

# LINDE TECHNOLOGY

Issue

*FEATURED TOPIC: NATURE'S POWERHOUSE*

#1.  
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*HYDROGEN FROM WIND*  
Storing regenerative energy

*ENERGY FROM THE EARTH'S CORE*  
Using geothermal power efficiently

*EXTRA-EFFICIENT SUN TRAPS*  
Solar modules with greater energy yields

*AT THE PATIENT'S SIDE*  
World of medical gases by Linde Healthcare

*CLEAN SAILING*  
Maritime infrastructure for LNG

*THE STORY BEHIND THE PIXELS*  
High-purity gases for high-tech displays

*INNOVATIVE TECHNOLOGIES FOR A MORE SUSTAINABLE FUTURE*

## NATURE'S POWERHOUSE



THE LINDE GROUP

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*The power of nature: The Earth offers numerous  
regenerative sources of energy, which can  
be unlocked with innovative technologies for  
a more sustainable future.*

#1.  
13

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# EDITORIAL

*Dear Reader,*

The world is still reeling from the effects of the latest economic and financial crisis. Recent events have again shown just how important it is to continuously question established concepts and adapt them to changing circumstances. Take our economic system, for example, which is based entirely on growth. We now have to find a way of enabling global economic growth while at the same time limiting the consumption of natural resources and lowering CO<sub>2</sub> emissions. In short, we need a new kind of growth – one that is built on sustainability.

The advancement of renewable energies is the key to achieving this goal. This calls for innovative technologies to efficiently harness the forces of nature. Wind farms, for example, can generate huge amounts of energy. However, wind power often fluctuates. As a result, we need to develop suitable storage solutions – such as hydrogen. This gaseous reservoir could be used to balance fluctuations in the power grid and even fuel vehicles.

Geothermal energy is another promising energy opportunity for the Group. We are currently building a power plant in Kirchweidach in the German state of Bavaria that will enable us to maximise the potential of underground heat. And in the world of solar energy, our new anti-reflection coating is raising the efficiency levels of photovoltaic modules.

You can read all about these developments in this edition's featured topic: "Nature's powerhouse". In this issue of Linde Technology, you can also read about another global megatrend – healthcare. Demographic changes are increasingly shining the spotlight on healthcare. Following a number of strategic acquisitions, Linde has become the world's leading healthcare provider in the gases industry. In this special feature, we take a look at our healthcare products and services. You will find us everywhere – from hospitals and rehab centres to the patient's own home.

I hope you enjoy reading this interesting edition.

A handwritten signature in blue ink that reads "Belloni". The signature is fluid and cursive, with a large initial 'B'.

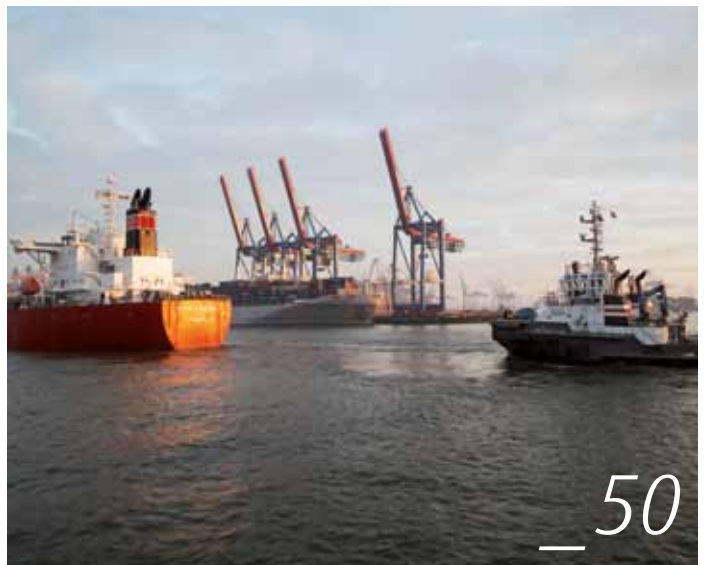
Professor Dr Aldo Belloni  
Member of the Executive Board of Linde AG



*WIND POWER: Hydrogen stores energy efficiently*



*HIGH-TECH DISPLAYS: Specialty gases for high-performance electronics*



*MARITIME FUEL: LNG terminal for port of Hamburg*



*HEALTHCARE: Medical gases at a glance*

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*Innovative engineering and gas technologies from Linde help increase the yield from regenerative sources of energy for a more sustainable, climate-friendly future.*

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*Linde builds biggest ethane cracker complex for Borouge*

# THE ART OF PLASTICS

↳ Image source: Linde AG





Polyethylene (PE for short) is a real all-rounder. This plastic is used in everything from bottles to films and from pipes to car components. No surprise, then, that PE feedstock ethylene is the most widely produced petrochemical. Borouge, a joint venture between the Abu Dhabi National Oil Company (ADNOC) and Borealis, is a leading provider of innovative, high-quality PE plastics. At its Ruwais location in Abu Dhabi (UAE), Borouge operates several ethylene production plants – all built by Linde. In 2010, Borouge tripled its annual output thanks to a second ethane cracker (pictured) with an ethylene capacity of 1.5 million tonnes. “At Linde Engineering, we are proud to be the ethylene technology provider for the Ruwais complex,” comments Professor Dr Aldo Belloni, Member of the Executive Board of Linde AG. And Borouge remains firmly on its growth course, with Linde’s continued support: the gas and engineering specialist is now constructing the third ethane cracker in Ruwais, set to go on stream at the end of 2013. A capacity of 3.89 million tonnes per year will make this unit the largest ethane-based polymer complex in the world.

LINK:

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

# NEWS

ASIA:

## AIR SEPARATION UNITS IN VIETNAM AND INDIA

The Asian steel industry is booming – and with it demand for air separation units (ASUs). In Vietnam, Linde AG is preparing to supply steel company POSCO SS-Vina with the industrial gases it needs for its production processes. This means constructing the country's largest ever ASU, with a total investment of around 40 million euros. It will be located in the Phu My industrial park in Ba Ria, Vung Tau province. "We are delighted to be working on another on-site project with our customer POSCO. This is also Linde's biggest single investment in Vietnam to date," confirms Sanjiv Lamba, Member of the Executive Board of Linde AG and responsible for the company's business in the Asia Pacific. This venture is set to strengthen the Group's position in the fast-growing Southeast Asia region. The new, state-of-the-art ASU will have a production capacity of 35,000 normal cubic metres of air gases per hour and is scheduled to go on stream in 2014.

Linde will also be engineering two major air separation units in India for Tata Steel Limited – one of the world's largest steel companies – with an investment volume of around 80 million euros. Construction of these ASUs is part of a long-term agreement for on-site gas supply to a new Tata steelworks, now being built at the Kalinganagar industrial complex in the Indian state of Odisha. Each ASU will have a production capacity of 1,200 tonnes of air gases per

day. Set to become operational in 2014, they will provide the Tata Steel plant currently under construction with gaseous oxygen, nitrogen and argon. They will also produce liquid gases for the regional market. Linde is planning an extensive pipeline network at the Kalinganagar industrial complex, enabling it to deliver industrial gases to other steel manufacturers in the future.







## LIQUID NATURAL GAS:

*ADDITIONAL LNG PROJECTS*

## LIQUEFACTION PLANT FOR MALAYSIA

A member of the PETRONAS oil and gas group, Malaysia LNG Sdn. Bhd., has asked Linde to build a mid-scale natural gas liquefaction plant. This new facility for reliquefying boil-off gas will have a capacity of 1,840 tonnes of liquid natural gas (LNG) per day. "This is the latest in a series of medium-sized LNG projects with particularly demanding technical features which we have recently won," comments Professor Dr Aldo Belloni, Member of the Executive Board of Linde AG. The plant will be situated in the Bintulu LNG complex in the state of Sarawak, eastern Malaysia, and should be operational by the end of 2014.

## LNG TERMINAL IN SWEDEN

Linde is to construct a mid-scale LNG import terminal for Norwegian company Skangass AS, located in Lysekil on the west coast of Sweden. Alongside engineering, procurement, construction and commissioning activities worth around 44 million euros, Linde is also responsible for interface management with the tank manufacturer. The plan is to open the new terminal for operations in spring 2014, supplying natural gas to the nearby Preem refinery as well as to industrial and transport companies. The terminal will have storage capacity for 30,000 cubic metres of LNG and include a truck filling station. The natural gas originates from the LNG facility near Stavanger.



## RUSSIA:

*NEW ETHYLENE PLANT*

The largest Russian petrochemical company, SIBUR LLC, has contracted Linde to engineer one of the world's biggest ethylene plants to date. Using ethane, propane and n-butane as feedstock, this new facility will produce around 1.5 million tonnes of ethylene, 500,000 tonnes of propene and 100,000 tonnes of butadiene per year. These products are important building blocks for the plastics manufacturing industry. The ethylene plant is to be constructed within the planned ZapSibNeftekhim petrochemical complex, owned by the company of that name – a SIBUR subsidiary – in Tobolsk, western Siberia. Linde is currently engaged in building a polypropylene plant for SIBUR at the same location, set to go on stream in 2013 with an annual capacity of 500,000 tonnes. This project is currently one of the key investments in Russia's petrochemical industry.



CO<sub>2</sub> MANAGEMENT:*THE GREENER GREENHOUSE*

The Linde AG has acquired the remaining shares in the Organic CO<sub>2</sub> for Assimilation by Plants (OCAP) joint venture from Volker Wessels Stevin Deelnemingen. The OCAP project supplies carbon dioxide (CO<sub>2</sub>) to Rotterdam and Amsterdam, where it is fed into greenhouses to promote plant growth. The carbon dioxide is sourced from the largest Shell refinery in Europe and an Abengoa bioethanol facility in the industrial port of Rotterdam. OCAP uses a 100 kilometre-long pipeline to supply around 400,000 tonnes of CO<sub>2</sub> to more than 580 greenhouses in the area. A small amount is also used by the food industry to keep products fresh. The gas recycled by OCAP eliminates the need to burn 115 million cubic metres of natural gas each year otherwise required to source the CO<sub>2</sub>; in other words, the annual emissions of a city in Western Europe with 150,000 inhabitants. The acquisition strengthens Linde's position as a leading provider of clean technologies.



## CLEAN MOBILITY:

*HYDROGEN FUELLING AT THE HANNOVER MESSE TRADE SHOW*

Demand for environmentally friendly energy carriers is growing. Hydrogen (H<sub>2</sub>) is proving an increasingly popular, zero-emissions fuel. In April 2013, Linde teamed up with the Clean Energy Partnership (CEP) initiative to showcase the latest developments in hydrogen fuelling technology at the Hannover Messe trade show. The fuel cell cars displayed in Hanover by the CEP were refuelled using a mobile station developed by Linde. The green hydrogen was manufactured in Leuna from crude glycerine. Linde

has also advanced its stationary fuelling technologies. In the last two years, the company has developed and built three hydrogen stations which produce hydrogen directly on site using electrolysis. These stations show that electricity from renewable sources can be converted to hydrogen in a zero-emissions process. With power-to-gas technology hydrogen can be used as an efficient storage medium for regenerative energy resources.

## CHINA:

*OXYGEN FOR COAL-TO-LIQUID PROJECT*

Coal is becoming an increasingly important source of energy. To make the most of this valuable raw material, more and more energy providers are building liquefaction plants to convert coal to liquid. All



coal-to-liquid (CTL) processes require oxygen; and Linde supplies the air separation units required to deliver that oxygen. Drawing on its gases and engineering expertise, Linde is currently building six major air separation units for Shenhua Ningxia Coal Industry Group Co. Ltd. and Shenhua Logistics Group Co. Ltd. in Yinchuan, in the north-west of China. Each of the six facilities will supply around 100,000 normal cubic metres of gaseous oxygen every hour to the CTL complex at Shenhua's Ningdong Energy Chemical Base. In total, this site is set to produce four million tonnes of CTL products per year, primarily liquid fuel from coal, making this one of the largest CTL projects worldwide. Linde is responsible for the engineering, supply of machinery and equipment, supervision services at the job site, turnkey supply of the cold boxes and training the buyer's personnel. The air separation units are scheduled to go on stream in 2015.



GERMANY:

## LINDE SUPPORTS DLR GAS TURBINE TEST BENCH

Tomorrow's mobility choices have to be cleaner and more sustainable. And it's not just land travel that is getting greener. The energy efficiency spotlight is also on air travel. Although manufacturers have significantly increased engine performance while reducing emission and noise levels over the past decades, experts at Germany's national research centre for aeronautics and space (DLR) in Cologne believe that there is still much room for improvement. Which is why DLR is expanding its research capabilities in aircraft propul-

sion and power generation – with the help of Linde. In April 2013, two new systems went into operation at DLR: a hydrogen supply station designed by Linde and a cutting-edge high-pressure compressor. These innovations will enable engineers to develop more energy-efficient, powerful gas turbines for aerospace and other applications.

Engineers at DLR use the combustion chamber test beds to explore flexible combustion concepts that burn fossil and alternative fuels as efficiently and cleanly as possible. Hydrogen (H<sub>2</sub>) has

emerged as a key contender in the move towards environmentally sound turbine technologies. This lightweight gas is compatible with the powerful combustion chambers. It is extremely energy efficient and does not release any CO<sub>2</sub> when burnt. "This project clearly demonstrates how the special properties of hydrogen make it ideal for a wide range of innovative applications," explains Dr Andreas Opfermann, Head of Clean Energy & Innovation Management at Linde. The H<sub>2</sub> supply infrastructure designed by Linde includes a cryogenic storage tank and a highly efficient cryo-pump system that converts the liquid gas (stored at minus 253 degrees Celsius) into high-pressure hydrogen. After a build window of less than one year, the H<sub>2</sub> supply facility is now ready to be used by DLR engineers and the centre's industry partners.



ENERGY SUPPLY:

## NEW NATURAL GAS TERMINAL FOR THE NORTH SEA COAST

Norway is a major energy provider for Germany. To secure natural gas supplies to Germany, the Norwegian company Gassco AS is building a new terminal in the town of Emden in northern Germany. The company has commissioned Linde to build the facility. The new natural gas terminal will replace the Norseas Gas Terminal, which has been in operation for over thirty years and is also run by Gassco. The order is worth around EUR 260 million. Linde is responsible for the engineering, procurement and construction

of the terminal. "We have a wealth of experience in handling natural gas. This project enables us to further promote the use of this environmentally sound fossil fuel," explains Professor Dr Aldo Belloni, Member of the Executive Board of Linde AG. The facility will be largely pre-assembled in modules. These modules will then be assembled on location in Emden. The new natural gas terminal is set to go on stream at the end of 2015.

*High-purity specialty gases for the electronics industry*

# THE STORY BEHIND THE PIXELS

High-definition displays continue to grow in popularity, offering the viewer an incredibly immersive experience with bright colours and crystal-clear images. However, the race to produce better and brighter high-tech screens is pushing today's technology to its limits. Linde is helping producers to challenge the boundaries with a broad portfolio of high-purity electronic gases. The company is also helping improve the multimedia industry's environmental footprint.

When it comes to pixels, more is definitely better. More and more of these tiny dots are being squeezed into modern TV displays so that the action scenes in a James Bond film burst out of increasingly slimmer and larger screens in razor-sharp quality. Even now, though, the next "big thing" in multimedia entertainment is already waiting in the wings: Three-dimensional, ultra-high definition TV (UHD-3D). This new technology is designed to make viewing even more realistic – whether you're enjoying the latest Hobbit movie, the Olympic Games or a fascinating nature documentary. UHD-3D flatscreens have a definition four times higher than that of full HD displays. This means that an image is made up of over eight million pixels and the TV panel has a refresh rate of at least 480 images per second. This is four times higher than normal TVs, and it is the only way of achieving a 3D effect.

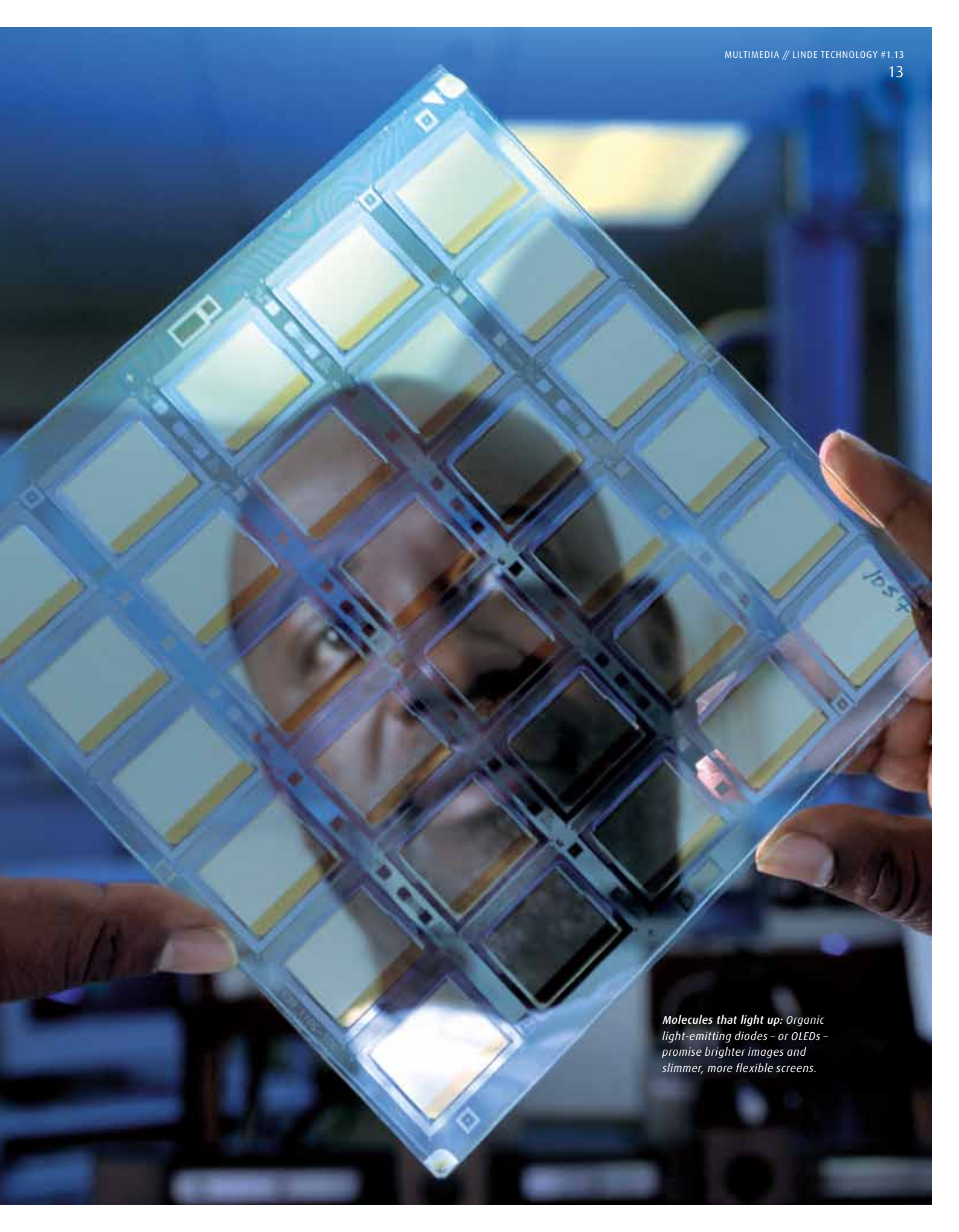
These high-performance screens are already taking today's technology to its limits, however. Each pixel needs a tiny transistor to be controlled electronically. And this means that eight million

of these switches have to be crammed onto the back of a UHD-3D display. "Transistors have to shrink to achieve this level of definition," explains Andreas Weisheit, Head of Market Development Flat Panel Displays & Solar at Linde in Shanghai. However, today's switches are not powerful enough for these new display developments. This is because most thin-film transistors (TFTs) in today's flatscreens are made of amorphous silicon; in other words, the individual silicon atoms do not form a regular crystalline structure. "As a result, the conducting electrons cannot move fast enough to achieve the frame rate required for these new devices," continues Weisheit.

Thin-film transistors made from polycrystalline silicon are currently seen as the most promising alternative. The material's homogenous atomic structure enables it to conduct electrons much more effectively. The manufacturing process, however, is more expensive because the amorphous silicon must first be converted to a crystalline form using a laser. "This higher cost is acceptable

*RAZOR-SHARP  
QUALITY WITH  
MORE THAN EIGHT  
MILLION PIXELS.*





*Molecules that light up: Organic light-emitting diodes - or OLEDs - promise brighter images and slimmer, more flexible screens.*

with smaller displays, for example in smartphones. However, it is simply not a viable option for large TV screens," elaborates Weisheit. Manufacturers such as Sharp and LG are therefore turning to a new transistor material known as metal oxide. These semiconducting compounds comprise oxides of the metals indium, gallium and zinc. They cost around the same as conventional silicon transistors but are much more powerful.

Switching to this material, however, does involve further changes. "Transistor size is only one of the challenges in flatscreen production. Manufacturers also have to apply these tiny switches to large surface areas – and this is another major hurdle," explains Weisheit. The switches themselves are around one tenth of a millimetre in size. Millions of these high-quality thin-film transistors have to be applied evenly to glass plates measuring over five square metres in size. A number of high-purity gases play a key role at different stages of these processes. The noble gas argon, for example,

is used to sputter materials that make up the different components of a transistor. Those substances are deposited on the back of the glass plate, creating, for example, metallic and semiconducting films as well as insulating films and protective layers. Part of the material is then etched off again to create, for instance, conductive paths on the glass plate. For these steps, manufacturers require another group of gases. "Ten different gases are needed in total," explains Weisheit. "Phosphine, for example, is used to dope semiconductors, while nitrogen is used to dilute emissions. Helium cools the glass plate, and fluorine gases are used for etching," continues the Linde expert. The end result of this multi-step process is a transistor – a high-precision electronic component comprising six to seven wafer-thin, specially formed layers.

A silicon dioxide film is applied to the new, more powerful metal oxide transistors to protect them from moisture. Manufacturers use nitrous oxide ( $N_2O$ ) – also known as laughing gas – to

## LAUGHING GAS FOR THE NEXT TRANSISTOR GENERATION.

### REPLACING HARMFUL GASES

Sulfur hexafluoride ( $SF_6$ ) is the most potent greenhouse gas. It is a long-living compound that has a global warming potential of 23,900 times that of carbon dioxide. It has long been used as an etching gas in screen manufacturing. During this process, small amounts can escape into the atmosphere. "There is enormous pressure on manufacturers to use a different substance," explains Andreas Weisheit, Head of Market Development Flat Screens & Solar at Linde in Shanghai. Looking beyond Europe, environmental pressures are also rising in Asia. Linde has been working with a Korean engineering company to find a climate-friendly alternative. And they have come up with a suitable candidate: Pure fluorine gas ( $F_2$ ).  $F_2$  is a more effective etching gas that dissolves superfluous transistor material faster and more evenly. The resulting emissions are easier to process, which reduces overall power consumption. The Korean Display Industry Association recently officially approved Linde's process, which involves building small, on-site generators that produce  $F_2$  at customer sites. A number of electronic manufacturers have already worked with these small fluorine facilities. Back in 2003, Linde developed a process that used  $F_2$  instead of the greenhouse gas nitrogen trifluoride ( $NF_3$ ) to clean reactor chambers used to deposit material during display production.

*Vaporise, separate and etch: Up to ten high-purity gases (right) are used to create tiny conductive paths on transistors. Magical, vivid-colour screens are the result (below).*



create this layer. "Without a secure supply of high-purity laughing gas, manufacturers would not be able to switch from silicon to metal oxide transistors," adds Weisheit. Linde and Linde LienHwa, a joint venture with the LienHwa MiTAC Group in Taiwan, already operate six laughing gas plants in Asia with a capacity of 3,000 tonnes per year. The companies aim to increase this figure to 10,000 tonnes of laughing gas per year. They are currently expanding an existing facility in Taiwan and building a new production plant in South Korea to achieve this. LienHwa has also purchased a facility in the Chinese province of Jiangsu. Demand is high. "Nine metal oxide projects are currently under development. New factories are being built and existing plants retrofitted," reports Bruce Berkhoff, Chairman of the LCD TV Association. "We are expanding our capacity to establish Linde as the leading provider of electronic gases in Asia," explains Weisheit. "Our ongoing investments will help to drive innovation in this forward-looking market," he continues.

### Powerful transistors for OLED displays

Weisheit believes that tripling Linde's laughing gas production capabilities is crucial to meet evolving market needs. "A single display factory needs up to one thousand tonnes of this gas per year," he explains. Metal oxide transistors are not just important for the flatscreen sector. These powerful switches can also reduce power consumption in smartphones – making them a very interesting option for manufacturers. Smartphone displays are one of the main reasons why batteries often need recharging after just one day. LEDs located behind the transistors light up the screen, yet they also consume the lion's share of the battery power. Smaller transistors let more light through. The metal oxide versions could therefore significantly cut power consumption. These powerful transistors could also have a positive impact on screens powered by organic light-emitting diodes (OLEDs). OLEDs promise brighter images and slimmer screens. Despite this, OLED screens have not been widely commercialised (see interview). One of the main reasons is that OLEDs require a lot of power to illuminate the organic substances and thus need powerful transistors. Metal oxide transistors could provide the answer to this challenge.

A market analysis carried out by Linde has shown that the overall outlook for display manufacturers is positive. Although the number of flatscreens sold rose only slightly in 2012, "the market is moving toward larger displays for smartphones and TVs," says Weisheit. Analysts thus expect revenue for the industry to grow by five per cent in 2013. Prospects are also good for Linde. After all, specialty gases play a vital role in the development of new electronic devices. "And as the displays get bigger, more gases will be needed," concludes Weisheit.

#### LINKS:

[www.oled-info.com](http://www.oled-info.com)

[www.linde-gas.com/en/industries/electronics/index.html](http://www.linde-gas.com/en/industries/electronics/index.html)

#### SHORT INTERVIEW

## "ORGANIC FILMS MAKE DISPLAYS FLEXIBLE"



*Linde Technology talked to Professor Jianhua Zhan, Director of the Key Lab of Advanced Display and System at Shanghai University, about display technologies of the future. The institute is collaborating with Linde on research into organic light-emitting diodes (OLEDs).*

#### ↳ WHAT ARE THE ADVANTAGES OF OLED DISPLAYS?

Organic light-emitting diodes comprise an organic thin film between two conductors. These emit light when an electric current is passed through them. Unlike liquid crystal displays (LCDs), there is no light source behind the screen. OLED displays are thinner and more efficient. They also generate bright colours and respond very quickly. In the future, OLED displays could also be flexible and transparent.

#### ↳ SO WHAT IS STANDING IN THE WAY OF WIDESPREAD MARKET ADOPTION?

Cost is one of the main reasons here. That said, however, OLEDs have the potential to be cheaper than LCDs because they have a simpler structure. The large investment required for mass production could be another hurdle. Some OLED products are already on the market today, however, including models in the Samsung Galaxy range.

#### ↳ WHAT ARE SHANGHAI UNIVERSITY AND LINDE RESEARCHING?

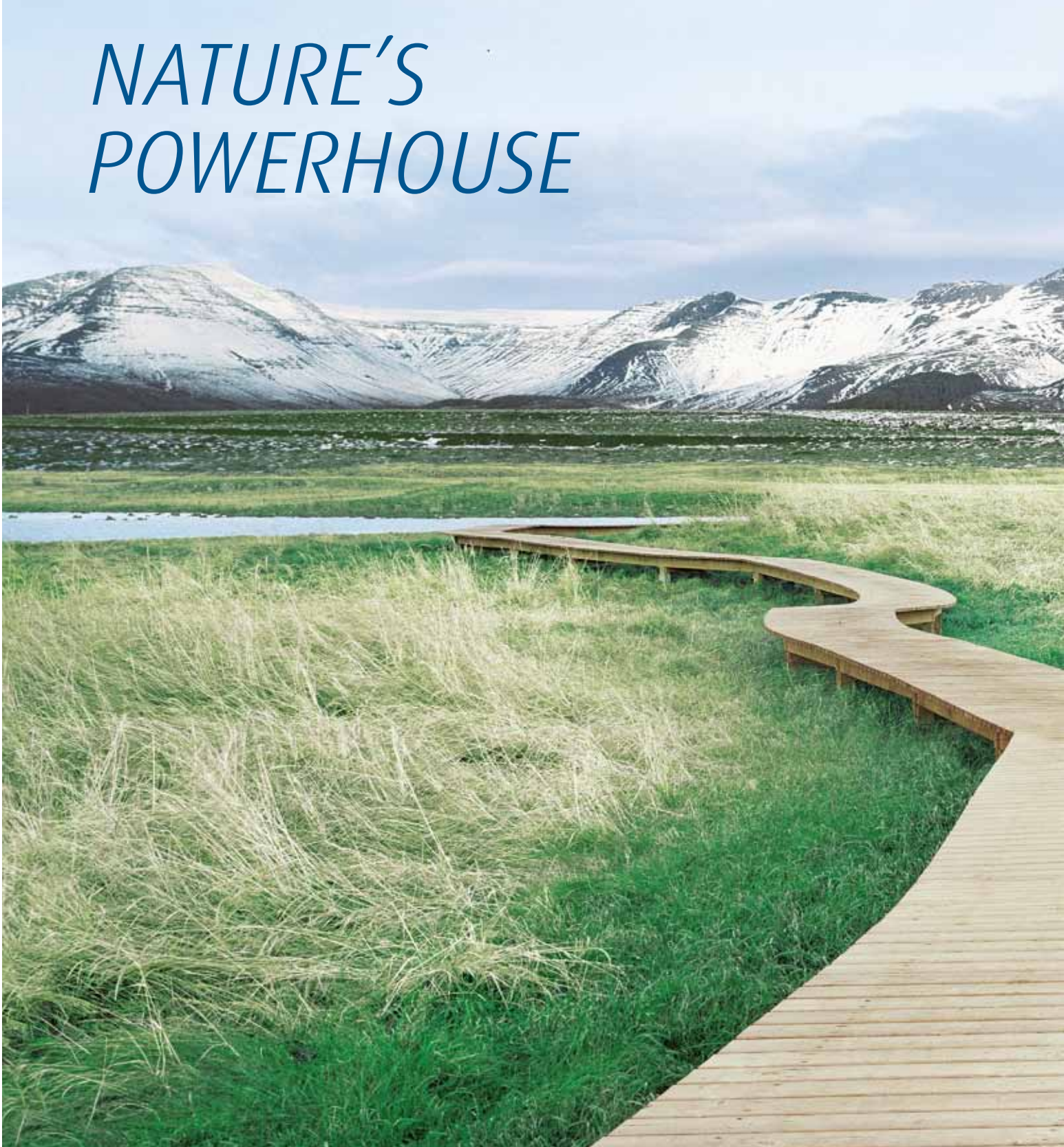
We are collaborating on a new technology for encapsulating thin films. The organic film is extremely sensitive to oxygen and moisture. These two factors can drastically reduce the service life of an electronic device. Encapsulating OLEDs is therefore a key production step, especially for flexible displays.

#### ↳ HOW LONG WILL IT TAKE FOR OLED DISPLAYS TO REPLACE CONVENTIONAL DISPLAYS?

It's difficult to say. Both technologies are evolving. However, I believe that OLED displays will play a key role in five to ten years' time.

INNOVATIVE TECHNOLOGIES FOR A MORE SUSTAINABLE FUTURE

# *NATURE'S POWERHOUSE*





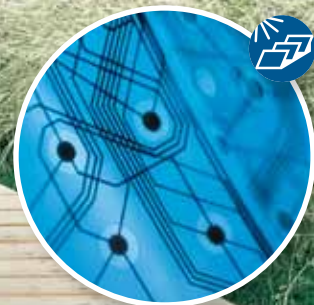
Across the globe, our hunger for energy continues to grow. Yet climate change and dwindling fossil fuel supplies are forcing us to rethink our energy policy and turn increasingly to renewable resources. Achieving a sustainable energy mix and eco-friendly mobility options demands innovative technologies. And that is where Linde's gas and plant engineering specialists come in, developing efficient processes and providing crucial momentum for a greener future.



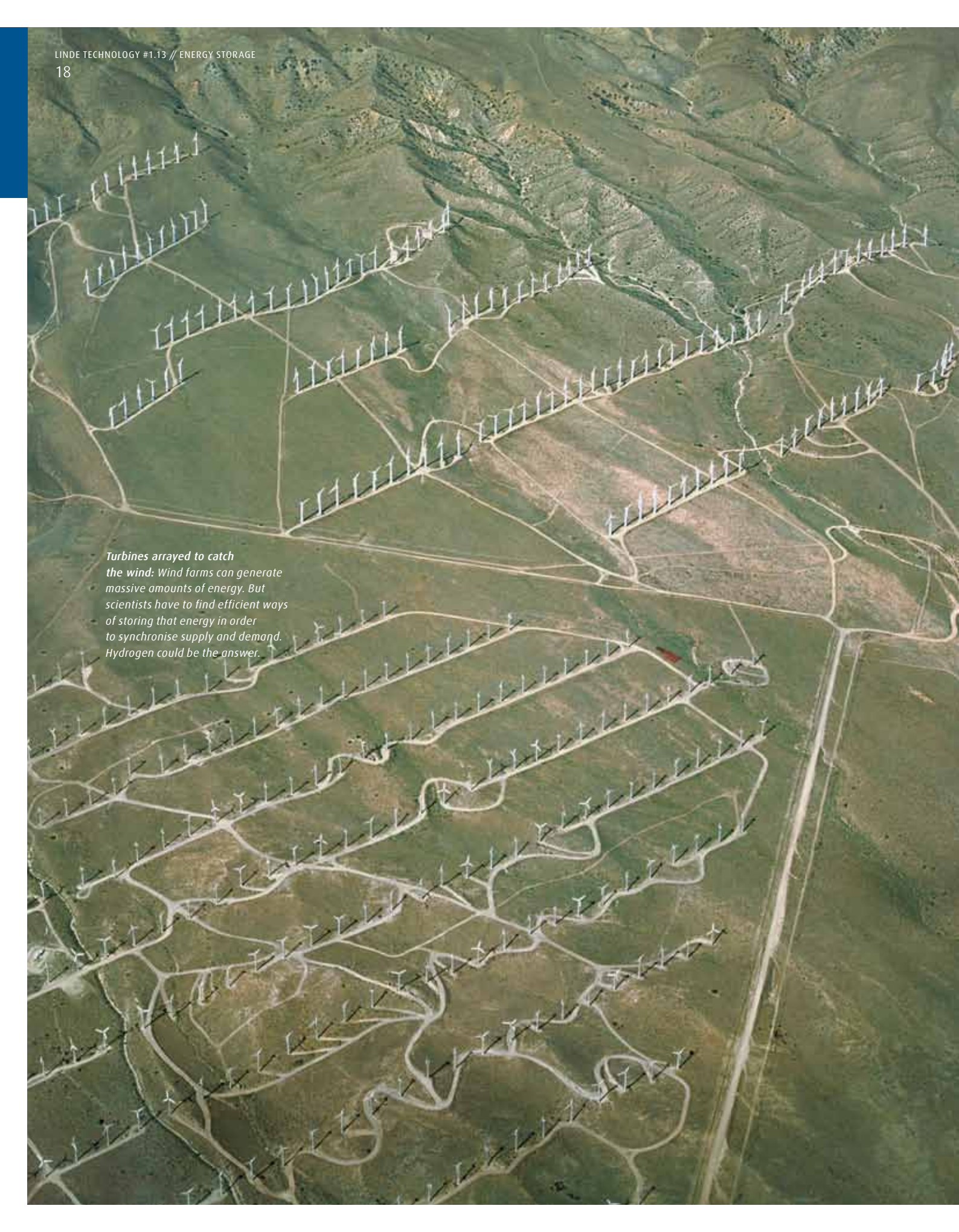
**Wind power**  
Storing large amounts of energy efficiently with hydrogen.



**Geothermal energy**  
Making optimum use of the Earth's heat resources.



**Solar power**  
Harnessing more of the sun's energy with anti-reflective glass.

An aerial photograph of a vast wind farm. The landscape is hilly and green, with numerous rows of white wind turbines stretching across the terrain. The turbines are arranged in a grid-like pattern, following the contours of the hills. The perspective is from a high angle, looking down on the farm. The sky is not visible, and the focus is on the layout of the turbines and the surrounding land.

*Turbines arrayed to catch the wind: Wind farms can generate massive amounts of energy. But scientists have to find efficient ways of storing that energy in order to synchronise supply and demand. Hydrogen could be the answer.*



Image source: Bernhard Edmaier/SPL/Agentur Focus  
Author: Tim Schröder

## Power-to-gas: Flexible, efficient storage of renewable energy

# HYDROGEN FROM WIND

Wind and solar power are set to play a key role in securing future energy supplies. However, these energy sources call for flexible storage options. Hydrogen is a promising contender here. It is an ideal medium for storing fluctuating streams of renewable energy until the power is actually needed. Hydrogen gas can be easily generated by electrolysing water. It can be efficiently stored, is easy to transport and can be converted back to electricity on demand. Linde engineers are collaborating with the companies Enertrag and Total to implement the new power-to-gas technology at Berlin's airport.

On a gusty day, wind turbines spring into action, generating plenty of power for the grid. Strong winds, however, can soon give way to weak breezes. And when the wind drops, gas- or coal-fired power plants have to step in to bridge the gap. This is because power grids are complex and vulnerable. Supply and demand must be matched to ensure a secure, reliable stream of electricity. Power sourced from the sun and wind, however, is intermittent, and this imbalance is proving a major challenge for grids. There are often large windows between supply and demand. At night, for example, demand is low and there are few takers for energy from regenerative sources. During the day, power grids have to cope with extreme wind speeds and bright sunlight as well as weak winds and dense cloud cover. These peaks and troughs can fluctuate drastically by up to several gigawatts in just a few minutes, and grids have to balance out these fluctuations. "This is becoming an increasingly important issue as the share of wind and solar power in the energy mix increases," explains Dr Christoph Stiller, Head of Energy Storage, Clean Energy Technology at Linde. In recent years, providers have had to reduce power generation at wind farms to prevent them from overloading grids. A lot of valuable energy is being lost in this

way. Feeding green energy into the power grid presents energy engineers with a mammoth redesign challenge – one marked by many technical hurdles.

"We will have to expand existing power lines and, most importantly, develop suitable technologies for storing excess wind energy – for hours, days or even weeks – and then feeding it back into the grid," adds Stiller. Pumped-storage hydroelectric plants are a viable option, although this is limited to certain geographic regions. In Germany, for example, the potential for this technology is almost exhausted. The country's total installed storage capacity here is currently around 40 gigawatt hours, which is not enough to cover expected power storage requirements. If Germany's energy needs were to be sourced entirely from renewable power, 40 to 80 terawatt hours of storage capacity would be required – two thousand times more than the current figure.

Power-to-gas technology could have the potential to resolve this issue as it involves converting regenerative energy into hydrogen (H<sub>2</sub>). "This lightweight gas is an ideal buffer and can be produced by electrolysing water," continues the Linde expert. The power for electrolysis can be generated by renewable sources such as wind. The resulting hydrogen can then be fed into the national

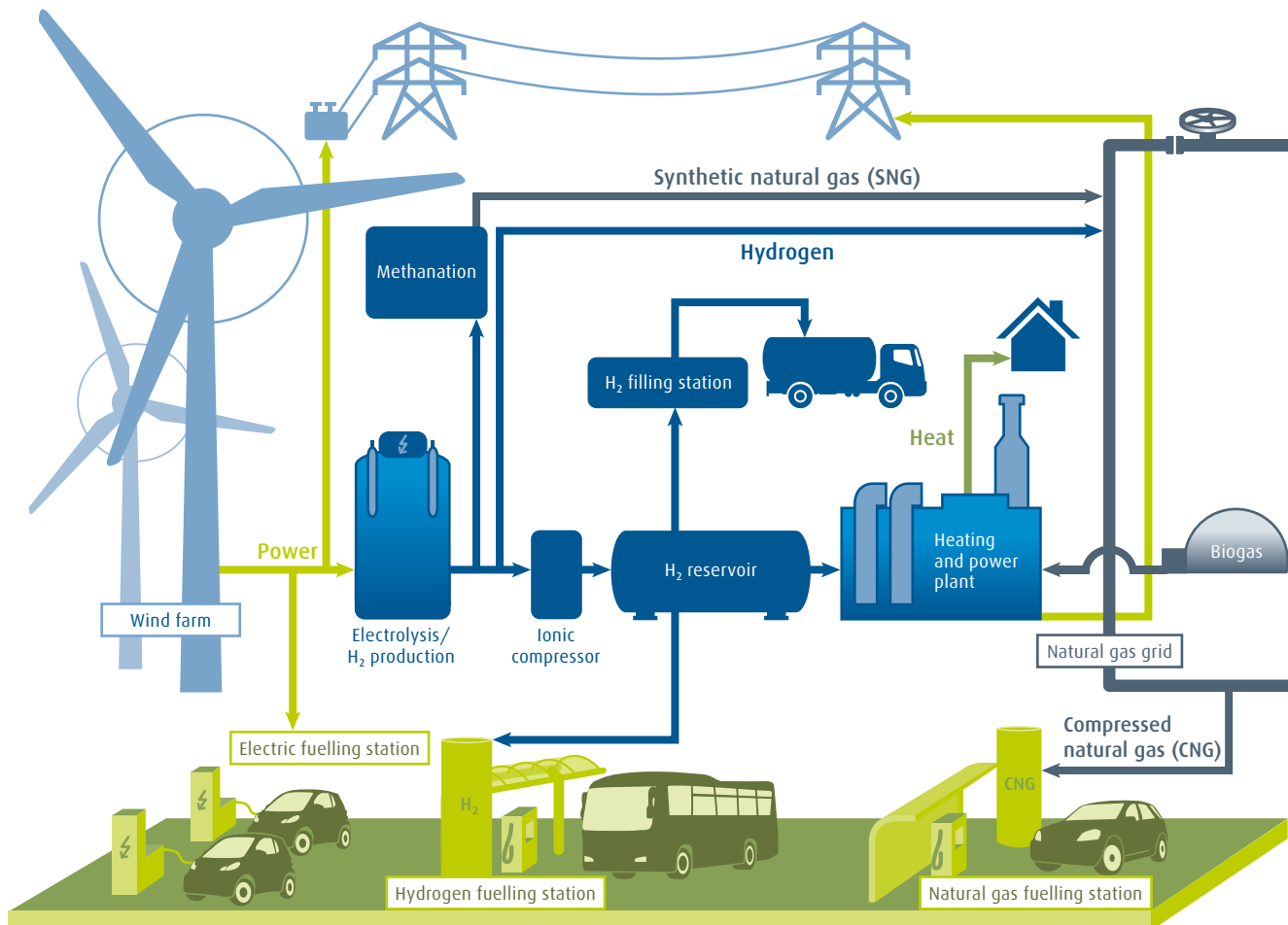
**ENERGY STORE**

*One kilo of hydrogen contains three times more energy than one kilo of crude oil.*



## NETWORKED HYDROGEN ECONOMY

Wind farms produce large volumes of regenerative energy. Depending on needs, it can be fed directly into the grid, it could be used to power electric cars for instance – or stored in the form of hydrogen. There are many different applications for H<sub>2</sub> generated from wind power. It can be used to power fuel-cell vehicles, co-fed into natural gas pipelines or converted into synthetic natural gas (SNG) by means of methanation. It can even be used as a fuel in heating and power plants.



energy grid in a number of different ways. H<sub>2</sub> can be converted back to power in gas-fired power plants, for example, or it can be fed into the natural gas network. At present, the German natural gas grid can absorb up to five percent hydrogen. Methanation is a further option. "Hydrogen can be methanised to produce synthetic natural gas, and this can be fed into the natural gas grid without any restrictions," elaborates Stiller. The carbon dioxide required for this process can also be taken from renewable sources such as biogas or wastewater treatment facilities. Fuel cells can also be used to convert energy stored in hydrogen to heat and electricity, powering heating systems, household goods and electric cars. H<sub>2</sub> energy storage systems could bring renewable energy to the street. Excess renewable energy could be used to power fuel-cell cars running on hydrogen, for example.

Linde and the two energy companies Enertrag and Total are collaborating on the project "H<sub>2</sub>-BER" to show how H<sub>2</sub> can link power networks with mobility solutions. The project is being coordinated by Linde Gas Germany in collaboration with Linde's Clean Energy team. It is funded by Germany's national innovation programme (NIP) for hydrogen and fuel cell technology. The partners are currently building the world's first hydrogen fuelling station to be powered directly by a wind farm at what is to be Berlin's main airport. The H<sub>2</sub> fuel will be used in fuel-cell buses and cars. Enertrag has built a wind farm close to the airport. It uses the power generated to operate a major electrolysis facility, which produces hydrogen. The electrolysis process, and subsequently the amount of H<sub>2</sub> produced, can be adapted to the amount of green energy available. Linde is supplying all of

the technology needed to efficiently store, compress and deliver the hydrogen. The company is also providing the refuelling technology. The Total Group is investing in the refuelling station and will be operating it, using Linde's refuelling technology to serve both cars and buses.

"If you take a close look at the individual technical components that go into building a hydrogen fuelling station, you'll see just how complex the entire project is," explains Tim Heisterkamp, Head of the "H<sub>2</sub>-BER" project at Linde Gas Germany. "Building a hydrogen refuelling station requires storage technologies as well as powerful, highly durable compressors to condense the hydrogen," continues Heisterkamp. This know-how is part of Linde's core expertise. "It's still a very challenging project for us," he adds, "because we have to combine a wide range of new technologies in a single facility." The station compressors, for example, have to run continuously and should therefore have very low maintenance requirements. This led Linde's engineers to develop an ionic compressor, a device that uses ionic liquids and consumes significantly less energy than conventional piston or membrane compressors. "This means that more of the wind power can go into making hydrogen," says Heisterkamp.

### Efficient storage and fuelling solutions

The hydrogen destined for the H<sub>2</sub> fuelling station at the capital city's airport will initially be stored in large tanks at a pressure of around 45 bar. It would not be economically viable to store it long term at a higher pressure. The hydrogen is fed from the large tanks to the ionic compressors, which pump the lightweight gas to smaller buffer tanks at pressures of up to 900 bar. This higher pressure enables drivers to refuel quickly at 700 bar. The buffer tanks contain enough gas to refuel around ten vehicles. The project also includes a fuelling station for trucks that will carry excess hydrogen to other points of use and industrial customers, including fuelling stations operated under the umbrella of the Clean Energy Partnership. This association of automotive, energy and technology organisations and companies already operates around 50 hydrogen cars in Berlin. The fleet is scheduled to increase to around 100 vehicles soon and will therefore require more hydrogen.

In future, Linde aims to deploy a new trailer for transporting hydrogen over long distances at a higher pressure. Trailers today can store around 6,000 cubic metres of hydrogen at 200 bar. The new trailer will enable pressures of up to 500 bar in future, which will more than double current transport capacity.

The "H<sub>2</sub>-BER" project is about more than just one fuelling station, however. "We are showing how a networked hydrogen economy can work in real life," elaborates Stiller. "We are connecting renewable energy with car fuelling and distribution over larger distances." Linde is also part of the nation-wide H<sub>2</sub> association "Performing Energy", together with 15 other partners. The organisation is researching and testing further hydrogen storage systems for the future. This includes assessing the viability of huge salt caverns as H<sub>2</sub> storage sites, capable of holding up to 200 gigawatt hours of green electricity. The collaborative project between Linde, Total and Enertrag is just the beginning, but nevertheless a crucial milestone on the road to tomorrow's hydrogen economy.

### SHORT INTERVIEW

## "RESPONDING TO FLUCTUATIONS IN A MATTER OF MILLISECONDS"



*Linde Technology spoke with Gaelle Hotellier, Head of Hydrogen Solutions at Siemens in the German city of Erlangen, about the role of hydrogen in tomorrow's energy mix.*

#### ↳ WHAT DOES HYDROGEN BRING TO THE ENERGY TABLE?

Hydrogen is just one of the building blocks in the energy landscape of the future. However, it has a very important role to play. What makes it so appealing is its versatility. Hydrogen is not only a means of storing regenerative energy, it can also be used as a source of power for industry, as a fuel for vehicles and as an energy carrier.

#### ↳ HOW CAN H<sub>2</sub> BE GENERATED SUSTAINABLY AND EFFICIENTLY?

Under the umbrella of the Performing Energy industry collaboration, a number of projects show that wind and solar power are ideal, climate-friendly sources of energy to generate hydrogen. The resulting gas is a carbon-free energy carrier that can be used, for example, as a fuel for vehicles. We are focusing on high-pressure electrolyzers with proton exchange membrane technology (PEM). They are ideal for high current densities and can react to dramatic fluctuations in the supply generated by renewable energy in a matter of milliseconds. Unlike conventional electrolyzers, they do not need to warm up and, depending on the way they are used, they can also achieve efficiency rates of between 65 and 90 percent.

#### ↳ IS THIS TECHNOLOGY READY FOR INDUSTRIAL-SCALE USE?

Before it can be advanced to industrial scale, this technology has to become more robust, powerful and cost effective. Our long-term goal is to create electrolysis parks capable of producing power in the three-digit megawatt range. These facilities would be able to turn excess energy from large wind farms into hydrogen, which could balance the power grid.

#### LINK:

[www.cleanenergypartnership.de](http://www.cleanenergypartnership.de)

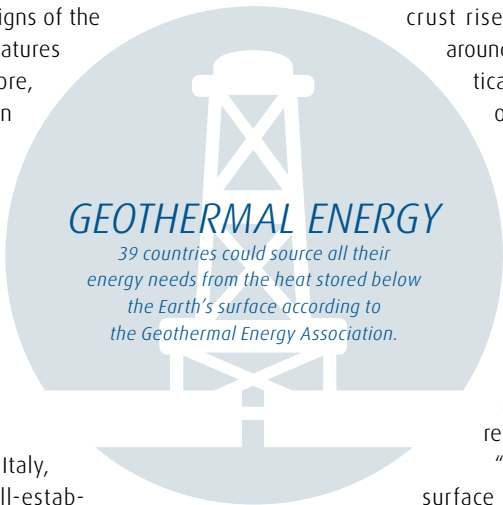


*Using geothermal power efficiently*

# ENERGY FROM THE EARTH'S CORE

The heat stored and flowing beneath the surface of the Earth is an endless source of natural energy. It powers volcanoes, hot springs and geysers – and could supply the world with warmth and power. Linde engineers are using innovative technologies to help capture this geothermal energy efficiently.

A surprisingly thin barrier sits between us and the fireball – the Earth's crust is like a jigsaw consisting of huge sheets of rock, with molten lava spurting out at the cracks. Volcanoes spewing fire and gushing thermal springs are signs of the seething substrate, hinting at the temperatures within. The natural heat of the Earth's core, or geothermal energy, is inexhaustible on a human scale. "And that's what makes it so promising from an energy supply perspective. It can be captured and converted into electricity – an ideal form of renewable energy," explains Professor Dr Rolf Bracke, Head of the International Geothermal Center of Excellence (GZB) in Bochum, Germany.



## Inexhaustible source of heat

Countries with active volcanoes, such as Italy, Iceland and Indonesia, have a long, well-established track record in the development of geothermal energy sources. "In some countries, such as the Philippines, geothermal sources already meet up to 30 percent of national power requirements," Bracke confirms. According to the Geothermal Energy Association (GEA), 39 countries could theoretically obtain

100 percent of their energy this way. But places with fewer visible signs of the intense heat below the surface can still tap into thermal energy too, since the temperature of the Earth's crust rises with increasing depth – generally by around 30 degrees Celsius per kilometre. "Sophisticated technologies and heat transfer methods are making geothermal energy more and more attractive across the globe," comments Martin Weiß, Project Manager Sales Carbon and Energy Solutions at Linde's Engineering Division in Dresden. Drawing on its extensive engineering experience with chemical and gas plants and the innovative technologies delivered by Linde Group member Cryostar, Linde has the know-how to efficiently recover the Earth's hidden heat reserves.

"The ideal scenario uses steam close to the surface to drive turbines and thus produce electricity," Weiß explains. However, this flash steam process requires water vapour temperatures of several hundred degrees. "This kind of high-energy geothermal field only occurs near the surface at tectonic plate boundaries," clarifies Weiß. A case in point can be found in the Mayacamas Mountains in California (USA), north of



Author: Thomas H. Loewe  
Image source: Stocktrek Images/Getty Images



*Energy unleashed: Strokkur (Icelandic for "churn") is a fountain geyser that erupts around every 10 minutes with a 20-metre jet of steam and water.*

San Francisco and home to the most productive geothermal field in the world today: The Geysers. Below the line of hills, molten rock bubbles in a chamber around 14 kilometres in diameter. The heat emitted is transferred into the layers of rock above, bringing the groundwater there to boiling point. Across the entire area, hot, dense steam is released from the ground at high pressure as a result. This was first used to produce electricity as far back as 1960. The power plants of US energy provider Calpine alone now generate around 725 megawatts (MW) on this basis – enough to power a city like San Francisco with its 800,000 inhabitants.

### Turning geothermal power into electricity

Nowadays, technological advances mean geothermal energy can be captured even far away from such highly active boundary areas. "Instead of direct steam solutions, we then use binary-cycle systems," reveals Weiß. Binary refers to the fact that the heat from an initial, closed heating cycle is transferred to a second, cooling cycle.




In the heating cycle, a high-power pump conveys hot geothermal water to the surface from deep below ground. The second cycle then uses a heat exchanger to transfer the heat of this water to a "working" substance – usually a fluid – after which the water is pumped back into the ground again. This maintains the subsurface pressure and prevents the water source from drying up.

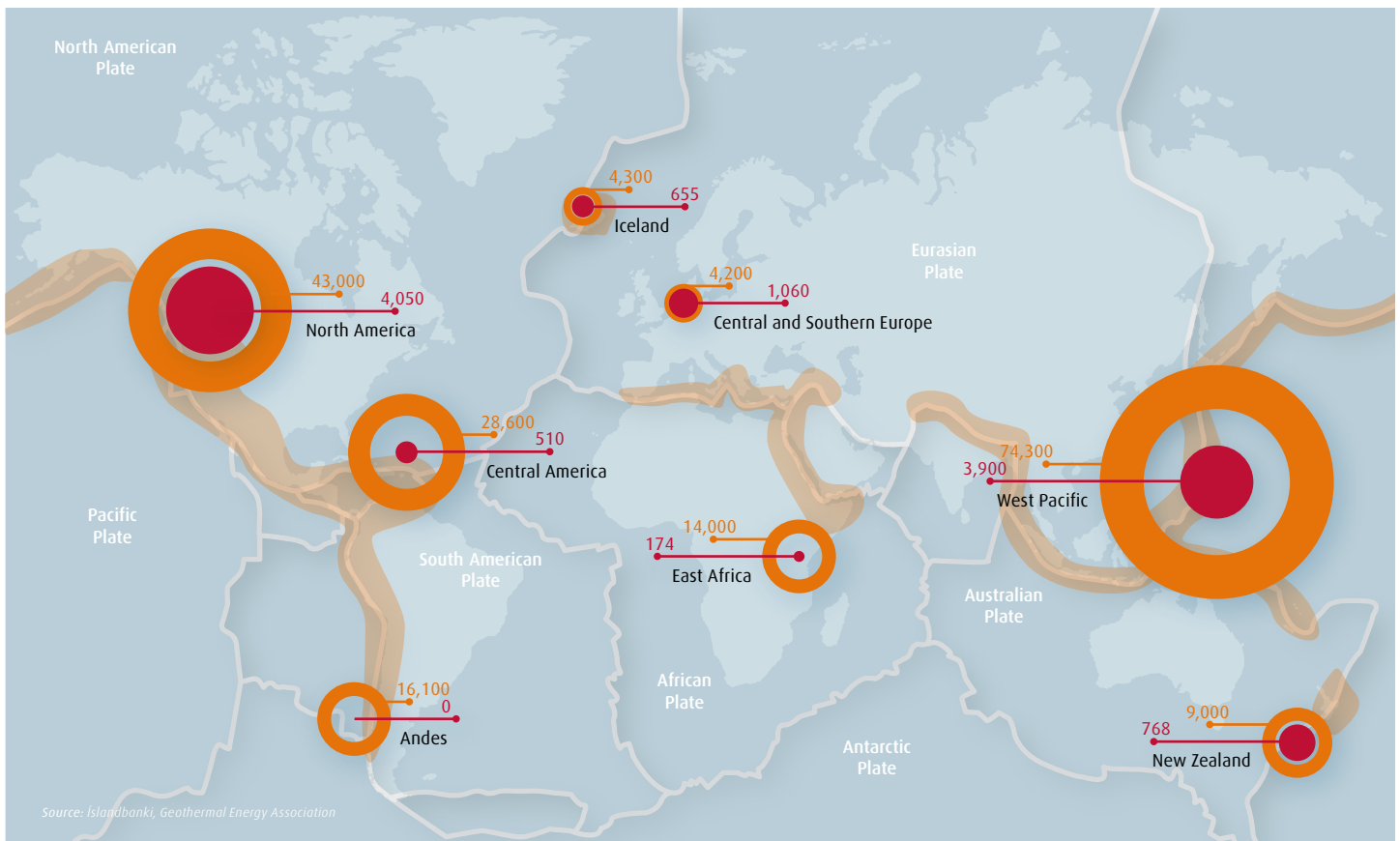
The fluid in the surface-based cooling cycle is vaporised by the heat drawn from below ground. "And this even works at lower temperatures," adds Weiß. This vapour then powers a turbine, which is an extremely efficient way of generating electricity. Linde's engineers favour organic working substances such as propane for this process, or the types of coolant used in refrigerators and air conditioning units. This is reflected in the name of the process: Organic Rankine Cycle (ORC).

The experts at Linde's Cryostar subsidiary have scrutinised not only the working fluid but also the thermodynamic characteristics of the ORC. Building on these insights, they now offer a special

## GEOTHERMAL MAP OF THE WORLD

Massive energy reserves: Dating back to when the Earth was formed, residual heat is sufficient to keep our planet supplied with energy for thousands of years to come.

-  Extremely active regions (tectonic or volcanic activity)
-  Current installed capacity in megawatts
-  Potential capacity in megawatts





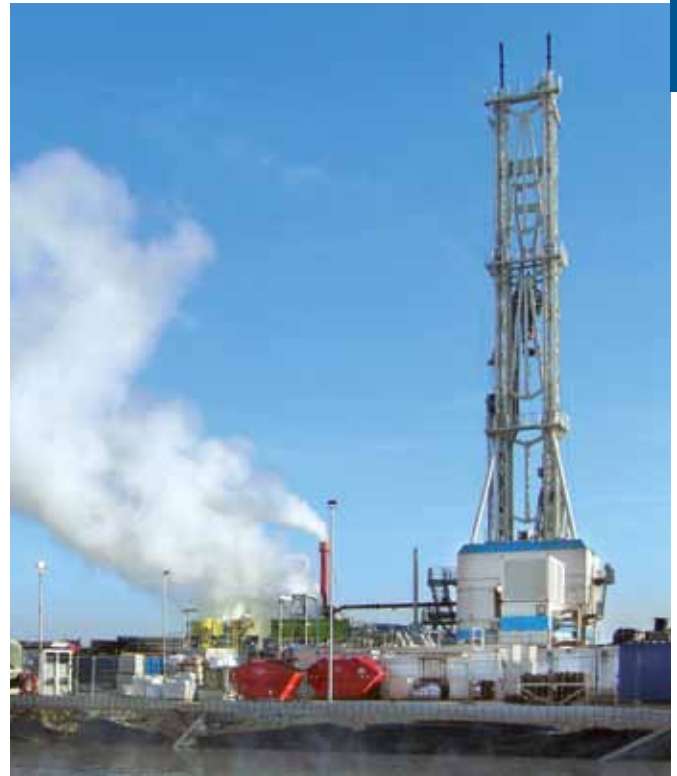
supercritical ORC process. This involves placing the working substance under increased pressure during the cooling cycle, changing it entirely into a gas-like state. "This reduces energy loss and increases the amount of power generated. With the added bonus of a longer lifespan for the turbines," declares Weiß. At such high pressure, even the smallest droplets can damage the hard metal of the turbine blades, causing erosion. However, as Weiß explains: "In this gas-like phase, no droplets are formed in the first place."

Together with Cryostar, the geothermal experts at Linde's Engineering Division are currently implementing their first ORC system in Kirchweidach in the German state of Bavaria. "We have been aware of huge hydrothermal reservoirs lying beneath the Alps for some time," asserts Weiß. However, the water in these aquifers is confined in porous Jurassic limestone layers situated three to five kilometres below the surface. The deeper they lie, the harder it is to locate such pockets of hot water. "In the worst case scenario, that means changing the drilling direction several times to find anything at all," warns Weiß. And this entails a substantial financial risk – a single deep borehole can cost up to ten million euros. "That's why we often support our customers from the very outset – in other words, from the concept development and financing stages onwards," Weiß explains. He and his team can call on a strong network of project partners, who then work together to ensure optimum results.

### Geothermal plants booming worldwide

In constructing the Kirchweidach facility, Linde's specialists are able to draw on in-depth expertise acquired from many years of engineering plants for the chemical and gas industries. "We are supplying the complete framework for the cooling cycle – from the air condenser and heat exchanger right through to pipelines and the electronic control system," says Weiß. Meanwhile, his colleagues at Cryostar are taking care of the heart of the system, along with the turbine and generator. "Our customer can look forward to a turnkey system from a single source," as Weiß underlines. Linde also offers an operation and maintenance service, giving the customer the option of connecting the plant to the company's Remote Operation Centre (ROC) in Leuna (Germany). This way, Linde can provide remote monitoring and dispatch a technical team straight away if required.

Demand for geothermal power plants is growing: "These days, colleagues come from all over the world to visit our research centre in Bochum – most recently from New Zealand, Turkey and Latin America," GZB head Bracke reports. "Few places conduct such intensive and interdisciplinary research into geothermal energy as we do." GEA surveys also show that investment in this energy source is increasing worldwide. The Philippines are keen to outpace the United States, aiming to generate almost 3,500 MW of electricity from geothermal energy by 2030. Neighbouring Indonesia has even more ambitious plans, sitting as it is on 28,000 MW of geothermal potential – roughly 40 percent of the world's geothermal energy reserves. 5,000 MW of geothermal power is set to go on stream there by 2025. Other active zones are located in Africa, as well as in South and Central America. In these regions, too, numerous countries are taking steps to establish or expand their geothermal resources. Pacific nations are par-



*Harnessing the Earth's heat: Linde supplies air coolers, heat exchangers, pipelines and electronic controls for the Kirchweidach geothermal power plant in southern Germany (above). Cryostar is responsible for installing the turbines and generators (below).*

## SHORT INTERVIEW

## "HUGE POTENTIAL FOR COMBINED HEAT AND POWER"



*Professor Rolf Bracke is head of the International Geothermal Center (GZB) in the German city of Bochum. The GZB is a research and excellence hub and also a point of contact for anyone with questions relating to the capture and use of geothermal energy.*

#### ↳ WHY HAS BOCHUM BEEN NAMED THE NEW INTERNATIONAL CENTRE OF GEOTHERMAL ENERGY?

The Ruhr area in Germany is a perfect location for researching geothermal energy. We have a long tradition of mining here and many local companies have over one hundred years' experience in mining and energy technologies. People know and accept the industry. We receive positive feedback from colleagues from Auckland, Istanbul, Reykjavik and San Salvador, who regularly come here to work. At the start of 2011, the International Geothermal Association (IGA) opened its head office at the International Geothermal Center at the University of Bochum and now runs its day-to-day operations from its secretarial office on the campus. Bochum has thus evolved into a world-class geothermal research hub.

#### ↳ WHY IS GEOTHERMAL ENERGY AN IMPORTANT PART OF OUR FUTURE ENERGY MIX?

One of the major benefits of geothermal energy is that it can be harnessed to generate both electricity and heat in cogeneration power plants. Because it is a good baseload source, geothermal could become an important source of district heating for major urban areas. By 2050, around 80 percent of the world's population will live in urban areas and megacities. This growing need for district heating is often underestimated. Particularly as we move away from fossil-fired power plants, we need to look at ways of closing the massive gap that this will present on the supply side. Environmentally friendly geothermal energy could help close this gap, providing large numbers of homes and buildings with electricity and heat. Industry also needs a lot of heat, and much of this could be met with this regenerative source of energy. Cooling is another important potential application. Here, geothermal energy could be used to power absorption refrigerators. Air conditioning units for distribution centres, hotels and exhibition centres could all be powered by environmentally sound geothermal energy in the future.

#### ↳ WHAT NEEDS TO BE DONE TO ENSURE THE WIDESPREAD ADOPTION OF GEOTHERMAL ENERGY?

We need to develop new technologies that can be deployed almost anywhere, even beyond regions with ideal geological conditions. And these technologies need to be accepted by society. Enhanced geothermal systems, for example, can be used to obtain energy from warm layers of stone far below the Earth's surface with low natural permeability. This technology involves drilling down to the source and pumping water down at high pressure to expand existing micro-cracks. This creates an artificial thermal source: the water is quickly heated below ground and can be brought back up to the surface and used for generating energy. These kinds of systems are still in the early stages of development worldwide. In Bochum, we are investigating different technologies at a graduate school created specifically for this purpose. We have a 7,000 square metre on-site field lab where we can make extensive test bores and use the findings to develop equipment. We can also carry out tests under realistic production conditions using a micro-seismic network and hydro-chemical analyses.

#### ↳ HOW DOES THE PUBLIC VIEW GEOTHERMAL ENERGY?

One of the greatest challenges we face is to promote acceptance of this renewable energy and communicate its benefits. We have to talk openly about the opportunities and risks involved with these technologies. This is crucial in order to bring geothermal energy to urban areas. Our research findings and new communication centre will help achieve this goal.

#### THE EARTH'S HEAT

Part of the heat used to generate geothermal power dates back to when the Earth was first formed. The rest is natural nuclear energy created by the radioactive decay of elements such as uranium, thorium and potassium. These processes ensure that heat continuously flows from deep below the Earth's crust to the surface. Although the Earth's crust is between five and 70 kilometres thick, its liquid magma core means over 99 percent of the planet is hotter than 1,000 degrees Celsius. Only the topmost three kilometres – in other words one thousandth of the Earth's mass – is cooler than 100 degrees Celsius.



*100 percent renewable: Iceland meets all of its electricity needs from renewable geothermal and hydro power.*

ticularly well located to tap into these energy reserves, with several tectonic plates bumping and scraping past each other beneath the coastal areas of this ocean basin. The 40,000 kilometre volcanic chain around the Pacific includes some of the world's most active volcanoes. And these high temperatures can be tapped at low depth.

However, experts have also identified high geothermal potential in regions that are less geologically active – for instance in Germany. Thanks to advancing technology, the Federal Environment Ministry (BMU) estimates Germany's geothermal potential at up to 15,000 MW. Efficient exploitation is even possible in the absence of thermal aquifers: "Enhanced geothermal system (EGS) technologies pump water into subsurface rocks. This hydraulic stimulation –



## THE USE OF GEOTHERMAL ENERGY IS PRESENT IN MANY VOLCANIC REGIONS.

or fracturing – activates existing rock fractures," Bracke explains. The water captures the heat of the rocks and transmits it to the land surface, creating an artificial thermal spring.


To gain a better understanding of the effects below the surface, Bracke and his colleagues are setting up a 7,000 square-metre field laboratory in Bochum. This will enable researchers to explore new drilling and reservoir technologies in real conditions and test power station processes. Sensors in multiple observation bores will measure the water chemistry and register even the smallest tremors. "If we can understand and predict the changes caused underground, we can ensure environmental sustainability and public acceptance," argues Bracke. He is confident of a successful future for geothermal energy – and of its necessity, since: "Shutting down fossil power plants will lead to a huge shortfall in supply, particularly for combined heat and power generation. Geothermal energy can play a major role in closing this gap."

### Meeting baseload needs

Geothermal power stations already generate twice as much baseload electricity as the solar sector and four to five times the amount of useful heat. And support for geothermal projects is set to rise around the globe as more and more countries recognise the economic value of their geothermal reserves. As Bracke concludes: "The market should really start to take off around 2020 – especially in less geologically active regions." For Martin Weiß, one thing is sure: "When there's no wind or sun, geothermal energy can still be relied on to produce power." Above all, however, geothermal energy is practically inexhaustible.

LINK:

[www.geo-energy.org](http://www.geo-energy.org)



*Skyscrapers catching the sun's rays:  
Solar modules turn roofs and façades into  
power generators. Anti-reflection glass  
significantly increases the energy yield  
of solar cells.*



*High transparency glass for greater energy yields*

# EXTRA-EFFICIENT SUN TRAPS

Solar modules are sensitive. Which is why they are usually protected from the outside environment by a layer of glass. However, glass also reflects light, sending energy back into the atmosphere. Special coatings can be applied to the surface to ensure that more sunlight gets through, thus increasing the amount of energy. Linde experts have been working with glass processing machines manufacturer LiSEC to develop a ground-breaking coating process.

Image source: Lester Lefkowitz/Getty Images  
Author: Tim Schröder



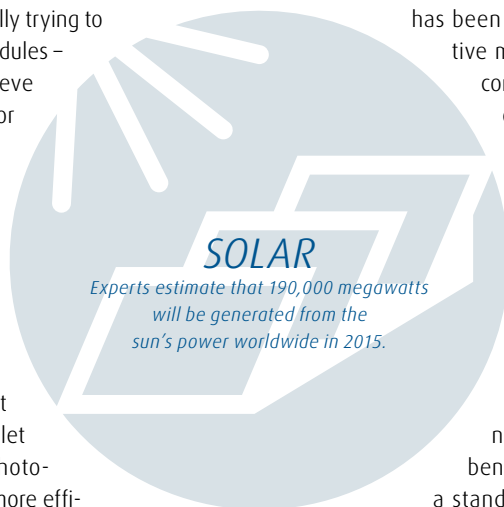
The sun's energy travels a long way through space to reach photovoltaic systems on the roofs of millions of houses across the globe. Each panel quietly and reliably converts this energy into electricity. Yet these panels could produce more. Materials scientists and physicists the world over are continually trying to increase the energy efficiency of solar modules – one percentage point at a time. To achieve this, they are creating new semiconductor materials and analysing their atomic structure with instruments that fill entire laboratories.

Yet there is a much simpler way of raising the energy yield of a photovoltaic module. Glass plates with an anti-reflective coating, for example, protect solar modules and their sensitive solar cells from the surrounding environment and other sources of damage. They also let more solar radiation through to the photovoltaic module, which makes the panels more efficient. Up to three percent more light passes through anti-reflective glass. This extra energy hits the solar cells and increases their yield. According to market research carried out by Glass Global, only around twenty percent of all photovoltaic modules are equipped with anti-reflection (AR) glass. This is set to rise to 80 percent by 2020.

There's just one problem, though. The machines and processes used to manufacture AR glass are either extremely expensive – which raises the cost of photovoltaic modules – or they produce glass that is not durable or transparent enough. Over the last two years, Linde

has been collaborating with LiSEC to find an alternative method for producing AR glass. The Austrian company LiSEC develops machines that process, cut, harden and laminate glass. In each machine, the glass plates glide from station to station on a conveyor belt. The new process, known as S-COAT®, slots seamlessly into existing production lines. It is a more cost-effective approach that produces unparalleled levels of durability and transparency. The principle itself is relatively simple: Engineers spray the coating onto the glass, which forms a film comprising nanopores when it dries. One of the major benefits of this method is that the spray unit is a stand-alone module that can be integrated into existing glass production flows. "We don't need to make

any major adjustments," explains Linde project head Steve Carney. This is not the case with conventional processes. In many cases, glass plates often have to be dipped in a bath of a special solution and then dried. This process is known as sol-gel coating and means



that the glass plates have to be taken out of the production line and temporarily stored elsewhere. Vacuum deposition is another established process. Here, the glass plates are transported on the conveyor belt to a vacuum chamber where the coating is vaporised and applied to the glass. Systems like these require pressure locks and complex vacuum technology, which makes them several times more expensive than the S-COAT® solution. "Our aim was to develop a solution that is more technologically advanced yet also cheaper than processes currently available on the market," says Ulrich Hanke, responsible for marketing and business development in the metal and glass sector at Linde.

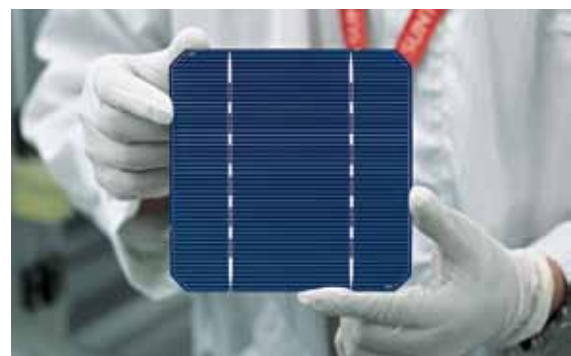
### SHINY PROTECTIVE COATING MADE OF NANOPORES.

#### Improved penetration at specific wavelengths

The S-COAT® module comprises several stations. Firstly, the surface of the approaching plate of glass is activated so that the coating material can be distributed as evenly as possible. In the next step, the plate is sprayed with the special coating developed by Linde, and then dried. All of this is done in a special gas atmosphere. Carney is unwilling to reveal the exact ingredients of the coating, but he will admit that it comprises one main component and several additional substances. "Most importantly, the coating is non-toxic and can be easily recycled once the photovoltaic module reaches the end of its lifecycle," says the Linde expert. What initially sounds like a simple process actually involves a great deal of process know-how, all of which is protected against imitations by several detailed patent applications. After all, Linde's engineers are developing a coating that is not only robust but also offers an exact nanostructure. "The size of the pores is extremely important as they determine which wavelengths

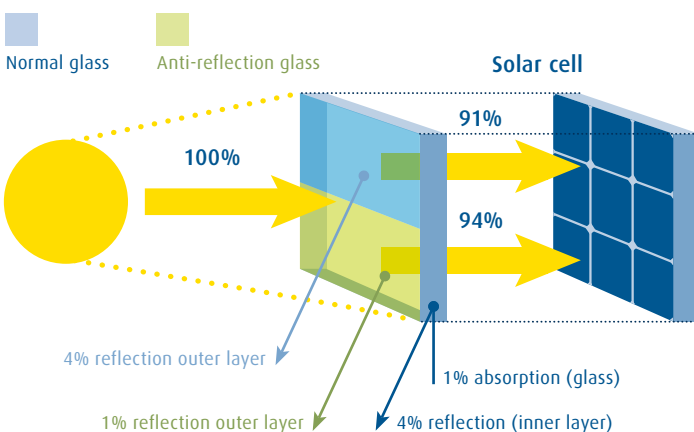
will be able to pass through the glass plate," continues Carney. Solar cells can generate a particularly large amount of electricity with wavelengths between 550 and 800 nanometres, and so demand for nanopores in this range is particularly strong.

One of the big challenges facing the glass experts involved setting the control parameters of the module to ensure that the pores in the sprayed film have the exact size they wanted. "Key settings include drying time and temperature. The composition of the gas atmosphere is also important as it enables us to achieve the right product characteristics and a perfect optical finish," adds Carney. "It took us some time to get the process settings right," recalls the Linde expert. But their efforts have certainly paid off. The film increases the amount of light transmitted into the cell by up to three percent compared with untreated glass. This may not sound like much but it is an enor-



#### LESS REFLECTION, MORE SOLAR POWER

Three percent more solar energy passes through anti-reflection glass to reach the solar cell and improve energy yield.



mous gain. "When it comes to improving the efficiency of solar cells and modules, every percentage point is a triumph," underscores Carney.

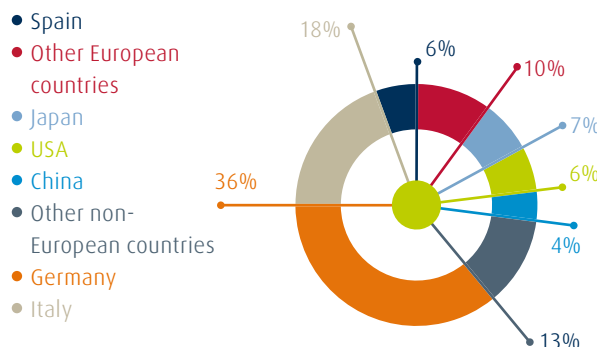
The S-COAT® process not only makes glass less reflective, it can also be used to tailor glass to specific environmental conditions. The various parameters can be adjusted to create a thicker, more scratch-resistant film, for example. This is particularly important in desert or coastal locations where sand and salt crystals in the air act like sandpaper over time, dulling the glass and making it less transparent. The new AR film is robust enough to withstand this constant abrasive effect. Following in-depth tests in a climate chamber, the developers expect their film to last at least 25 years. "We adapt the process to customer needs," explains Carney. The experts are currently working on making the film biologically active so that it can repel bacteria, algae and moss. This does not involve making the film toxic. Instead, the experts are modifying the nanostructure to prevent deposits or microbes forming on the glass surface. Any layers of organic matter reduce transmission and subsequently energy yield.

### Solar energy continues to grow

A pilot unit has been up and running at LiSEC since mid-2012, where it is used to coat glass for selected customers. The S-COAT® module can coat fifteen metres of glass per minute, fast enough to keep pace with the glass production line. It can be used with glass panels up to 1.7 metres in width and can therefore easily process conventional solar modules, which have standard dimensions of 1.68 metres by 1.1 metres. "Our module is extremely flexible. We can turn it on and off without having to make any adjustments to the production line," elaborates Johann Weixlberger, head of business development at LiSEC. If the factory is manufacturing a batch of glass that does not

### SOLAR POWER WORLDWIDE

*In 2011, the photovoltaic capacity installed worldwide amounted to around 69 gigawatts distributed across the countries below.*



*According to Enerdata, EPIA*

need to be coated, the module is deactivated and the plates simply slide through unprocessed. The spray process can be activated immediately, however, without long start-up times or the need to prepare a bath.

The spray unit will be officially premiered at the Intersolar trade fair in Munich mid-June 2013. "We will be presenting the S-COAT® process to a large number of glass producers and solar module manufacturers," explains Hanke. He is convinced that potential customers will be impressed by the process. S-COAT® delivers outstanding results at the lowest cost, and this is exactly what the solar industry is looking for in these economically challenging times. Although the industry is currently making headlines in the media with reports of consolidation and overcapacity, the global end consumer market is still developing strongly. According to Germany's Federal Ministry of Economics and Technology, solar energy's share of electricity consumption in Germany rose from less than one percent to 5.7 percent between 2004 and 2012. And this trend is set to continue at international level. In 2010, photovoltaic modules with a total output of 39,531 megawatts were installed across the globe – this is roughly the same output as 40 nuclear power stations. Experts predict that around 190,000 megawatts will be produced in 2015, with China and the US leading the way.



*Sunny days: Solar modules are being installed on more and more façades of large buildings such as City Hall in London (left, above). Every percentage point counts when it comes to increasing the energy efficiency of solar cells (left, below). New coating processes must integrate smoothly into existing glass production lines (right).*

#### LINKS:

- [www.epia.org](http://www.epia.org)
- [www.lisec.com](http://www.lisec.com)

*Harald Dimpflmaier, Chief Engineer,  
Swiss Reinsurance Company Ltd.*



## Essay

# "TOWARDS A SUSTAINABLE ENERGY FUTURE"

Combatting climate change while securing future energy supplies is one of the most demanding challenges facing our growing global population. As investment in new technologies increases, so too does the need for effective risk management and improved insurance models.

Fossil fuels have powered our economy and shaped our way of life for more than a century. Their use has helped create unprecedented wealth for more people than ever before and allowed them to lead longer and more productive lives. Accompanying these economic developments, the world's population has grown from one billion to seven billion over the last 200 years, having increased by only about 700 million in the previous eight centuries combined.

And yet for all their benefits, fossil fuels have also had a detrimental side effect: greenhouse gas emissions. These emissions trap heat in the atmosphere, pushing up average temperatures and adversely affecting the Earth's climate system. Today we are living with the impact from decades of fossil fuel-driven growth and the effect it has had on our climate.

As economies and populations expand, global demand for energy will continue to increase. The International Energy Agency estimates that world energy demand will rise by 40 percent between now and

2035 and that 90 percent of this demand is expected to come from non-OECD countries, notably China and India. To meet these growing energy needs, global investment of 38 trillion US dollars is required to build and maintain an adequate energy supply infrastructure over the next 25 years.

But the world has hit a crossroads. Greenhouse gases in the atmosphere are continuing to rise as a result of burning fossil fuels. If current trends persist, rising emissions not only threaten to exacerbate climate change, but also to cause abrupt and permanent environmental damage.

Even a relatively low two degree Celsius warming above pre-industrial temperatures – an ambitious and increasingly unrealistic goal agreed at the 2009 Copenhagen climate summit – would significantly alter weather patterns. The result would be more intense heat waves, erratic rainfall, storms and flooding that would jeopardise even more people and infrastructure.





*Teamwork for turbines: The European Wind Turbine Committee initiated by Swiss Re offers European insurers a platform for dialogue with the wind energy sector.*



## WORLD ENERGY DEMAND WILL RISE 40 PERCENT BY 2035.

insurers to forge partnerships with the renewable energy industry to help advance innovations in solar, wind and hydroelectric technologies. Central to these partnerships is the aim of enhancing risk management expertise and developing new, cost-effective insurance products that will enable the risk-taking essential to growth and innovation in the renewable energy sector.

An example of these joint efforts is the European Wind Turbine Committee (EWTC), initiated by Swiss Re. It gives European insurers and reinsurers a forum to discuss trends and technologies with representatives from the wind energy sector, including wind turbine manufacturers, project developers, plant owners and operators, lenders and engineers. The EWTC dialogue aims to support the development of tailored insurance products that better meet the needs of the industry.

The EWTC has also started an initiative to ensure minimum risk management standards for offshore wind energy projects, which are particularly complex and large in scale. Participants in this effort are insurers, reinsurers and the offshore industry. With the adoption of risk management standards, participating companies want to support the long-term insurability of offshore wind projects, which includes the development of new risk transfer products for the construction and operation of offshore wind farms.

A number of innovative risk transfer products are already available to reduce renewable energy risks. These comprise insurance products to manage weather volume risks and risks associated with the construction and operation of renewable power infrastructure, including third-party liability, contractor plant and equipment and assets. The EWTC has also launched an initiative to ensure binding minimum standards for risk management in offshore wind energy projects. This effort brings together insurers, reinsurers and offshore companies.

Tackling climate change while meeting the energy needs of a growing and developing world is therefore a matter of urgency. But this dual objective is highly complex and fraught with risk. What is certain is that it will require a fundamental change in the way we produce and consume energy. This can only be achieved by improving energy efficiency and switching to low-carbon options, including renewable energy sources. As investment in these new technologies increases, so will the demand for improved risk management and insurance. Based on risk analysis, green scenarios supported by concerted action on climate change offer the greatest market potential for renewable energy sources. This is largely due to the fact that they will enable a more rapid transition to a green economy supported by coordinated low-carbon policies. The unique risks associated with renewable energy make a strong case for insurance.

While the basic categories of risk apply equally to renewable and non-renewable energy sources, renewable energy projects face very specific challenges that distinguish them from fossil fuel-powered installations. This is because they use novel and less mature technologies, are exposed to the impact of adverse weather, often operate in difficult geographic locations such as offshore wind farms, and for the time being rely on public subsidies and regulations to be competitive on a commercial scale.

For all these reasons, the risks associated with renewable energy require unique risk management practices and new risk transfer options that offer a viable alternative to some of the more conventional insurance products. This recognition is increasingly motivating

MANAGING RISK: RENEWABLE ENERGY CALLS FOR NEW APPROACHES BY INSURERS.

Image source: Swiss Re, Getty Images

LINK:  
[www.swissre.com](http://www.swissre.com)

*Keeping food cool with liquid nitrogen*

# FROSTY FREIGHT

Whatever the season, our supermarket shelves are packed full of produce from the four corners of the globe. Seamless logistics and, above all, a secure cold chain are essential if we want our pineapples from tropical countries, lamb from New Zealand and shrimps from the Pacific to arrive in fresh condition. Linde engineers have developed an efficient, environmentally sound system that uses liquid nitrogen to keep food cool.

You might never know that the tropical fruit in our supermarkets has been flown thousands of kilometres around the globe. Jetlag doesn't seem to be an issue for the mangos that make their way to our fruit bowls. In fact, they normally look like they have come straight from the nearest mango grove. But appearance and taste are not the only quality benchmarks. Hygiene and food safety are also top priorities, especially when transporting fish and meat. Harmful bacteria can multiply extremely quickly if these products are not stored properly. Standards across the food industry are high, and they apply to five-star restaurants just as much as to fast-food outlets and convenience food providers.

Refrigeration is a key success factor in food transport. Nutrients and vitamins survive longer at low temperatures and bacteria find it more difficult to develop. "Fresh, high-quality produce calls for an uninterrupted cold chain. But this can be tricky at times, especially on long routes or when products are being transferred from ships to trucks," explains Mark Ewig, Head of Global Strategic Marketing and Development at Linde's Food and Beverage department. The vehicles used to transport perishables have to provide the best possible cooling performance throughout the entire supply chain, from container ports through wholesale markets to dealers and restaurants. Ewig and his team have developed a sophisticated food refrigeration system for

**MORE THAN  
170,000  
REFRIGERATION  
TRUCKS.**

these distribution trucks based on liquid nitrogen (LIN). The engineers have been focusing on LIN, which has a temperature of minus 196 degrees Celsius, for some time now. The FROSTCRUISE® cooling system is the result of their work.

The market for in-transit refrigeration is growing rapidly and so the new LIN solution could not have come at a better time. According to a study carried out by the London-based market research institute TechNavio, the number of temperature-controlled vehicles on the road in the UK alone rose to over 170,000 in 2012 – an increase of almost 30 percent relative to 2010. And the fact that FROSTCRUISE® is more environmentally friendly, quieter and faster than conventional diesel-powered cooling systems gives it an additional lead in this dynamic market.

One of the key – and challenging – steps in the project entailed integrating LIN delivery into trucks/vehicles and trailers; this proved challenging. The most obvious option of directly spraying liquid nitrogen into the storage chamber was not viable as LIN displaces oxygen in the air. Suppliers would have to carefully ventilate the goods before unloading to bring the level of oxygen in the air back to an acceptable 18 percent. "This introduces a lot of warm ambient air into the transporter and disrupts the refrigeration process," explains Ewig.



*Touch of frost en route: Liquid nitrogen protects fish, meat, fruit and vegetables from the effects of ambient temperatures during transit.*



The Linde engineers developed a more effective solution, pumping liquid nitrogen from a double-walled, insulated steel container under the floor of the truck through a heat exchanger into the storage area. "This method cools the air in the storage area yet also keeps the nitrogen separate," elaborates Ewig. Six high-power fans are also integrated into the storage chamber. Three of these are in continuous operation, circulating the cold air and ensuring that it reaches every corner of the trailer. The remaining fans are controlled by sensors and can be activated on demand. In contrast, conventional cooling systems only use one fan to circulate air. "With a single fan, there is always a risk that the products will not be cooled as evenly or effectively as possible, which in turn can spoil produce," continues Ewig.

The LIN tanks on the refrigerated trucks can hold up to 530 litres of nitrogen, and they can be refilled at Linde partner stations. "Several factors influence how long a tank will last, including the actual produce being transported," explains Ewig. Minus 25 degrees Celsius, for example, is ideal for ice cream, while ready-made frozen meals and mixed vegetables require a temperature of minus 18 degrees. Fresh meat has to be transported at a temperature of four degrees or below. Even apples are transported at refrigerator temperature. The temperature of produce as it is loaded into the truck also affects LIN consumption, as do the insulation technology and the outside temperature. The number of times the truck is opened for unloading also plays an important role. The Linde expert estimates, however, that "an eight-and-a-half-metre truck will consume on average between 28 and 40 litres of nitrogen per hour to maintain a temperature of two degrees Celsius. Under these conditions, a single tank lasts at least twelve hours".

### Less energy, better CO<sub>2</sub> balance

In the past, almost all refrigerated trucks were equipped with diesel-powered mechanical cooling systems that alternately compress and expand coolant in much the same way as household refrigerators. When coolant expands rapidly, it cools the surrounding air. These conventional systems, however, feature diesel motors, compressors, oil and filters – a combination that makes them prone to breakdowns. The FROSTCRUISE® system does not contain any of these components. Its simple design makes it easier and less costly to maintain.

It is on the environmental front, however, that the new system really excels. "Its CO<sub>2</sub> footprint is significantly smaller – something that is becoming increasingly important for our customers," confirms Ewig. Producing LIN requires electric power, and transporting it to nitrogen fuelling stations further contributes to the total life-cycle carbon footprint of LIN. But once the liquid coolant is in the refrigeration system, energy consumption – and thus also carbon dioxide emissions – is zero. Conventional refrigeration systems release up to 20-50 percent more greenhouse gases every day than the LIN cooling solution. Diesel generators also release nitrogen oxide and soot particles. The Linde system does not require any of the harmful coolants that conventional systems use, for example halogenated hydrocarbons. This is a crucial factor according to Ewig, as a significant amount of the coolant can escape into the environment through tiny leaks despite the closed system design. "Up to one litre of the cool-



ant can escape during the course of a year," he adds. With the LIN system, leaks are no problem because nitrogen is one of the main components of air and therefore totally harmless.

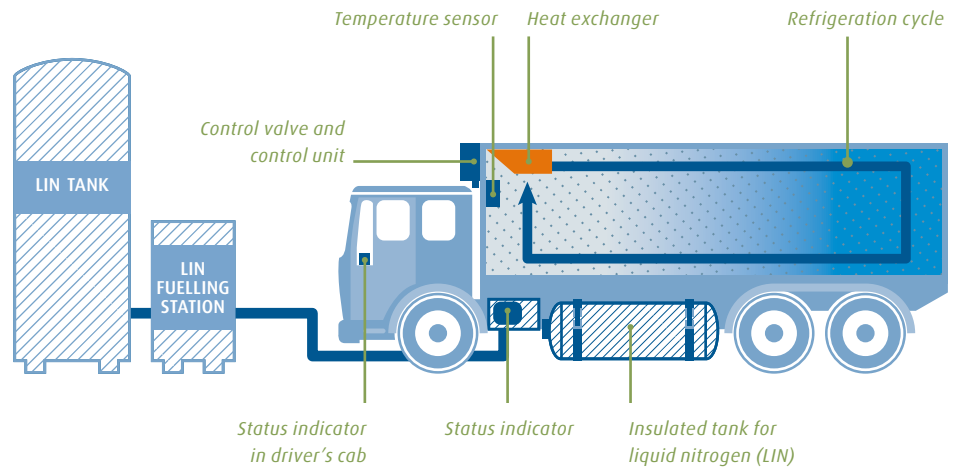
Liquid nitrogen cools products much faster than conventional refrigeration methods, making the LIN system ideal for very hot climates. Linde has been collaborating with the company McFood to test this effectiveness. McFood supplies McDonald's restaurants with food in the tropical heat of Malaysia, where temperatures exceed 30 degrees Celsius in the shade during the day and seldom drop below 20 degrees at night. Yet the beef burgers, chicken wings and filets of fish still have to be kept fresh and tasty until they can be prepared and served in the fast-food outlets. Cooling systems also have to contend with hot air from outside: "Whenever the door is opened to unload products, very warm air enters the cooling unit. This happens repeatedly and at short intervals," continues Ewig. This



*Keeping the cool chain intact: Temperature-controlled trucks are needed to keep food fresh on its way from distribution centres and wholesalers (left) to supermarkets (bottom, right). Linde's FROSTCRUISE® innovation for the trucking industry uses liquid nitrogen to raise the bar for efficiency and environmental performance (below, left)*

## CHILLY TOUCH

*Linde partners operate nitrogen fuelling stations for trucks. The LIN tank of a temperature-controlled truck can hold 530 litres maximum. Six high-speed blowers ensure the cooling power is evenly distributed throughout the cooling compartment.*



is because the individual restaurants are located close to each other. A conventional refrigeration system can take up to one hour to cool the compartment area to the requisite temperature following a delivery. FROSTCRUISE® can do this in just under 20 minutes, even in a tropical climate. This time saving is also a benefit in more temperate zones. In the UK, Linde's logistic division Gist is already supplying one of the largest supermarket chains in the country. "Our customers are very excited about the potential of FROSTCRUISE®," says Sam de Beaux, Engineering Director, Gist. "The vehicles we have today are still development vehicles in the pre-production stage, but results to date for single drop operations show the system can be competitive as well as having environmental advantages," de Beaux adds.

Linde's new development is not just kind to the environment. It is also very quiet. The cooling system runs at less than 55 decibels, which is about as loud as two people talking. Modern diesel-pow-

ered systems are significantly louder, and older models can reach 95 decibels – in other words, as loud as a disco. These high noise emissions are a real problem for some carriers, as Ewig elaborates: "Most distributors make their deliveries at night to avoid daytime traffic, especially in large cities. Noise limits, however, are particularly strict at night in many urban areas, with thresholds as low as 60 decibels in some cases." This trend started in Europe in cities such as Paris, London, Amsterdam and Stockholm. Today, however, noise protection measures are in place in many other cities across Europe. Companies that use diesel generators therefore have to put a lot of effort into insulating noisy machines.

Ewig and his team of engineers are already looking at ways of further improving the technologies developed thus far. However, the Linde manager is not revealing the exact details of how their new concept works or whether it also uses liquid nitrogen. "If we can further increase efficiency, we will be able to cut energy consumption, emissions and also costs – which is exactly what our trucking customers are looking for," concludes Ewig. The refrigeration experts also have their sights firmly set on developing more climate-friendly technologies as more and more people are looking for environmentally sound food choices.

LINK:

[www.linde-gas.com](http://www.linde-gas.com)



*Using nitrogen to cut costs in automotive manufacturing*

## *PRESSURISED PLASTIC*

To make cars more lightweight, automakers are using plastic instead of steel and glass. Plastics reduce weight and help cut fuel consumption. They are also opening up new opportunities for designers. Linde experts have developed innovative production systems based on high-pressure nitrogen.

Car manufacturers need to watch their weight. And not just to meet the needs of tomorrow's electric vehicles. Every kilogram saved in automotive design leads to fuel savings later, on the road. Engineers are turning to high-tech plastics to design lighter vehicles. Plastics can be used for a wide range of parts, from instrument panels through bumpers to seats and door handles. On average, they are around 50 percent lighter than the equivalent glass or metal components. Robust plastic components now account for up to 15 percent of a car's total weight. And this figure is rising. Lightweight designs are essential in the drive to cut fuel consumption, curb CO<sub>2</sub> emissions and increase the range of battery- and fuel-cell-powered cars.

There is another plus to plastics. Injection moulding technology allows manufacturers to easily process and shape plastics, and tailor their properties to specific applications. To achieve the desired results, the automobile industry is increasingly relying on gas injection moulding technology. During this process, an extruder injects liquid plastic into an injection mould, known as a cavity, under high

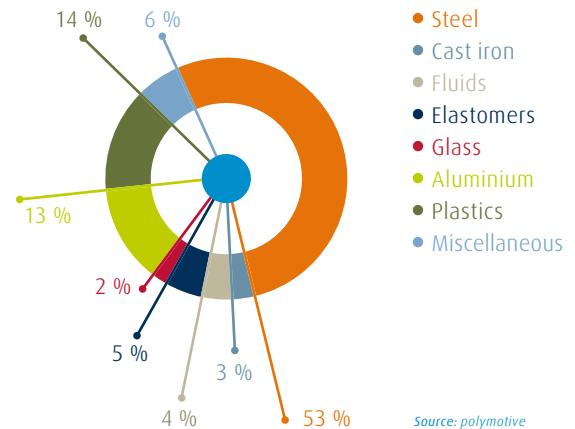
pressure. Gaseous nitrogen is then injected into the melt, displacing some of the plastic, for example, into a secondary cavity. The gas pressure is maintained until the part has hardened and can be removed from the mould. The resulting product is hollow, which reduces both material consumption and weight. "The final product is still sufficiently stable and hard," explains Rolf Heninger, Head of Plastics & Cryogenics at Linde's Gases Division. "The high pressure also ensures that the plastic mass evenly fills the mould and does not shrink when it cools," adds Heninger. He and his colleagues have now increased the efficiency of gas injection moulding even further with an innovative nitrogen boosting solution. The injection system often requires pressures in excess of 300 bar. Due to the physical forces involved, conventional compressors require enormous amounts of energy to achieve and maintain these pressures. Linde's PRESUS® N10 pressure-boosting plant presents an interesting solution to this challenge. Instead of compressing the gas, it feeds liquid nitrogen to high-pressure vaporisers at pressures of up to 350 bar.



*High-tech car bodies: Plastics not only make today's cars more economical and stable, they also enable futuristic designs.*

## COLOURFUL MIX

*Today's mid-class car is a colourful composition of different materials selected to ensure a lightweight, yet robust design.*



"Ambient air vaporises the nitrogen without having to change the pressure," continues Heninger. This cuts costs for manufacturers of plastic parts. In fact, PRESUS® N10 requires around 90 percent less energy than today's typical gas compressor solutions.

### Cryogenic nitrogen for shorter cycle times

Other factors also improve the pressure boosting system's energy performance. The pistons, for example, do not have to be in continuous use to compress the gas. "Once the pump has created the operating pressure required for the nitrogen, it stops. And because it is used less, it requires less maintenance," says Heninger. PRESUS® N10 is also very robust. "In theory, the system could run continuously for one year, which is a huge plus for our customers," says the Linde expert. Competition is tough among auto parts suppliers and so every production minute counts. Linde's system also eliminates the risk of contamination as, unlike conventional systems, the nitrogen does not come into contact with lubricant at any time. PRESUS® N10 delivers a much higher nitrogen stream than standard compressors costing roughly the same. In fact, its capacity is in the range of cryopumps that would typically be too big for this type of application.

Lightweight, ultra-stable plastics are also in demand in the aviation and electronics industries. Laptop casings, for example, can be injection-moulded more efficiently using Linde's innovative pressure-boosting solution, PRESUS® N10. This plant is also a promising alternative for other high-pressure applications. It is already being used to supply high-pressure nitrogen for thermal spraying, a surface coating process. Linde's solution also makes the actual manufacturing process – cooling the plastic mass – more cost-effective. During the moulding process, it can take up to several minutes before an injection-moulded part can be removed from the mould and the next part

injected. Linde's new inner cooling system shortens this period by using a secondary injector to cool parts from the inside. This second injector shoots cool nitrogen into the hollow centre of the hot part while the warm gas exits through the original injector. "This internal cooling process hardens the plastic in a significantly shorter space of time, accelerating cycle times by up to 50 percent," explains Heninger. This new method also makes the insides of parts smoother. Linde has developed a switching and flushing module to enable inner cooling to be carried out using conventional GIM controls.

The Linde engineers are keen to improve injection moulding efficiency even further and are already working on new enhanced gas injection moulding solutions, including an inerting step for injection moulds. The experts are using nitrogen to prevent liquid plastic from reacting with ambient oxygen when it is injected into the mould, as oxidised residues can cause clogging. "By inerting the mould, we aim to reduce maintenance requirements and increase productivity," explains Heninger. Linde is also developing a technique that uses carbon dioxide. "We believe that CO<sub>2</sub> is a promising alternative to the widely used water injection moulding technique," elaborates Heninger. Carbon dioxide has good thermodynamic properties, similar to water. CO<sub>2</sub> also reduces the risk of injection moulding tools becoming damaged by damp. This technology will be deployed on a series production line soon. "These processes make the production of plastic parts simpler, faster and more accurate, and this cuts costs," summarises Heninger. Above all, however, Linde's solutions drastically reduce energy consumption.

LINK:

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

*Increasing energy efficiency in metal fabrication*

# TURBO BOOST FOR FURNACES WITH OXYGEN

Cast iron has a number of special properties that make it ideal for a wide range of applications from water pipes through cars to machine components. However, the process of casting iron is very energy intensive. Linde engineers have been working with foundry experts to improve the cast iron production process. They've come up with an innovative oxygen solution that saves resources and money.

Cast iron pipes distribute life-sustaining water to the four corners of the globe. Without these underground networks, not only would entire industries grind to a halt, private homes would also struggle without safe drinking water. Despite a growing number of modern high-tech alternatives, cast iron is still the material of choice for these indispensable pipelines. In fact, this carbon- and silicon-rich iron alloy that has been manufactured by mankind for millennia plays a crucial role in many different sectors. Manhole covers, brake shoes for trains, gearbox casings, chassis components and machine parts are all made from this tried-and-tested material. Cast iron is an extremely rigid and impermeable material. It is also long lasting, resistant to corrosion, malleable and has very high compressive strength. "These properties make it an ideal material for water, gas and chemical supply pipes," explains Heinz Kadelka, head of the foundry team at Linde Gas Germany. However, the production of these mini pipelines is extremely energy intensive. And energy efficiency has become an increasingly important topic in recent years due to rising energy prices and concerns about CO<sub>2</sub> emissions.

Many foundries use a proven technology known as the cupola furnace to melt cast iron. There are around one thousand of these furnaces worldwide today. This simple technology is widely used but has always been resource intensive. "Researchers have only started to look more closely at cupola furnaces in the last twenty years," explains Kadelka. He and his colleagues have been working with experts from Fusoris Engineering GmbH and the Düker foundry in Karlstadt, Germany, to develop a technology capable of making cupola furnaces more energy efficient. Their innovation, known as the High Efficiency Furnace (HEF), has reduced emissions from the Düker foundry cupola furnace and also cuts energy and material consumption without impacting the quality of the final product. "In some cases, we were even able to increase the quality of the resulting cast iron," says Kadelka.

**50 PERCENT  
LESS EMISSIONS  
WHEN MAKING  
CAST IRON.**

The Linde experts achieved these savings through the innovative use of oxygen. In a conventional production process, normal air – referred to as blast air – is fed into the lower part of a cupola furnace through a number of nozzles. Once the coke in the furnace is ignited, it produces carbon dioxide and carbon monoxide. The hot gases move upwards, heating alternate layers of iron and coke. Carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>) combine with nitrogen (N<sub>2</sub>) in the air to produce the blast furnace gas. To eliminate harmful emissions, most foundries extract the gases from the upper part of the cupola furnace and feed them into a separate combustion chamber, where the carbon monoxide is burnt to carbon dioxide, and any organic contaminants are destroyed. The heat from this combustion process is then used to preheat the blast air.

In the HEF process, Linde's engineers use the blast furnace gas in a different way. They have developed a sophisticated gas cycle that makes particularly efficient use of the chemical energy from the emissions. During this cycle, part of the hot gas is extracted and fed back into the furnace. Before it is recycled, however, the blast furnace gas is enriched in a mixing chamber with pure oxygen.

In the HEF process, Linde's engineers use the blast furnace gas in a different way. They have developed a sophisticated gas cycle that makes particularly efficient use of the chemical energy from the emissions. During this cycle, part of the hot gas is extracted and fed back into the furnace. Before it is recycled, however, the blast furnace gas is enriched in a mixing chamber with pure oxygen.





gen from a separate tank. This mixture is then injected directly into the layer of coke via three water-cooled copper nozzles, which were specially designed by Kadelka, his colleagues and Fusoris Engineering. "This not only makes better use of thermal energy but also improves the post-combustion process," adds Kadelka. The new process reduces the amount of blast air required by around 50 percent. This decreases the level of energy required to heat the air and – more importantly – the nitrogen content in the air. This is a valuable saving as the nitrogen ballast does not contribute to the combustion process. HEF actually increases combustion efficiency as the enriched blast furnace gas comprises up to 30 percent carbon monoxide, which is a flammable gas. Or as Kadelka puts it: "Carbon monoxide is basically pure energy." Getting the perfect combustion atmosphere in a cupola furnace, however, is an art form in itself. "Coke provides the carbon for the cast iron," elaborates Heinz Kadelka. "And so you can't randomly reduce it or replace it with another fuel." The blast furnace gas must comprise the perfect mix of carbon dioxide and carbon monoxide. This is because part of the CO<sub>2</sub> to CO decay process depends on the furnace temperature. This decay consumes energy. "If too much carbon monoxide is produced, the furnace will cool down," warns Kadelka.

### Saving costs – with environmentally sound processes

He doesn't think that getting the mix right will be a challenge with the HEF process, however. After a successful one-year test phase, the Düker unit went on stream in mid-2012. The Linde experts were able to make impressive savings during test runs, reducing coke consumption by 27 per-

cent and CO<sub>2</sub> emissions by 20 percent. Total emissions were cut by over 50 percent and the overall melting process was significantly faster. The HEF process is not just good news for the environment. It also makes sound financial sense. "If a foundry uses 30,000 tonnes of coke a year, a reduction of just two percent can save EUR 300,000," emphasises Kadelka. When used with a specific type of furnace known as a cold-blast furnace, the HEF process can also significantly extend run times. "These kinds of furnaces usually have to be thoroughly cleaned after one day of operation. Many foundries therefore have two furnaces running alternately," explains Kadelka. With the HEF process, cold-blast furnaces can run five, in some cases, even seven days in a row. "HEF enables foundries to increase production levels without having to invest in a new furnace," concludes Kadelka. Foundries are already showing great interest in this new process that could help modernise melting while conserving resources – on more than one count.

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#### LINKS:

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

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

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Author: Ute Kehlise  
Image source: Linde AG, Dieter Klein/laif



*Searing heat: The HEF process significantly improves efficiency and reduces environmental impact in cast iron fabrication (left). This robust metal is invaluable in drinking water pipelines in particular (above).*



*First responders:  
Equipped with  
medical gases.*



*Pharmaceutical product:  
Medical gases are applied  
during operational  
procedures.*

## *Vast portfolio of healthcare solutions*

# *AT THE PATIENT'S SIDE*

Supplying patients with medical gases comes with great responsibilities. Oxygen masks are often the patient's lifeline. Linde Healthcare provides solutions extending beyond the supply of medical gases.

In order to live, we have to breathe. Most of the time, we don't even notice we are doing it. But if our respiratory system is somehow compromised, we suddenly become all too aware of this vital function. And that is when Linde Healthcare comes into the picture. Linde Healthcare has vast expertise in the benefits of various respiratory therapies for patients of all ages. The company supplies, for instance, inhalational analgesic gas mixtures for pain relief during short surgical procedures. It also supplies medical oxygen to patients with respiratory conditions such as chronic obstructive pulmonary disease (COPD). In many cases, however, patients and medical professionals like doctors, therapists and nursing staff need more than "just" the medical gases.

"We support all players along the entire care chain from accident and emergency services through local General Practitioner and specialist practices to critical hospital and follow-up rehab care, even reach-

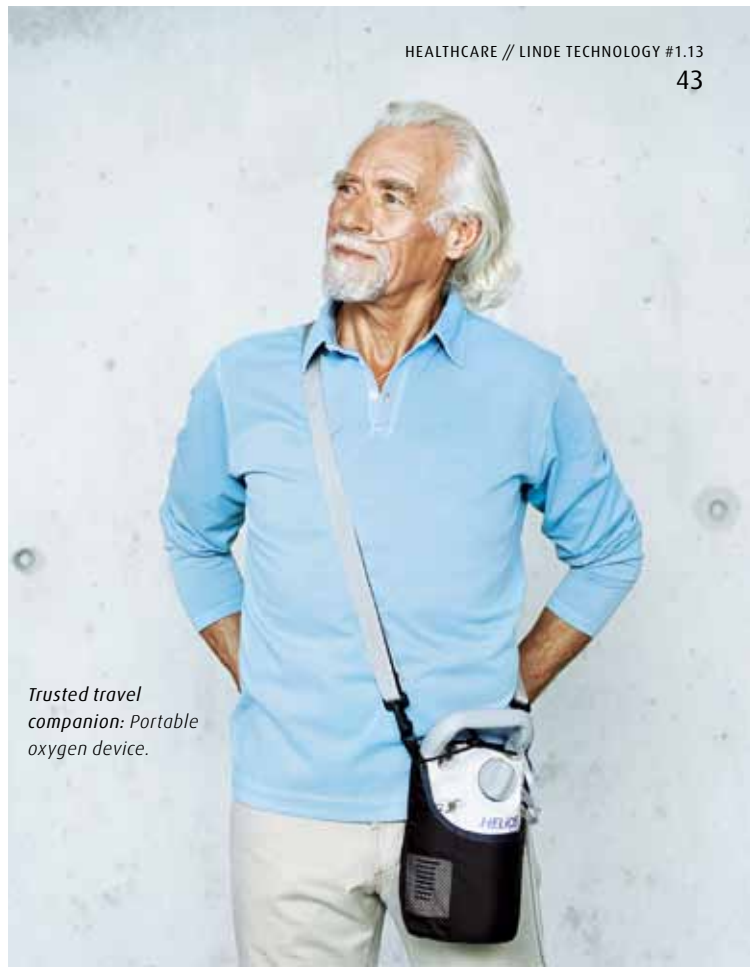
ing into the patient's own home with long-term oxygen therapies," explains Kenth Drott, Head of Hospital Care at Linde Healthcare. Linde Healthcare experts also advise patients on the devices best suited to their needs – a service that large hospitals in particular appreciate. "As doctors, we have to be sure that the gases we use are of the highest quality and purity," states Dr Francisco López, Head of the Clínicas Pichincha hospital in Quito, Ecuador. "Equally important, however, is the quality of the gas supply equipment and delivery devices."

Linde Healthcare offers end-to-end medical gas management solutions under its QI (Quality Improvement) brand. In addition, medical staff have to be trained to handle the gases correctly. This is why QI looks at the customers' entire medical gas system and process landscape. With its broad QI portfolio, Linde Healthcare thus helps customers to meet the considerable challenges of compliance and safety in today's

*Sustaining life:  
REMEO® centres specialise on  
long-term ventilation and weaning  
of ventilator-dependent patients.*



*Trusted travel  
companion: Portable  
oxygen device.*



healthcare environment. Linde Healthcare can provide balanced insights and flexible tools to improve safety, efficiency and coordination of medical gases throughout hospital facilities. This holistic approach resonates among customers. “For us, Linde Healthcare is more than just a supplier – the company is a reliable partner,” confirms López. Linde Healthcare has been working in this field for a long time now and the experts know, for example, that delays and bottlenecks are not an option, especially in emergencies. Linde consultants get inside the hospital to truly understand customer needs and the activities that are involved in dealing with medical gases. And based on that knowledge, they develop customer-focused solutions to ensure those needs are met.

Linde Healthcare focuses on all patients suffering from respiratory insufficiency. COPD patients, for example, are usually able to breathe independently for the foreseeable future and only need a supplementary stream of oxygen. Patients suffering from muscular dystrophy, multiple sclerosis or amyotrophic lateral sclerosis often do not have the power to expand their rib cages and create the negative pressure required to inhale and exhale. These patients often require mechanical ventilation based on positive pressure from an early age onwards. In many cases, accident victims can be weaned off long-term ventilatory equipment as they recover. This process often lasts several weeks. To bridge this gap, Linde Healthcare is setting up REMEO® centres across the globe, creating an environment where patients and families can prepare for a home-coming.

Oxygen therapy patients can also rely on Linde Healthcare for various support services beyond a clinical setting. “In the UK, for example, we have established a new rehabilitation offering that improves quality of life for people suffering from COPD,” explains Heike Thiele, Head of Homecare at Linde Healthcare. Thus an eight-week practical and education programme has been developed that gives patients the opportunity to meet other people affected by the disease, play sports together and get tips on the correct diet. “This reduces the risk of another hospital admission,” believes Thiele. “Oxygen therapy returns the freedom of mobility to many patients and, above all, increases their confidence.”

To increase quality of life for patients, Linde Healthcare delivers liquid oxygen or concentrators wherever they are needed – be that the sports hall of a rehab centre, an intensive care unit or an ambulance. “No matter where or how we are engaged, the safety of patients, doctors and nursing staff is always our number one priority,” emphasises Drott. He and his colleagues know that medical gases are a crucial lifeline for patients and a ticket back to the independence they once knew.

**LINK:**

[www.linde-healthcare.com](http://www.linde-healthcare.com)

*Dr Christian Wojczewski, Head of Global  
Business Unit Healthcare, Linde AG*



## *Interview*

# *“WE NEED A HOLISTIC VIEW OF HEALTHCARE”*

Dr Christian Wojczewski, Head of Global Business Unit Healthcare at Linde AG, explains how the company is positioning its healthcare offering, spanning medical gases, end-to-end services, medical devices and medical care, in this growth market driven by changing demographics.

### ↳ HOW DOES THE MEDICAL GAS BUSINESS DIFFER FROM THE INDUSTRIAL GAS SECTOR?

The most important difference is the patient. Our medical gases are in direct daily therapeutic contact with people of all ages, from newborns to long-term ventilated patients. Often, these therapies mean the difference between life and death for a patient. This has far-reaching consequences for our products, our services and our work. For instance, we must apply to the health authorities for marketing authorisation (MA) before placing a medical product on the market. Once the product has been launched, ongoing inspections and pharmacovigilance studies ensure compliance with standards such as Good Manufacturing Practice (GMP). Reliability is essential. In a medical emergency, one hundred

percent quality is the only option. Doctors and nurses count on us. We are always aware of this responsibility.

### ↳ SO LINDE HEALTHCARE’S WORK EXTENDS FAR BEYOND THE SIMPLE DELIVERY OF MEDICAL GASES?

Yes of course. We offer a whole range of services and therapies to healthcare professionals and directly to patients. For instance, we look after all the practicalities involved in supplying a hospital with medical gases – such as monitoring and maintaining pipelines. But we also train medical staff on how to safely handle medical gases and ensure they are delivered correctly to meet the therapeutic needs of the patient. On the homecare front, patients who require oxygen therapy or any other respiratory therapy for disorders such

as sleep apnoea can also rely on us. We help them choose the best device and equipment for their therapy needs, provide training on correct usage and deliver the medical gases. We also advise on lifestyle choices including nutrition and proper exercise. And we aim to further develop our medical skills in the future and evolve from a pure gases supplier to a healthcare partner for end-to-end solutions.

#### ↳ CAN YOU TELL US ABOUT LINDE HEALTHCARE'S INNOVATIONS?

We are concentrating on developing new products, devices and services along our Hospital and Homecare business. Our INOmax® mixture, for example, was the first medical gas to be approved as a drug to treat pulmonary hypertension in neonates by the European Medicines Agency (EMA) back in 2001. In March 2011, EMA approved INOmax® for an additional indication, namely for peri- and post-cardiac surgery. SEDARA® is a nitrous oxide blending device approved by the Federal Food and Drug Administration (FDA) and launched in the United States. Recently, we developed an innovative mobile cylinder solution known as the Linde Integrated Valve (LIV®), which is extremely user-friendly and ensures a high level of safety for doctors, nurses and patients. Our QI Medical Gas Services portfolio is another innovation highlight. It includes audits and technical maintenance of gas supply in hospitals. We also offer cryobanks for freezing biological tissue. And our REMEO® care concept for long-term ventilated patients is opening up an entirely new business model for Linde Healthcare, offering an integrated care path for patients requiring ventilation outside the acute care setting and at home.

#### ↳ WHAT TRENDS ARE CURRENTLY SHAPING THE HEALTHCARE SECTOR?

The health sector is primarily driven by demographic changes. The number of elderly people is increasing steadily and this is fuelling demand for age-appropriate care. Diagnostic methods and therapies for chronic illnesses have also developed significantly, opening up many new business opportunities for Linde Healthcare. At the same time, hospital operators are under massive pressure to make their services more efficient and cost effective – in an increasingly competitive and tender-driven climate, especially in Western markets. We are certainly feeling the effects of this. In addition, many hospitals are placing more focus on acute care. However, not every patient can return home immediately.

#### ↳ AND WHAT IMPACT DOES THIS GROWING MARKET PRESSURE HAVE ON LINDE HEALTHCARE SPECIFICALLY?

We are seeing a growing number of customers beyond the traditional hospital business – and these customers

often have different needs. Consequently, many healthcare services are now being provided beyond the hospital setting. At the same time, we are seeing an increasing need for bridging solutions such as pulmonary rehabilitation services, care centres and outpatient clinics. Our REMEO® centres align with this trend by caring for patients outside the hospital setting while still ensuring the highest standards of medical treatment. Also, outpatient surgery centres are on the rise. They offer 'day surgery' for procedures that used to be performed solely in a hospital. All of these new links in the care continuum mean that we have to adopt a more holistic view of patient treatment, overall, one that takes the complete patient care path into consideration. New developments in areas such as telehealth for instance provide patients with much greater freedom, enabling them to carry on living at home, safe in the knowledge that key statistics such as blood pressure and oxygen saturation are being monitored by healthcare professionals.

#### ↳ WHAT GOALS HAVE YOU SET YOURSELF IN THIS DYNAMIC ENVIRONMENT?

We want to further strengthen our position in the major healthcare regions of Europe and the US over the coming years and aim – through quality leadership – to become the partner of choice for patients, payors and healthcare professionals, whether they be general practitioners, nurses or doctors working in hospitals, day clinics or in the rehabilitation area. Recent strategic acquisitions have given us a strong global footprint in the homecare market. The acquisition of Air Products' Continental European Homecare business brought more than 250,000 additional patients to Linde Healthcare. And the acquisition of US homecare company Lincare gives us an even bigger advance in what is by far the largest regional homecare market in the world. Today, Linde Healthcare serves more than 1.3 million patients globally. In fast-growing geographies, we are also aiming for a leading position. Here we are focusing on new markets, for example in the four BRIC countries Brazil, Russia, India and China. We are the world's number one provider of medical gases and complementary services. In addition, we are the world's largest respiratory homecare provider – and we intend to strengthen our position as we move forward.

#### LINK:

[www.linde-healthcare.com](http://www.linde-healthcare.com)

Linde Healthcare partners with doctors, patients and care-givers

# WORLD OF MEDICAL GASES

A healthy adult breathes in fresh air 20,000 times every day, mainly consisting of oxygen and nitrogen. But those are not the only gases which are important for the healthcare sector. Linde Healthcare ensures a safe, reliable supply of all medical gases and services – from hospitals and medical practices through rehabilitation and REMEO® centres right up to the home.

Samples stored in a CRYOBOX unit. Linde supplies turn key facilities for cryopreservation.

At the delivery ward a full-term woman inhales a gas mixture consisting of 50 percent nitrous oxide and 50 percent oxygen for pain relief.

Sleep apnoea patient in a sleep lab.

Inside the hospital REMEO® operates clinics focused on weaning and rehabilitation of ventilator-dependent patients.

Patient receives oxygen from a portable cylinder – equipped with the Linde's Integrated Valve (LIV®).

Magnetic resonance imaging (MRI) requires liquid helium from Linde to cool magnetic coils.

Operating theatre with wall outlets for medical oxygen (white), medical nitrous oxide (blue), medical air (black) and vacuum (yellow).

Linde's QI Services encompass on-site supply of liquid nitrogen for cryogenic freezing and storing of medical samples.

In control centre: Remote QI Monitoring of gas supply systems and QI Tracking for cylinder traceability within hospital.

QI Medical Gas Services support the entire medical gas supply chain – design, engineering, logistics, on-site management and administration.

Refilling of a medical oxygen tank.

QI Services cover facility management for medical gases and cryogenic solutions. The Linde Healthcare technician also looks after the cylinder storage while ensuring overall safety compliance of all gas-related installations.

QI Medair and QI Medvac provide services from design, supply and installation to full provision of on-site plants.

Linde experts train medical staff on the correct handling of medical gases. Tutorial videos show trainees how to use the mobile LIV® cylinder system.

First responders apply medical oxygen carried in an emergency rucksack.

A medical gas mixture consisting of 50 percent nitrous oxide and 50 percent oxygen is used in emergency settings for fast pain relief.

Ambulatory surgery unit: Doctors use medical carbon dioxide, during laparoscopy procedures to insufflate and elevate the abdominal wallout.

Physician checks a patient's breathing patterns using pulmonary function testing equipment.

Pre-terms in incubators in newborn intensive care unit. Inhaled nitric oxide, a medical gas for pulmonary hypertension, improves lung functionality.

Portable oxygen device helps patients with chronic obstructive pulmonary disorder to remain mobile.

Nurse gives an injured child a 50/50 medical gas mixture of nitrous oxide and oxygen to relieve pain.



A mobile cylinder with the Linde Integrated Valve (LIV®) comes with an in-built pressure regulator, which means it can be directly connected to a patient mask or a pressure outlet with the same specification as the wall outlets in the hospital.

50/50 medical gas mixture of nitrous oxide and oxygen for pain relief during a dental procedure.

A CPAP (Continuous Positive Airway Pressure) device helps sleep apnoea patients enjoy more restful nights and avoid risks of follow-on complications such as cardiovascular diseases.

Doctor receives medical update from a patient via telehealth functionality.

A patient receives advice on his therapy.

REMEO® centre specialising on long-term ventilation and weaning of ventilator-dependent patients.

A Linde Healthcare expert gives a patient nutritional advice.

In a community centre Linde Healthcare physiotherapists show patients with pulmonary disorders how to exercise at a rehab workshop.

Therapist performing pulmonary rehabilitation.

Professional care for ventilator-dependent patients in their homes with 24-hours nursing availability and equipment management.

A patient reliant on oxygen therapy transmits medical data to his doctor using a telehealth device.

This illustration is a simplified representation. It makes no claim to be complete.



*Liquefied natural gas (LNG) for Hamburg's ships:  
The shipping industry is under pressure to improve its environmental performance. LNG is an effective way of reducing harmful emissions.*





## LNG terminals: Maritime infrastructure for liquefied natural gas

# CLEAN SAILING

Ports act as essential hubs in the global economy. But the rise in maritime traffic is taking a toll on the quality of air in ports and out at sea. From 2015 onwards, thresholds governing harmful emissions are being tightened in a bid to clear the air. All of which is driving interest in more environmentally sound fuels. Liquefied natural gas (LNG) is the perfect fit, more than complying with the upcoming regulations. To enable its widespread adoption, Linde is working full steam ahead to create a network of LNG terminals in Europe.

Image source: Frank Siemens/laif  
Author: Andrea Hoferichter



If you take a walk through the Altenwerder Container Terminal in the Port of Hamburg, you will not come across many people. But you will see a lot of machinery. And cranes as far as the eye can see. These remote-controlled giants lift steel containers weighing several tonnes from ships and load them onto auto-pilot trucks. The city of Hamburg is home to one of Europe's biggest ports. It handles over 130 million tonnes of goods every year from the 10,000-plus ships that dock there. All of these ships run on fuels that release a lot of emissions. "Shipping is actually a very environmentally friendly form of transport based on emissions per tonne-kilometre," explains Frank Horch, Economic Senator of the government of Hamburg. "Environmental regulations, however, are also being tightened in maritime transport." The International Maritime Organisation (IMO) has its sights firmly set on sulfur dioxide emissions in particular, and much tighter regulations are on the horizon. In Emission Control Areas (ECA), which include the North Sea, the Baltic Sea and a stretch off the US coast, a new threshold of just 0.1 percent will apply as of January 2015. From 2020 onwards, the global ceiling

will be gradually reduced from today's 3.5 percent to 0.5 percent. In addition, nitrogen oxide limits for new ships are going to be drastically reduced from 2016 onwards.

"This may seem tough at first glance. But it's actually quite lenient compared for instance with road traffic regulations, where sulfur dioxide emissions have been limited to 0.001 percent for decades," explains Dr Thomas Tork, Senior Business Development Manager Merchant LNG at Linde. The IMO has good reasons for toughening its stance on emissions. After all, they are not only a threat to water and soil, but can also trigger respiratory and cardiovascular health issues. Researchers at Denmark's Centre for Energy, Environment and Health calculated that shipping accounts for seven percent of the total healthcare spend on emission-related diseases

## 2020 ONWARDS: STRICTER EMIS- SION THRESHOLDS WORLDWIDE.

across Europe. That budget amounted to around EUR 60 billion in the year 2000. "The shipping industry needs to start thinking about switching to low-emission fuels now," adds Tork. Liquefied natural gas (LNG) is a promising alternative. It is largely made up of methane, which mainly releases water and carbon dioxide when combusted.

Linde and the company Bomin, a subsidiary of Marquard & Bahls, only recently joined forces to form the joint venture Bomin Linde LNG GmbH & Co. KG. The company plans to actively drive the transition to LNG, also building the infrastructure required to support such a move. Until now, shipping companies had cited the lack of fuelling facilities as a major hurdle. So it seems fitting that Bomin Linde's first project entails building an LNG terminal in the Port of Hamburg. "Linde and the Hamburg Port Authority have already showed in a feasibility study that the project is technically viable and that it also makes sound financial and environmental sense," continues Tork. In as little as two years, the Port of Hamburg could be home to several thousand tonnes of liquefied natural gas, stored in white steel towers, each as tall as a house, at a temperature of minus 161 degrees Celsius. This frosty temperature is required to keep the gas in liquid form. Bunker barges equipped with Linde technology will then transport LNG to the ships docked at the port, allowing them to refuel.

LNG as a maritime fuel will allow shipping companies to come well under the limits soon to be imposed by the IMO. When combusted, LNG produces almost no sulfur dioxide and around 80 percent fewer nitrogen oxides. In addition, it does not emit any heavy metals or soot particles. LNG-powered ships are also more energy efficient and climate friendly, emitting up to 25 percent less carbon dioxide. Last but not least, natural gas engines are quieter, something that sailors

and port residents will certainly appreciate. It is true that ships running on low-sulfur marine gasoil (MGO) and vessels equipped with on-board fuel purification and emissions treatment units will also meet the upcoming regulations. Tork maintains, however, that these solutions are nowhere near as clean as LNG and significantly more complex. Nor do they match LNG if you look at total cost of ownership. "Admittedly the upfront cost of adapting a ship to run on LNG today is higher than a comparable emissions treatment solution for conventional ships," explains Tork. "In the long-term, however, the conversion pays off as LNG is the cheaper option," he adds.

The LNG required for the new terminal at the Port of Hamburg is to be mainly sourced from large, international LNG import terminals located in ports like Rotterdam and Zeebrugge. Linde's mid-scale-terminal in Nynäshamn, Sweden, could act as a distribution hub for parts of the Baltic Sea. With a capacity of 20,000 cubic metres, the Nynäshamn terminal was built and is operated by Linde Group members Cryo AB and AGA AB. "Together with Bomin, we cover the entire value chain – offering liquid gas, stores, cryogenic technologies and bunker services from a single source," emphasises Tork.

The Port of Hamburg project is just the first milestone on the journey towards widespread maritime adoption of LNG. Bomin Linde is already planning further terminals in other strategic ports such as Bremerhaven, Kiel and Rotterdam. The LNG terminal currently being

## DEMAND FOR LNG EXPECTED TO RISE TO FIVE MILLION TONNES BY 2020.



*Ships refuel: Coastline terminals store liquid gas in giant tanks and distribute it from there around the world (top). The distribution hubs are supplied with LNG from liquefaction facilities such as the Stavanger station (above). The Port of Hamburg (right) could be equipped with an LNG infrastructure in as little as two years – using technology supplied by Linde.*



built in Lysekil on the western Swedish coast for the Norwegian company Skangass is close to completion. That project is also being managed by Cryo AB engineers. It is set to go on stream in 2013. "Initially, the terminal will mainly supply a refinery and local industry. However, we expect the maritime sector to become an extremely important area for us as we move forward," says Lars Persson from Cryo AB in Gothenburg.

### LNG for port service trucks

Olof Källgren, Head of Merchant LNG at Linde, believes that demand for LNG as a maritime fuel will rise rapidly. "The North Sea, Baltic Sea and US coastal regions will be leading the way here due to the particularly strict regulations that apply in those geographies," states the Linde expert. A study carried out by the Danish Maritime Authority confirms his confidence. The report estimates that demand for LNG in the maritime sector in the North Sea, Baltic Sea and English Channel could increase by a factor of fifty by 2020. This means a rise from today's figure of 100,000 tonnes to as much as five million tonnes. By 2030, demand could grow even further, up to eight million tonnes. If these forecasts prove accurate, over half of all ships would be powered by this cryogenically liquefied fuel at that point in the future. The Viking Grace ferry is a prime example of LNG's success at sea. The largest LNG-powered ferry in the world has been operating between Stockholm and Turku in Finland since January 2013, transporting up to 2,800 passengers as well as cars and trucks. The ship's liquefied natural gas comes from the terminal in Nynäshamn, transported by a bunker barge equipped with Linde technology.

Meanwhile, cleaning up the air in major port cities calls for more than just switching shipping vessels over to LNG. "One third of pollutant concentrations in the air over Hamburg's port, for instance, stems from trucks, shunting locomotives and cargo handling equipment – making them almost as big an issue as ships," says Tork. And so Linde plans to flank the LNG terminal with an LNG fuelling station at the port, thus also giving land-based vehicles the option of cleaner fuel.

Regardless of whether it is serving traffic at sea or on land, the new LNG infrastructure provides a reliable alternative to current fuel models according to Tork. He also says it is even compatible with regenerative fuels. "Our LNG systems and technologies can also be used for biomethane – which is biogas that has been treated," explains Linde expert Tork. Linde is a pioneer in this area too. The company operates a plant that liquefies methane recovered from landfill gas in collaboration with the refuse specialist Waste Management in Altamont, California. This proves that clean fuel can also be generated from waste. In the coming years, this fuel will probably be able to power entire fleets of trucks and possibly also benefit the shipping industry.

LINK:

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

### SHORT INTERVIEW

## "IT'S USEFUL TO KNOW WHERE LNG TERMINALS WILL BE BUILT"



*Linde Technology spoke with Dr Pierre Sames, head of research and development of rules and regulations at Germanischer Lloyd in Hamburg, about the future of liquefied natural gas as a maritime fuel.*

#### ↳ HOW DIFFICULT IS IT TO CONVERT A SHIP TO LNG?

Generally speaking, all types of ship can use liquefied natural gas as a fuel. The process is the same, whether you're building a new ship or refitting an existing vessel: You have to install special LNG tanks, drive mechanisms and supply systems. Most engines in ships today can be adapted for LNG. Some would have to be completely replaced, however. Retrofitting therefore requires additional investments. The tanks are the most expensive factor. Which is why in the coming years, LNG will primarily be used to power ships that have shorter routes closer to coastlines.

#### ↳ WHAT ARE THE GREATEST CHALLENGES INVOLVED IN THIS TRANSITION?

At the moment, LNG is only available as a maritime fuel in Norway. It will take another one to two years before it is available in other northern European ports. Once this fuelling infrastructure is in place, more shipping companies will retrofit their fleets or order new vessels. Announcing the locations of new terminals is a big help here, as it shows shipping companies that the energy sector is willing to take the first step and provide the requisite infrastructure to support rising demand.

#### ↳ WHAT DOES LNG MEAN FOR GERMANISCHER LLOYD?

Germanischer Lloyd supported the conversion process for the Bit Viking tanker. The ship has been running on LNG since autumn 2011. And we have further orders for LNG-powered ships and are also involved in many supporting projects for ship systems, ship designs and fuelling concepts. Together with MAN, we carried out a cost/benefit study on LNG-powered container ships. What we found is that the difference in price between crude oil and LNG as well as the time that a ship spends in Emission Control Areas (ECA) are the most important factors that influence return on investment.

## *Hypoxic environment for athletes*

# SWIMMING TO THE TOP

Training at altitude is a good way of building fitness. Now, swimmers at sea level can also use the altitude factor – thanks to Linde’s gas technology.

The air in the Pyrenees is thin. Air pressure – and thus oxygen content – drops with every metre. But that is exactly what makes mountainous terrain so appealing for athletes. Altitude training at two to three thousand metres is a great way to boost performance. This altitude factor has been well documented since the 1968 Olympic Games in Mexico City, which were held at an altitude of 2,240 metres. One record after another was broken in 1968, and altitude training was born. Competitors who spent longer periods at the 1968 Games and who trained at altitude showed improved athletic performance when they returned to sea level. This is because the body compensates for the oxygen deficiency by making more red blood cells which, in turn, transport life-sustaining oxygen to the muscle cells. And the increase in red blood cells improves the athlete’s performance. This form of training in oxygen-reduced air is also known as hypoxic training.

Professional swimmers in the German Swimming Association no longer have to trek up the Pyrenees or Sierra Nevada mountain ranges to benefit from the altitude effect. Linde’s experts have instead brought the mountains to Brandenburg’s Olympic training base in eastern Germany. Brandenburg’s training pool has been equipped with a hypoxia unit since April 2012. It works by reducing the oxygen content in the air without dropping the pressure. Altitude training at sea-level pressure is referred to as normobaric hypoxic training. “Experts maintain that oxygen-reduced training at normal pressure feels more natural to athletes than hypobaric training – which is at lower air pressures,” explains Johann Kaltenecker from Market Development Chemistry at Linde’s Gases Division in Unterschleissheim. “And there are indications that lower pressure induces altitude sickness more quickly,” continues the Linde expert. And so the hypoxia team modified the composition of the air at the facility in Potsdam, the capital city of Brandenburg. A dosing system mixes fresh air with additional nitrogen supplied by Linde before injecting the gas mixture into the pool house. This lowers the oxygen concentration, normally set at 21 percent. According to Kaltenecker: “At a simulated height of 4,500 metres, which the Potsdam pool is limited to for safety reasons, the oxygen concentration drops to twelve percent.” It’s as if the Potsdam swimmers were training at the peak of the Matterhorn mountain.

## SWIMMING POOL AT MATTERHORN ALTITUDE.

In addition to the nitrogen gas, Linde also supplies the entire process technology – including the complex measurement, monitoring and control systems. Precision sensors continually measure the temperature, air pressure, air humidity, oxygen level and carbon dioxide content. The entire atmosphere in the 3,000 cubic metres pool house is replaced eight to ten times every hour. “This maintains air quality under challenging circumstances while still simulating a steady altitude – or a steady air composition,” explains Jörg Steinke, Application Engineer and Product Manager for Hypoxia at Linde. The swimming facilities have high humidity and chlorine values, which makes it tricky for the measurement and control technology to maintain a stable ambient environment. One of the biggest challenges facing Linde’s engineers was ensuring compliance with the extremely strict air quality and hygiene regulations that apply to swimming pools. “Our hypoxia solution offers almost one hundred percent protection against bacteria such as legionella,” concludes the Linde expert.

Easy-to-use software means that the high-performance swimmers can choose their training altitude themselves. “As far as we can tell, the technology we have installed in Potsdam is unique in Europe,” says Steinke. The next Olympic Games in Rio de Janeiro are still three years away, but the German swim team is already training its way to the top and hopes to bring home its fair share of medals.

Author: Kathrin Wildemann  
Image source: Tim Tadder/Corbis



LINK:

[www.high-altitude-medicine.com](http://www.high-altitude-medicine.com)

CLEAN  
TECHNOLOGY  
BY LINDE

-45,000  
tonnes of CO<sub>2</sub>.



Producing LNG from organic feedstock: Landfill waste can be turned into valuable biofuel! We teamed up with Waste Management Inc. in California to build the world's largest conversion plant for landfill gas. Waste Management's refuse trucks now run on biofuel, saving around 20 million litres of gasoline or diesel – or 45,000 tonnes of CO<sub>2</sub> – every year. Just another example of how "Clean Technology" from Linde is making a difference to the world.

For more information, please visit [www.linde.com/cleantechnology](http://www.linde.com/cleantechnology)

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