds of plants and animals. Through this work, Liebig established the systematics of organic chemistry. He also identified chloroform and the aldehyde group as organic compounds – one of the most important classes of compounds in organic chemistry. Liebig did much more than revolutionize our understanding of chemical relationships; we can also thank the self-taught German for a number of practical discoveries, including many world firsts: baking powder, baby formula that could replace breast milk, chemical fertilizer and “Extract of Meat” – the first ever bouillon cube. ■



Justus von Liebig examined and noted the molecular compounds of hundreds of plants and animals. Using this information, he created the classification system of organic chemistry and discovered principles that still influence our lives today.



Above Another invention from Justus von Liebig: His “Extract of Meat” was the world’s first bouillon cube.



Above The “five-bulb apparatus” is made out of the finest glass and is filled with concentrated potassium hydroxide. In a short period of time it collects carbon dioxide created during combustion so that it can be weighed on an analytical balance. With this invention, Justus von Liebig revolutionized elementary analysis.

Pioneering thinker – Now

Junji Kido

“
I was sure that
this could be a
groundbreaking
discovery.

Professor Dr. Junji Kido, Professor at Yamagata University
in Japan

”

Organic chemistry

Organic chemistry studies the structure, composition and reactions of carbon-based compounds. These compounds may contain any number of other elements, including hydrogen, nitrogen, oxygen and sulfur. Today, scientists are aware of more than 15 million organic compounds. Carbon-based compounds form the basis of almost every life form. They are also used in a wide range of applications; the compounds form a key component of drugs, plastics, synthetic fibers, paints and foods. You can see their effects with the naked eye at breakfast time: If bread is left to toast too long, it turns black – this burning is a clear indicator of the presence of carbon compounds.

To this day, Japanese chemist Professor Dr. Junji Kido is driven by the same curiosity that characterized his visits as a boy to his father's plastics factory. In his organic chemistry research, he is fascinated by one idea in particular – creating things that have never existed. He has done exactly this by inventing the white OLED (organic light-emitting diode, see feature on pages 36-41). Before his discovery, only colored OLEDs existed, which were used in car radios and cell phones, though not in lighting technology.

While studying for his doctorate at the Polytechnic Institute of Brooklyn (now known as the Polytechnic Institute of New York University), he found a way to make illuminating plastics in his laboratory. Kido comments, “I was sure that this could be a groundbreaking discovery if I could just use it to make organic light-emitting diodes. These could then replace traditional light sources.”

In 1989, when he was named Assistant

Professor at Japan's Yamagata University, he immediately began working on OLEDs. A little luck played a key role, as he explains: “While we were working on existing polymer-based organic light-emitting diodes, we inadvertently created white OLEDs.” Rather than the expected red light, Kido and his colleagues saw a white light where they had applied orange coloring to a blue polymer. He realized that the color of the light came down to the concentration of the coloring. To move his discovery out of the lab and on to the market, he co-founded the lighting firm Lumiotec, which launched the first mass-produced OLED worldwide in 2011.

The multitasking innovator feels a close connection with the founding fathers of organic chemistry, particularly Justus von Liebig. After all, it was the method that Liebig developed to identify carbon and hydrogen in organic compounds that enabled Kido and his team to create high-performance semiconductors and over 1,000 different materials for carbon-based OLEDs. ■



With his invention of the white organic light-emitting diode (OLED), Professor Dr. Junji Kido is following in the footsteps of Justus von Liebig, the founder of organic chemistry.

Chemistry around us



What makes a non-iron shirt stay crease-free?

Very few people actually enjoy ironing. But how exactly do non-iron textiles maintain their shape, and prevent creasing? Ordinarily, cotton fibers swell during washing and fail to regain their prior form once dry. This is what causes fabric to look wrinkled. Non-iron materials, however, are treated with special products known as binders that

stabilize the cotton and prevent the fibers from swelling up and creasing.

These materials do not need to be ironed – this saves energy and helps protect the environment. An added bonus of this technology is that treated cotton dries faster because it absorbs less water. ■

Tip:

Non-iron shirts are best left to drip-dry on a coat hanger. They should then be ready to wear – if any small creases remain, they will smooth out with the effect of the wearer's body heat.



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Imprint

Published by:
BASF SE
Communications & Government
Relations BASF Group
Elisabeth Schick

Editorial by:
BASF SE, Corporate Publications
Axel Springer AG
Addison, London

Designed by:
Addison, London

Printed by:
Saarländische
Druckerei & Verlag GmbH

Cover photograph:
Russ Kierisch

Photographic credits:
Russ Kierisch (page 17, 59)
Lee Mawdsley (page 20-21, 59)
Joey de Leon (page 26-27)
Paolo Ferrarini (page 38)
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