LINDE TECHNOLOGY

Issue
#2.
08

FEATURED TOPIC: ENERGY MIX OF THE FUTURE

FILL UP NATURALLY
Second-generation biofuel

ON THE MOVE WITH H_2
Hydrogen infrastructure in Hamburg

SOLAR POWER AT NIGHT
Storage systems for solar heat

SPACE
Refrigerator for the ISS

MEDICINE
Gases for pain relief

PARTICLE PHYSICS
CERN's 'World Machine'

EFFICIENT CLIMATE PROTECTION

ENERGY MIX OF THE FUTURE

THE LINDE GROUP

#2.
08

Imprint

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Mobility requires energy: Oil supplies may be dwindling but we still want to progress. Fuels such as hydrogen, bioethanol or methane could be an ecologically and economically sensible alternative.

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EDITORIAL

Dear Readers,

Climate protection is one of the key issues of our time. Although we are currently preoccupied with the financial crisis and the world economy, we mustn't lose sight of our endeavours concerning sustainable energy production and the reduction of CO_2 emissions in the future. Because it is only with such efforts that we can make it possible for future generations to enjoy high living standards in an intact environment.

The featured topic of this issue therefore addresses a particularly important aspect of climate protection: energy production. Because a rapidly growing world population as well as dynamic economic development in emerging markets – in Asia, for example – require more and more fuels, electricity and heating energy. And, as is often the case, the solution does not lie in one single technology or resource that's suitable to all regions and requirements. In fact, future energy demands can only be met by a combination of different kinds of energy. Because only a well-balanced mixture of energy sources can sensibly secure supplies both ecologically and economically.

Engineers from the Linde Group are using innovative technology that provides a sustainable energy supply while simultaneously boasting a low carbon balance. We are, for instance, developing design concepts for the production of second-generation biofuels. Since they are based exclusively on agricultural plant waste, they present no threat to food sources. Our specialists are also developing trailblazing technologies for the efficient storage of solar power and the use of biogas as a fuel. Over and above that, we are also pressing further ahead with hydrogen technology such that we are facilitating the development of a comprehensive infrastructure that will provide the cars, busses, ships and airport vehicles of a metropolitan area with the fuel of the future. But hydrogen is also a key element in the production of low-sulphur fuels. For example, the gas is used in the large, North American refineries to purify oil from Canada's gigantic bitumen deposits.

These examples prove that we are rising to the great challenges of our time by contributing innovative technologies and concepts to provide solutions for a sustainable future energy mix.

I hope you enjoy reading this issue.

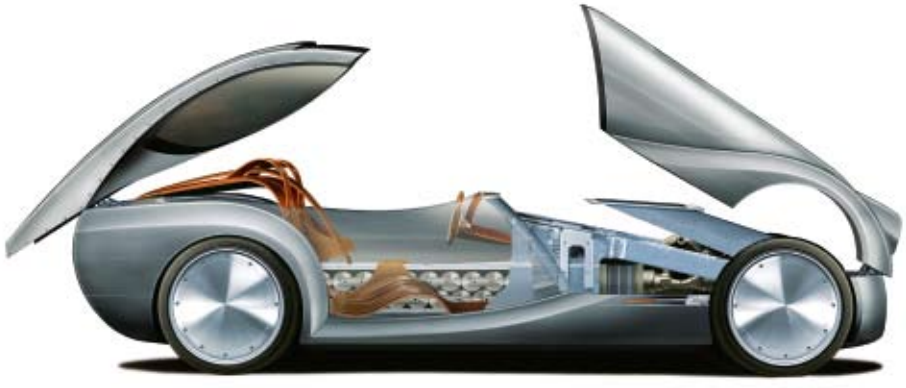
Dr Aldo Belloni
Member of the Executive Board of Linde AG

ENERGY MIX OF THE FUTURE

ENERGY MIX OF THE FUTURE

The whole world needs energy – and a rapidly growing world population requires more and more of it. A well-balanced combination of energy sources can sensibly secure future supplies in both an ecological and economical way.

Image source: Morgan Motor Company



Classic meets high-tech: *The Morgan 'LIFECar' runs on hydrogen – the fuel cell under the bonnet takes this sports-car from zero to 100 km/h in less than seven seconds.*

HYDROGEN FOR CLASSIC RACER

Linde fuelling system supplies Morgan sports-car

The British car-maker, Morgan, stands primarily for modest roadsters with wooden load-bearing parts. With its new 'LIFECar' model, the company has now combined its classic design with the very latest technology. Under the LIFECar's distinctive Morgan bonnet is no ordinary combustion engine. Instead there's a fuel cell that supplies four electric motors with power – one for each wheel. The car also features capacitors, which store the braking power, in order to reuse it during acceleration. This way the fuel cell remains relatively small, with a 22 kW capacity – as opposed to comparable systems that require around 85 kilowatts.

Another advantage is that the Morgan model only weighs about 600 kilograms. This allows it to accelerate from zero to 100 km/h in less than seven seconds, and to reach a maximum speed of almost 140 km per hour. This lightweight's chassis consists of aluminium placed over Morgan's typical ash-wood frame. The sports classic's complete hydrogen and atmospheric oxygen-consuming fuelling system was designed by engineers at Linde. The designer car can cover a distance of about 400 kilometres on one charging. Its design concept comes from RiverSimple; the electric drives were developed at Oxford University; and the fuel cell technology was contributed by QinetiQ.

LINKS:

www.morgan-motor.co.uk/lifecar/lifecar.html
www.linde-gas.at/produkte/wasserstoff/wasserstoff.html
www.riversimple.com
www.linde.com/hydrogen

NEWS

ROMANIA:

GAS SUPPLIES FOR STEEL PRODUCTION

The steel industry is flourishing worldwide. Prices are increasing due to the higher cost of raw materials and because of growing demand from newly industrialising countries. The primary driving forces behind the steel boom are countries such as China, India, Russia and Brazil, as well as Eastern European countries, which require more and more of this basic material for car and machinery production. According to the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen), world steel production will increase to 1.47 billion tonnes in 2009. The world's largest steel maker is ArcelorMittal. The corporation produces about 110 million tonnes annually – that's about ten percent of the steel produced worldwide. The Linde Group has a long-term industrial gases supply contract with the market leader. The agreement comprises the building of a new air separation system at ArcelorMittal's Galati site in Romania, as well as the modernisation of the systems already in place there. The total investment adds up to a total of more than 100 million euros. "This contract secures the deal to cooperate long-term with one of our most important clients and confirms our leading market position in Eastern Europe", said Dr Aldo Belloni, member of the Executive Board of Linde AG.

As soon as the Linde Group took over in mid-2008, they began taking measures to improve the existing gas production plants, as well as building the new air separator. The new system will produce 2,000 tonnes of oxygen daily, as well as smaller amounts of nitrogen and argon for the ArcelorMittal steelworks on site.

BELGIUM:

BRUSSELS RUNS ON HYDROGEN

Thanks to technology from Linde, it's now possible to fill up with hydrogen in Brussels. The oil company, Total, opened Belgium's first hydrogen fuel station in the capital, at an inauguration supported by the Flemish Ministry for the Economy, Enterprise, Science, Innovation and Foreign Trade. Both the storage technology for liquid hydrogen, or LH_2, and the fuelling system were developed by Linde. The Total filling station, located on the E 19 freeway that leads to Paris, was built as part of a partnership between BMW and Total. "As pioneers of hydrogen technology we have a certain responsibility to promote the implementation of a sustainable, hydrogen-based fuel for vehicles", said Dr Aldo Belloni, member of the Executive Board of Linde AG. "Network partners from the political, scientific and the economic spheres all have an important role to play in achieving this. Together we can build the infrastructure for such seminal energy sources onwards and upwards." And Miguel del Marmol, Managing Director of TOTAL BELGIUM added, "With this new filling station we exemplify that it's possible to integrate hydrogen very well into conventional petrol stations."

UNITED ARAB EMIRATES:

AIR SEPARATOR FOR NATURAL GAS IN ABU DHABI

When it comes to natural gas reserves, the United Arab Emirates rank fifth in the world after Russia, Iran, Qatar and Saudi Arabia. It is estimated that the kingdom owns gas resources totalling to approximately six quintillion cubic metres. That's about 3.5 percent of the world's reserves and should last for at least the next 150 years. About 95 percent of the reserves are to be found exclusively in Abu Dhabi.

Nitrogen is required for natural gas extraction. It's injected into the onshore natural gas condensate deposits. The Linde Group and the Abu Dhabi National Oil Corporation (ADNOC) now want to build two large air separation plants in Abu Dhabi via their joint venture, Elixier. ADNOC controls both the onshore and offshore oil, gas and petrochemical trade in Abu Dhabi and has access to about 90 percent of Abu Dhabi's crude oil and natural gas reserves. Linde owns 49 percent of Elixier while the oil company owns 51 percent of the joint venture (legal name: ADNOC Linde Industrial Gases Company Ltd.), which was founded in December 2007. In total, about 800 million US dollars is being invested in the new plants. As of the end of 2010, they will be connected to the local gas supply and pipeline network, making nitrogen available for natural gas extraction in the city of Habshan. The two plants have a combined total capacity of 670,000 standard cubic metres (scm) of nitrogen per hour at their disposal. "With our expertise in more efficient fuel production in the Persian Gulf, we are making another important contribution toward solving the energy issue", said Dr Aldo Belloni, member of the Executive Board of Linde AG. "This project adds a new quality to our presence in the Middle East. At the same time, we are consolidating our leading position in this compelling, growing gas and engineering market."

The crude oil and natural gas industries form the United Arab Emirates' most important economic sector – in fact the country's prosperity is entirely based on these industries. But natural gas is not just an export success. Abu Dhabi's government has announced that by 2012, at least 20 percent of the kingdom's motor vehicles will have to run on natural gas. The first projects toward achieving this goal are due to begin soon.

CHINA:

FUEL PRODUCTION JOINT VENTURE

China is becoming more mobile and is therefore demanding more fuel. SINOPEC Fujian Petrochemical Company Limited (FPCL), a subsidiary of China Petroleum & Chemical Corporation (SINOPEC), is Linde's joint venture – founded for the purpose of supplying industrial gases long term. These gases should facilitate the processing of imported crude oil into petroleum products, such as low-sulphur fuels, light diesel oil and aviation fuel.

Around 100 million euros in investment is tied to the deal. The Fujian Linde-FPCL Gases Company Limited joint venture will be based at its headquarters in Quangang Petrochemical Industrial Park in Quanzhou, Fujian, producing and selling nitrogen, oxygen and argon there. Each of the two partners, FPCL and Linde Gas (Hong Kong) Limited, owns 50 percent of the new joint venture. Fujian Linde-FPCL Gases Company Limited is currently building two air separation plants in Quanzhou, each with a capacity of 40,000 scm of oxygen per hour. In future, these plants will primarily supply our main client, Fujian Integrated Refining and Ethylene Project (FREP) in Quangang with air gases via a pipeline. FREP represents one of China's largest domestic refinery and petrochemical projects between Chinese and foreign partners. The project is a joint venture between FPCL, ExxonMobil China Petroleum & Petrochemical Company Limited, and Saudi Aramco Sino Company Limited.

IONIC COMPRESSOR:

FUELLING SYSTEMS FOR NATURAL GAS AND BIOGAS

According to the International Energy Agency (IEA), up to two million vehicles will run on natural gas in 2020 in Germany alone. Today there are already seven million cars that run on gas worldwide. Leading the way are countries such as Argentina, Pakistan and Brazil, each with 1.5 million vehicles. Which makes it all the more important, that the volatile fuel is effectively transported to the fuel tank. For this purpose, Linde has developed innovative gas compressors. Linde has entered into a joint venture with the American company, Flowserve Corp., Irving, Texas, in order to press ahead with the marketing of the iKompressor™ fuelling system for natural gas and biogas in Europe. The iKompressor™ systems are based on ionic fluids – organic salts – that are in liquid form at the desired temperature. The gases are thus compressed at a steady (isothermal) temperature without the need for any solid compression pistons. The headquarters of the two firms' joint venture, Flowserve Compression Systems GmbH, will be located in Brunn am Gebirge – a suburb of Vienna, Austria – near Flowserve Austria's site. The iKompressor™ fuelling systems will be on offer in Germany, Austria and in bordering European Union countries. The company would like to deliver at least 70 of these innovative systems by 2009, thus supplying vehicles with natural gas and biogas.

GREAT BRITAIN:

AIR SEPARATOR FOR 80 MILLION EUROS

The Linde Group has signed a long-term industrial gases supply deal with the international steel producer, Corus – which belongs to Tata Steel. The agreement includes plans to build a new air separation plant at the Corus site in Scunthorpe, North Lincolnshire, UK, at a cost of about 80 million euros. The new air separation plant will have a capacity of 1,600 tonnes of oxygen a day, as well as smaller amounts of nitrogen, and will start operation in mid-2010. This will facilitate an increase in steel production at this production site. On top of this, the Linde investment is also intended to help modernise the existing air separation system, and to pay for a comprehensive extension of the pipeline system that supplies the steelworks.

PHOTOVOLTAICS:

GASES FOR THE SOLAR INDUSTRY

Linde Nippon Sanso (LNS), a Linde Group enterprise, has made an exclusive deal with Malibu GmbH & Co. KG in Bielefeld, making it the sole provider of all gases required for the manufacture of photovoltaic modules. Malibu will initially build a photovoltaic module production plant in Osterweddingen, Saxony-Anhalt, Germany, with an annual capacity of 40 megawatts. The solar plants are based on tandem solar cells that use thin-film technology, and are therefore especially efficient. As part of the deal, Linde will also supply a complete gas distribution network and a gas detection system. LNS will also take over the management of gases and chemicals on site. What is more, Linde and Malibu have also established a joint development programme for innovative gas technologies, which should help improve the efficiency of the solar cells, as well as increasing the plant's production output and profitability. Malibu is a joint venture between the energy corporation, E.ON, and Schüco – one of the largest providers of building envelopes worldwide. "Based on our development programme, we will make a point of further improving our gas technology, thereby contributing to cost reduction per watt in solar cell production", said Andreas Günther, President of Linde Nippon Sanso.

LINDE RECEIVES PRIME INVESTMENT STATUS:

REWARDED FOR SUSTAINABILITY

The rating agency, oekom research, has classified Linde AG as a particularly sustainable company. In its Corporate Responsibility Rating report, oekom research assesses the sustainability activities of around 1,000 listed companies worldwide. Linde is among the top-ranking companies in its field. This rating qualifies Linde's shares as an environmentally and socially ethical investment.

"Investing in sustainability-driven companies is about more than environmental and social responsibility", says Oliver Rüdel from oekom research, Senior Analyst responsible for the chemical industry. "Opting for a sustainable investment also makes sound financial sense. After all, resources are growing increasingly scarce, and social conflicts hinder economic development." Linde also received praise for its widespread promotion of sustainability, as was announced in its last corporate responsibility report. The assessment also cast a positive light on the fact that the takeover of BOC – a company that also meets high sustainability standards – went smoothly.

Linde had already entrusted the Sustainable Asset Management (SAM) Group from Zurich with the task of producing an analysis of how Linde can better measure its commitment to sustainability. They concluded that in principle, Linde has a high potential for becoming an exemplary company in the field of sustainability.

GERMANY:

HYDROGEN FOR THE CHEMICAL INDUSTRY

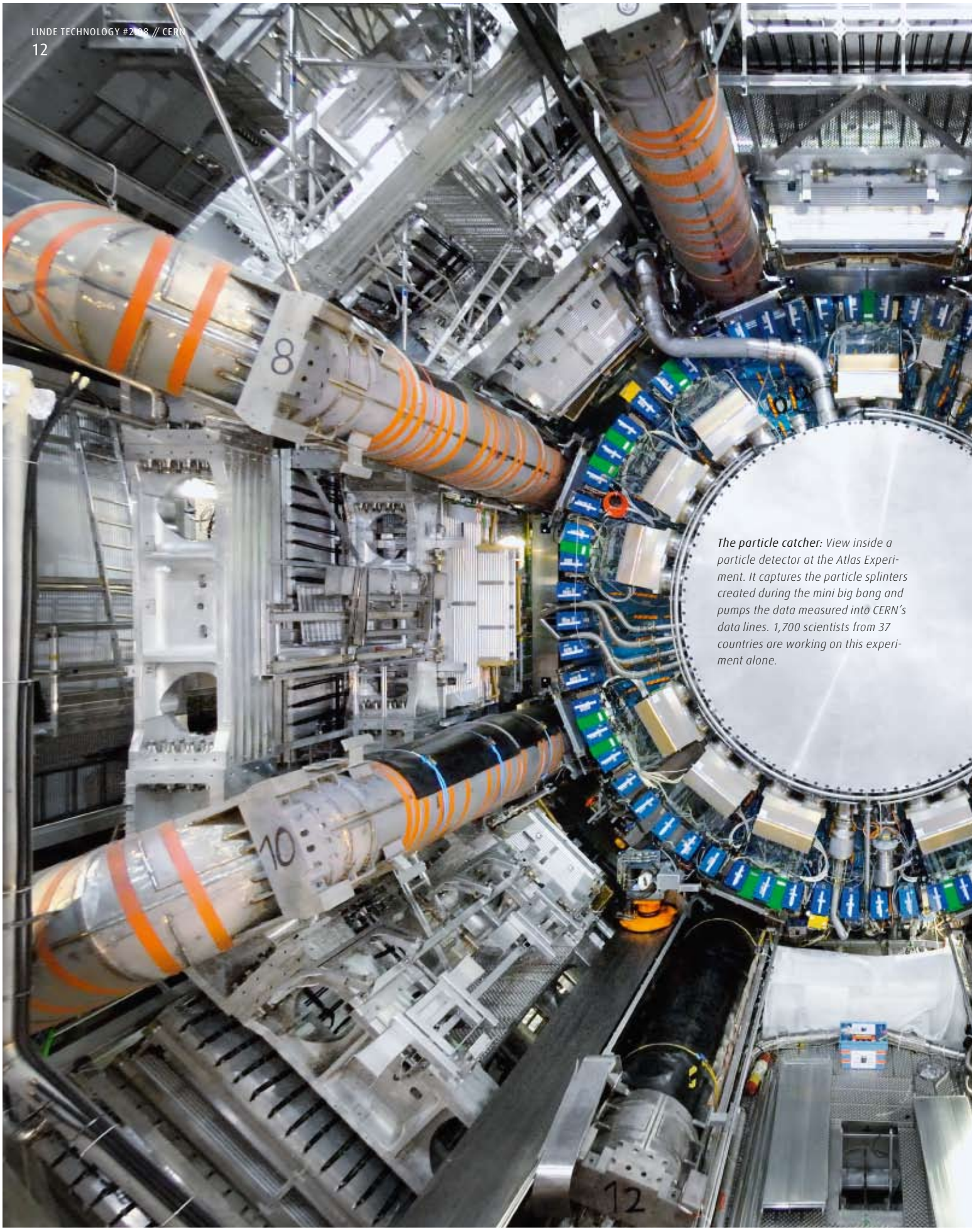
BASF, the chemical company, has contracted the Linde Group to build a large hydrogen plant at their Ludwigshafen site. Aside from the basic and detail engineering, and the purchase of materials, Linde will also be in charge of the installation and commissioning of the hydrogen plant, which will be ready to start operation in mid-September 2009. Thanks to the efficient implementation of Linde processing technology, not only will running costs be optimised, but emission levels reached will in part be much lower than the maximum allowed by environmental regulations. Linde had already built oxygen and ethylene production systems at BASF's Ludwigshafen site in the past. But the Linde hydrogen plant is the first of its kind for the chemical company. Linde has already constructed more than 200 systems of this type around the world. Once the new plant begins operation, the chemical company's on-site hydrogen capacity will increase by 50,000 scm per hour. The high-purity hydrogen will then be fed into BASF's own integrated network.

CLIMATE PROTECTION:

CO_2 CAPTURE IN COAL POWER PLANTS

In September 2008, the electricity company Vattenfall officially began operation of the world's first pilot plant for a 30-megawatts coal-fired power plant with CO_2 capture at its Schwarze Pumpe site. Carbon dioxide produced there will be almost totally isolated, liquefied and further processed so as to be stored underground long term. The Linde Group and Vattenfall Europe Technology Research GmbH, a subsidiary of the energy company, Vattenfall, have come to a comprehensive technological agreement on the capture of CO_2 in coal-fired power plants. The aim of the CO_2 cooperation is to test oxy-fuel combustion techniques for lignite and anthracite and to develop the technology for later use in larger power plants. The experiments will be carried out at the research installation of the now operational Vattenfall power plant located in Schwarze Pumpe in Lausitz, Brandenburg (Germany). Linde has built an air separator and a carbon dioxide liquefier for the pilot plant.

During the first experimental phase, and within the framework of their technological partnership, Linde is backing Vattenfall with comprehensive scientific and technical support until the end of 2011.



The particle catcher: *View inside a particle detector at the Atlas Experiment. It captures the particle splinters created during the mini big bang and pumps the data measured into CERN's data lines. 1,700 scientists from 37 countries are working on this experiment alone.*

REFRIGERATOR FOR THE BIG BANG

Linde Kryotechnik cools the world's most powerful accelerator at CERN

A new era in elementary particle physics has begun: physicists at CERN in Geneva are investigating new phenomena of matter, energy, space and time with a gigantic particle accelerator. To bring the tiny particles almost up to light speed, the 27 kilometre long LHC accelerator must be cooled to almost absolute zero – using Linde technology.

↑ *Image source: CERN, European Organization for Nuclear Research*
↓ *Author: Bernd Müller*

In the beginning was the Big Bang. Our universe was no bigger than a pin point and its temperature was an unimaginable 10^{32} degrees Celsius. Then it expanded nearly at the speed of light. It is this moment that physicists at the European Organization for Nuclear Research, CERN, want to recreate – with a gigantic particle accelerator for hadrons, the Large Hadron Collider (LHC). The tunnel ring is about 27 kilometres long and lies 100 meters below the Earth's surface near Geneva. In this tunnel scientists will fire proton packets against each other almost at light speed. During the collision, particles burst out of the hot energy flashes – a similar situation to right after the Big Bang. Physicists hope to discover new particles here, that are currently only known in theory. Four giant experiments – ALICE, ATLAS, CMS and LHCb, each as big as an apartment building, will detect particle traces. The LHC needs more than 120 Megawatts of power to operate, which would be enough to cover the electricity demands of the city of Geneva with its roughly 160,000 inhabitants.

The physicists' experiments will run in three phases: first, the protons have to reach a certain speed in the SPS (Super Proton Synchrotron), the smaller accelerator ring. Then they are directed into the big LHC ring with its 27 kilometre circumference. The protons race around this circuit over 11,000 times per second, finally accelerating almost to light speed. Last of all come the actual measurements: when the protons collide in the detectors. The LHC accelerates the protons up to an energy of seven trillion electron volts each. This corresponds to the temperature of the universe in the very first trillionth of a second after the Big Bang: more than 10 trillion degrees Celsius.

Only a few centimetres away from the hot proton beams it is bitterly cold. To keep the charged particles on their circuit, magnets are required with a field strength of more than eight tesla, 200,000 times as strong as the earth's magnetic field. Only superconducting electromagnets, where an electrical current flows without resistance, can create such enormous field strengths. That's because: the lower the temperature of the magnets, the stronger the magnetic field and the greater the deflection of the charged particles – which means the circuit's circumference is also smaller. "If we used normal conducting magnets, the LHC would need to have a circumference of 120 kilometres and would use 30 times as much energy", says Laurent Tavian, Chief Engineer for Cryogenics at CERN.

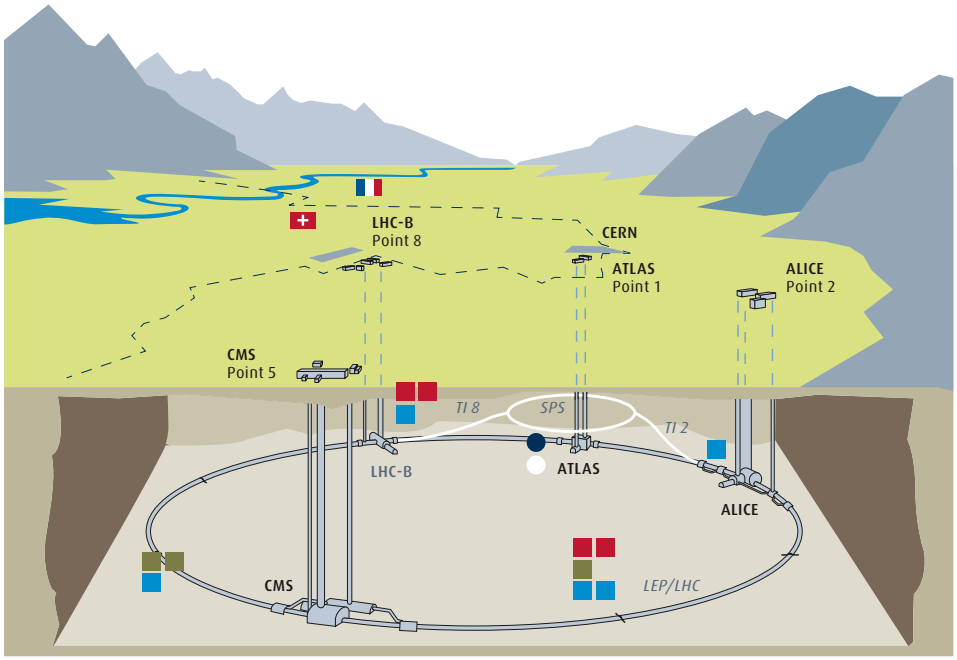
Proton crash at minus 271.3 degrees Celsius

To make the field as strong as possible and thus maximise the particle energy for a given ring size, the cryo-team at CERN cools the magnet coils down as close to absolute zero as possible. The operating temperature of the LHC: 1.8 Kelvin, or in other words, minus 271.3 degrees Celsius. "That is only possible with helium, the only substance that is a liquid at this temperature and not frozen", explains Andres Kündig, physicist and advisor for process technology at Linde Kryotechnik in Pfungen near Zurich. To cool the gigantic cold mass of 37,000 tonnes – the weight of all the magnets together – down to 80 Kelvin, requires 10,000 tonnes of liquid nitrogen. In addition, the Swiss researchers need 130 tonnes of helium for filling the accelerator. The LHC is not only the largest machine of all time – "it is also the biggest refrigerator in the world", according to Tavian. And this refrigeration machine is a technical masterpiece. The ring elements, each 15 metres long and more than a meter thick, shrink by several centimetres during cooling. Special buffers are needed to compensate – which is the only way to keep the system absolutely leak-proof.

To ensure that the temperature is the same everywhere around the long proton race track, a clever distribution network is necessary for the coolant: it begins its journey at five positions

EXTREMELY COLD IN THREE STAGES

To cool the Large Hadron Collider (LHC) in Geneva to ultra low temperatures, three phases are necessary:



The coloured dots show the number and location of the individual refrigeration systems by Linde.

■ *1st phase: gas purification and pre-cooling unit →*
Liquid nitrogen purifies and pre-cools a helium flow. The result: ultra-pure helium – 99.9999 percent – and a temperature of 80 Kelvin. This procedure may be necessary once a year during shutdown for maintenance activity when the LHC is warmed up and then cooled down again. Duration of the pre-cooling phase: two weeks.

■ *2nd phase: refrigeration system →*
It gets even colder with helium expansion turbines: the temperatures sink incrementally from 80 to 4.5 Kelvin. This is the boiling point of helium at a pressure of 1,250 millibars.

■ *3rd phase: cold compression system →*
Refrigeration power at 1.8 Kelvin is generated by the vaporisation of helium at an absolute pressure of 16 millibars. Cold compressors are used to recompress the vapour.

Linde technology also cools in the ATLAS experiment:

● *Cooling of the heat shield in the ATLAS detector to 40 Kelvin.*

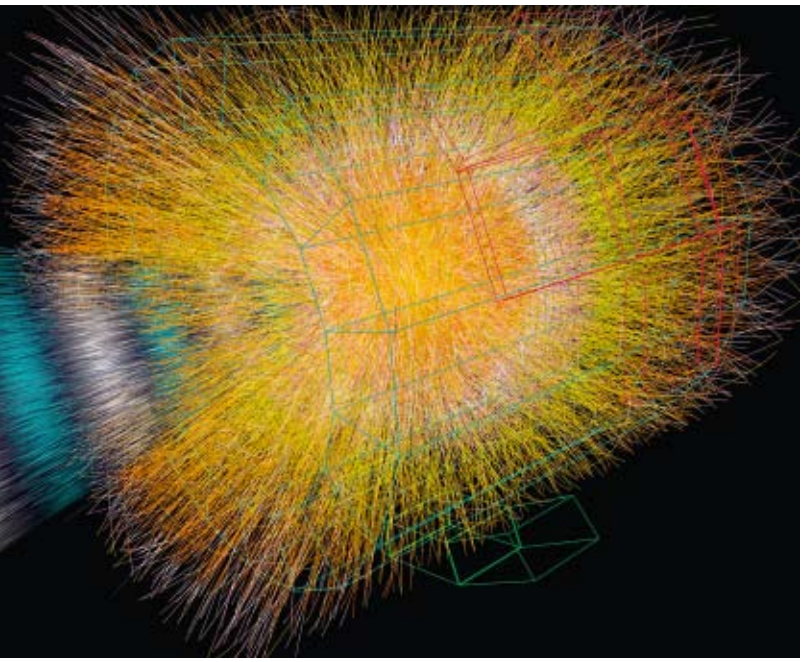
○ *Test bench for superconducting magnets at 4.5 Kelvin.*

spread out along the accelerator ring, with one or two refrigeration systems in each position. Each refrigeration system delivers two helium flows: a gaseous flow at a temperature of 50 Kelvin and a supercritical flow at 4.5 Kelvin. The helium flows are then sent down to a depth of about 100 metres underground. The cryogenic helium will be fed through a complex underground distribution system, supplying the various ring elements, and will flow through magnetising coils, cooling jackets and cooling plates. The cold compression system provides even lower temperatures: to reach a temperature of 1.8 Kelvin, the process pressure has to be lowered to an absolute value of 16 millibars. This is achieved with a multi-stage turbo compressor with active magnetic bearings, variable speed and a sophisticated control system. "These cold compressors not only reduce space requirements, they also save energy", explains Kündig. The drop in pressure in the underground distribution system has to be as small as possible because the temperature is only allowed to vary by 0.1 Kelvin – and that over a length of more than three kilometres. Each of the eight refrigeration systems, together with its associated cold compression system, consumes 4,500 kilowatts of electricity at maximum load.

The cryogenic systems that Linde delivered have received special attention: CERN management recognised the high technical performance by awarding the Golden Hadron Award 2003. They commended among other things some of the new cold compressor systems, helium refrigerators, pre-coolers and adsorber units, as well as the upgrade of two existing refrigeration systems from the earlier accelerator, the LEP, with new turbines.

Once a year the LHC is shut down and warmed up for maintenance work: in winter when the cheap power from France becomes scarce and Swiss energy would make operation more expensive. Both warming up and cooling down take about a month. In the meantime, most of the helium is stored in pressure containers. Only a small part is lost through flushing processes.

All the low temperature refrigeration systems at CERN today are operated and maintained by a consortium of specialists from Linde Kryotechnik and other companies. Kündig is certain that Linde will also play an important role in large research projects in the future: for instance in the 10-billion-euro fusion research reactor ITER, which will begin operation in 2020 in French Cadarache, and will test energy generation following the sun's example. Kündig: "We are already working on studies about a refrigeration concept for ITER." There is already one model project: Linde will deliver the refrigeration system for the Wendelstein 7-X fusion research reactor next year. This reactor is currently being built by the Max-Planck-Institut für Plasmaphysik in Greifswald, Germany and in 2014 will ignite the sun's fire on earth.



Proton Racetrack:
9,563 magnets keep the charged particles on their circular course in the pipes (photo, right). A field intensity 200,000 times the strength of the Earth's magnetic field is required for this. When the proton packets collide, it looks similar to this computer simulation (photo, left). In doing this, physicists hope to discover new particles that are currently only known in theory.

LHC IN FIGURES

The protons circle the LHC 11,245 times per second. A beam can circle the LHC for 10 hours, covering more than 10 billion kilometres – enough to travel to Neptune and back.

Circumference	*27 kilometres at a depth of 100 metres*
Ammunition	*2,800 packets of 100 billion protons each*
Speed	*99.9999991 percent of light speed (almost 300,000 kilometres per second)*
Lap time	*0.00009 seconds*
Temperature of the magnets	*1.8 Kelvin (about minus 271.3 degrees Celsius)*
Temperature at the collision point	*10,000,000,000,000,000 degrees Celsius*
Amount of data	*15 million gigabytes per year (20 million CD-ROMs – a stack 24 kilometres high)*
Costs	*2.2 billion euros (accelerator), 800 million euros (detectors)*
Staff	*2,500 permanent staff plus thousands of guest scientists from around 40 countries*

DESPERATELY SEEKING SUSY

Why does matter have mass? This is one of the questions that the LHC aims to answer. If the predictions are correct, the gigantic accelerator will find the Higgs particle, and proof of the existence of a Higgs field, named after the English physicist Peter Higgs. All matter particles "suck" their mass from this field, which fills the whole universe. CERN physicists would also like to discover supersymmetrical particles. The Susy theory states that for every known particle in the standard model of particle physics there is also a heavier symmetrical partner. Susy would be a key component for the world formula, which would combine all four fundamental forces – and thus finally also the gravitational force – into a single unified force.

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Bernd Müller is a freelance technology journalist based in Esslingen. Amongst other work, he regularly writes for "bild der wissenschaft" and "Focus".

LINKS:
www.cern.ch
www.linde-kryotechnik.ch
www.weltmaschine.de

THE WORLD NEEDS ENERGY – AND CLIMATE PROTECTION

Worldwide energy demand is increasing phenomenally. Climate change and the scarcity of oil reserves necessitate new technologies to meet the growing demand. Only a well-balanced combination of energy sources can sensibly secure future supplies in both an ecological and economical way.

The whole world needs energy – and a rapidly growing world population requires more and more of it. Because the standard of living in emerging developing and newly industrialising countries such as China and India is conforming more and more to the standards in western industrialised countries. And although they only make up 15 percent of the global population, industrialised countries today already consume almost half of the energy used annually worldwide.

In the face of climate change, sustainable future energy supplies can only be secured with technologies that also boast a low carbon balance. Engineers at Linde are contributing to this with the most up-to-date hydrogen technology, that supplies busses, cars and even ships with environmentally friendly fuel – and with solar power systems that innovatively store solar energy. The Linde Group's energy experts provide purification and liquefaction technology for biogas plants, which convert organic waste into biofuels. In addition to that, and in cooperation with their partners, they are developing methods of bioethanol production in which microorganisms produce biofuel from waste straw, thus posing no threat to food production.

However, the switch to new energy sources cannot be made immediately. That's why other technologies also have to be developed further, which will utilise the still available fossil fuel resources as environmentally friendly as possible. Linde technology is making a considerable contribution to this. Hydrogen plants help remove the sulphur from fuels that originate from the gigantic oil sand deposits in Canada. They've also come up with technology that allows CO_2 emitted by modern-day brown coal power plants to be stored climate-neutrally underground. The featured topic in this issue provides multifaceted examples of how Linde technology is helping to secure future energy supplies with an energy mix that is both ecologically and economically sensible.

ENERGY MIX OF THE FUTURE

Rising energy demands:
The world's big cities are growing fast – and people need electricity and heating and want to be mobile.

ENERGY MIX OF THE FUTURE

FILL UP NATURALLY

Second-generation biofuel: Enzymes transform straw into fuel

Researchers are concentrating more and more on finding alternatives to fossil fuels in order to combat climate change and oil shortages. One solution could be found in enzymes and microorganisms, which produce bioethanol from waste straw. Biotechnologists, chemists and process engineers at Linde and Süd-Chemie are working together to develop an energy-efficient process for the production of bioethanol. This does not compete with foodstuffs and boasts an excellent carbon emissions balance sheet.

Image source: Getty Images
Author: Caroline Zörlein

Wood for the engine. What at first sounds like a return to the beginnings of car development could soon emerge as a high-tech alternative to fossil fuels. This will be made possible thanks to a combination of natural materials and the most modern of biotechnology. The main players in this process are microorganisms from the kingdom of fungi and bacteria. These little helpers – also known as decomposers – are specialised in breaking down difficult-to-digest foods, such as the wood component, cellulose. These tiny mites work in forests and fields to ensure that dry leaves, old branches and dead trees decay, thus releasing basic chemical components and minerals so that they are available to other living things once more. Enzymes also help in this process of breaking down the dead plant matter into smaller components. This results in individual sugar molecules – or monosaccharides. Once yeast cells are brought into contact with this sweet liquid, the chemical process generally known as alcohol fermentation gets underway. As in the beer brewing process, the yeast converts the sugar into alcohol. And this bioethanol is precisely the substance that is meant to fill our tanks in the future – or at least reduce the proportion of crude-oil based fuels.

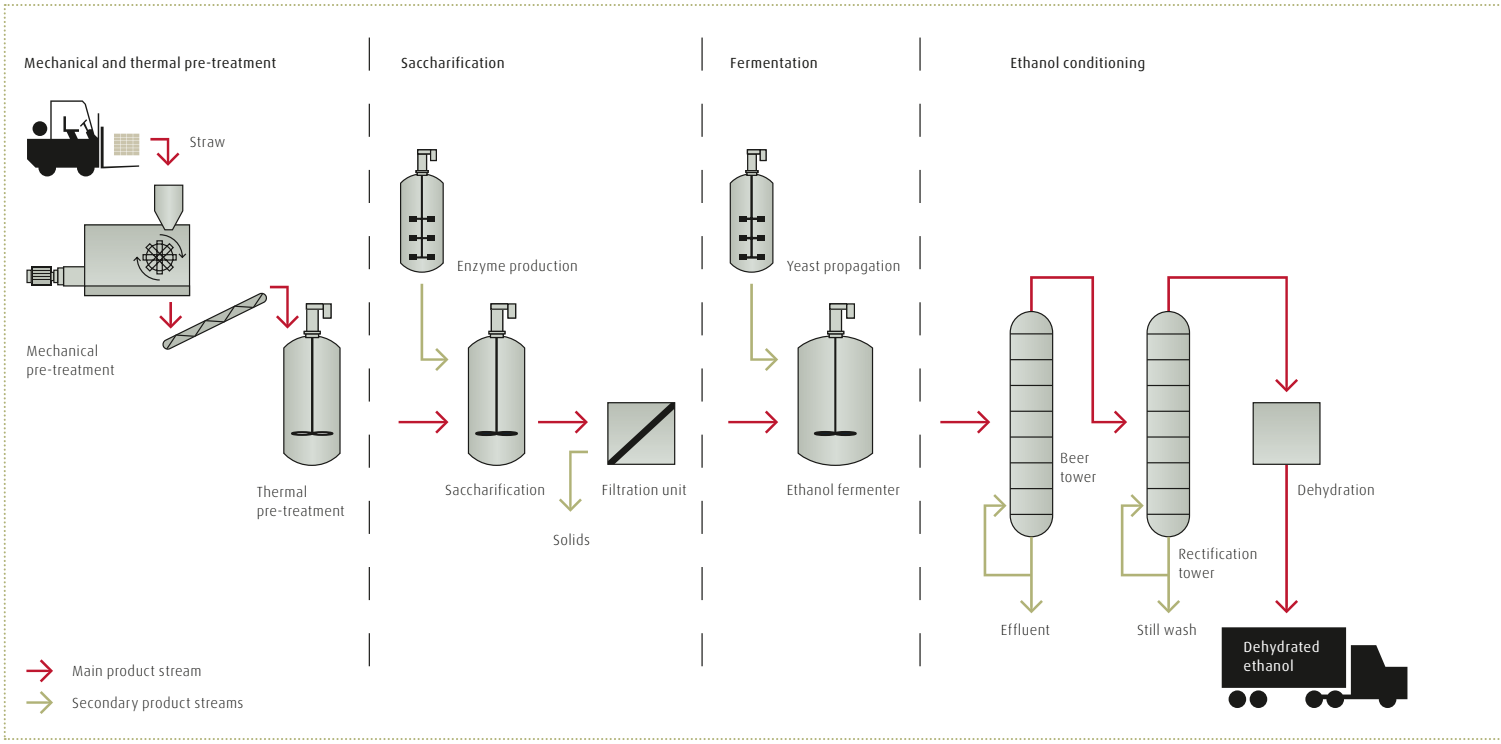
Microorganisms hungry for straw

However, producing green fuel alternatives such as biodiesel from rapeseed, or biofuels from maize or wheat is still a contentious issue. This is because oil and starch-based agrarian raw materials are needed as food. This 'tank or plate' dilemma is now set to clear the way for a new generation of cellulose-based biofuels. "The raw material we use to produce biofuel is straw that accumulates as agricultural waste", explains Uwe Welteroth, Manager of the Biotechnology Plants at Linde-KCA-Dresden GmbH. "Biofuels of this so-called second generation are a sensible alternative to petrol from fossil sources. And that's precisely because they do not compete with food", adds the engineer.

In a unique pan-European alliance between two large corporations, Linde and Süd-Chemie are therefore developing biotechnological systems for the production of second-generation biofuel. Starting with cellulose-containing plant matter, they produce sugar and finally, ethanol. At the moment, there is a joint project underway to build a small-scale pilot system at Süd-Chemie's research headquarters in Munich. That's where microorganisms are transforming straw into bioethanol. As part of the alliance, Süd-Chemie's biotechnologists and chemists primarily bring their expertise in biocatalysts and bioprocess engineering to the table. Linde-KCA – a biotechnology plant specialist – has many years of experience in industrial applications for chemical and pharmaceutical processes. The partnership between these two companies is noteworthy because all parties approached each other at such an early stage. Already in 2006, the first contact was made and discussions took place. "Ultimately, it's most important that engineers, biotechnologists and biochemists learn to understand each other's language so that they are able to work together and find innovative solutions", explains Welteroth.

Guided by nature

But it's not only the humans who are effectively cooperating on this project. "Our biocatalysts – the enzymes – are also a well-attuned team", says Dr Markus Rarbach, Manager of Süd-Chemie's Biocatalyst Department in Munich. The researchers have observed much of what takes place in nature and then optimised the naturally-occurring biocatalysts. "Because only when the source material, processing parameters and enzymes are optimally attuned to one another does such an operation deliver useful results for both industry and the environ-



From straw to biofuel: *Using a specially developed method, the plant run by Linde and Süd-Chemie processes cellulose-containing plant material, such as straw, using a multi-stage method that at first converts it to sugar and then to bioethanol.*

ment", says Rarbach. This is a great challenge. In order to quickly target the most effective enzyme cocktail, Süd-Chemie is also making use of automated screening methods. In this way, hundreds of thousands of enzyme and microorganism variations can be fully automatically tested, and then optimised to the source materials and processing parameters.

Steam not sulphuric acid

In the forest and in the fields, these enzymes decompose the structural cell wall material, or lignocellulose, of various plants. This stable structure is in turn made up of cellulose, hemicellulose and lignin, but the quantities vary in different types of plants. Whereas these biocatalysts can be described as all-rounders that process almost all woody plants in their natural setting, they need to be trained as specialists in industrial applications. Because "the enzymes that we modify for bioethanol production should be particularly good at breaking down straw", explains Rarbach. This agricultural raw material is available in large quantities and the 'tank or plate' debate does not come into play at all.

Exactly how the golden yellow fibres are spun into liquid gold – bioethanol – is a painstaking task when done fully automatically on an industrial scale. The straw's journey begins with a thermal pre-treatment, where the shredded material is decomposed. To achieve this, steam heats up the lignocellulose, thereby releasing its individual components. "Other methods employ chemicals such as sulphuric acid in this step", explains Dr Michael Buchmann, Discipline Manager Industrial Biotechnology at Linde-KCA. "We only need hot steam. The water used for this can be recaptured and later placed back into the cycle." This makes the procedure especially energy efficient and resource efficient.

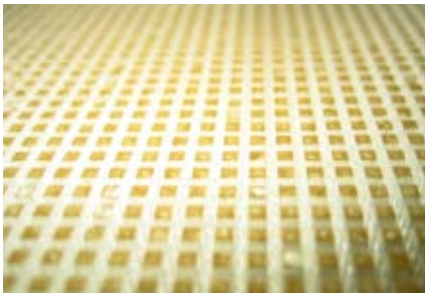
The product of this first step in the process is a paste-like mass of straw snippets and water. "It no longer has much in common with straw," says Rarbach, holding up a test tube filled with a viscous, brown concoction. This thick liquid requires an elaborate pump system to guarantee its successful transportation to the next section. That's where the molecular straw-digesters perform their work. They separate the now dissolved cellulose, a long-chain polymer made up of sugar molecules, into individual carbohydrates. This stage on the way from straw to biofuel is therefore also known as saccharification. A filter then removes any remaining solids and the liquid flows on into the fermenter. Yeast microorganisms now take over, fermenting the sugar into fine ethanol. The following step – the mash or "beer" column – has nothing to do with the drink. Instead, it serves to rectify and almost completely purify the extracted bioethanol. Even though the product of such a biotech plant contains a significantly higher percentage of alcohol than beer, it has a couple of things in common with brewing practices: delicate technology and mild reaction conditions without the need for added chemicals.

Biofuel with an optimal carbon balance

Many optimisation steps were required to be able to yield as high an output of ethanol as possible. To achieve this, biotechnologists, chemists and engineers had to reconcile various aspects. The plant had to be economically viable, the carbon impact had to be right and everything should be delivered to the customer from one source. "We benefited at the planning stage from our wealth of experience with bio-

IN ORDER FOR A BIOETHANOL PLANT TO OPERATE IN AN ECONOMICALLY AND ECOLOGICALLY SENSIBLE WAY, SOURCE MATERIALS, PROCESSING PARAMETERS AND ENZYMES HAVE TO BE OPTIMALLY ATTUNED TO ONE ANOTHER.

The biofuel makers: *Employees of Süd-Chemie optimally match enzymes and processing parameters to each bioethanol source material in the laboratory.*



Effective enzyme cocktail: *Using such Microtitre plates as part of a fully automated screening method, Süd-Chemie looks for the most effective straw-decomposing microorganisms among hundreds of thousands of mutations.*

Enzyme fodder: *Straw, the agricultural resource, is available in large quantities, meaning that for the second generation of biofuels, the 'tank or plate' debate does not come into play at all.*

Green oil alternative: *In the USA, about a quarter of today's fuel requirements are meant to be replaced by biofuels by the year 2022 – a large proportion of which will be second-generation biofuel.*

technology plants", says Welteroth, "we are now no longer far from an operational bioethanol plant." Because a specific catchment area is required for the source material and since logistics should not take the upper hand, those involved in the project expect the bioethanol plant to be of medium size. What this means in figures is 50,000 to 150,000 tonnes of ethanol per year. The biofuel experts at Süd-Chemie and Linde expect the first European bioethanol production plants to be opened over the next three to five years. "At the moment we are planning a pilot plant with production of about 1,000 tonnes per year", says Buchmann. At the end of 2008, the first pilot-sized plant should begin operation in Munich.

MCKINSEY PUTS THE WORLD MARKET FOR BIOFUELS AT 61 BILLION US DOLLARS BY 2010.

Tailor-made bioethanol plants

The alliance between Süd-Chemie and Linde will supply comprehensive plant design concepts. "We have not only developed individual steps in the process, but have optimally tailored the entire operation, from sourcing materials to the finished bioethanol product", says Welteroth. This also means that all of the material streams – water, energy and solids sorted out of the process, like lignin – will be effectively put to use. Aside from straw, the biofuel makers can however use many other source materials, or feedstocks, to process into bioethanol. The specific adjustments for each process take about four to six months, according to Rarbach. This results in a made-to-measure bioethanol system matched to each customer's requirements – and all from one source. Apart from ethanol, other precursors or intermediate products requested by customers in the chemical industry can also be produced biotechnologically from renewable raw materials, and this is done with the help of other microorganisms from the sugar solution process. And there's a lucrative market for such an offer. Consultancy firm McKinsey and Company puts the world market for biofuels at 61 billion US dollars by 2010. A new American law has also been introduced, stating that about a quarter of the current fuel consumed in the US has to be replaced with biofuels by 2022 – a large proportion of which will have to be second-generation biofuels. And in the face of shrinking oil reserves and CO_2 reduction measures, biofuel made from straw will play a key role in the energy mix of the future. That is because during its growth, this plant draws exactly the same amount of CO_2 from the atmosphere as the combustion engine will later put back into it.

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LINKS:
www.fnr.de
www.ec.europa.eu/energy/res/legislation/biofuels_en.htm
www.biofuelstp.eu
www.sud-chemie.com
www.linde-kca.com

BRIEF INTERVIEW

"NO COMPETITION AGAINST FOODSTUFFS."

"Linde Technology" spoke to Dr André Koltermann, Research and Development Manager at Süd-Chemie, about the production and prospects for second-generation biofuels.

↳ DOESN'T THE USE OF PLANTS IN ENERGY PRODUCTION COMPETE WITH THEIR USE IN FOOD PRODUCTION?

For us, the 'tank or plate' debate doesn't come into play. That's because we use by-products that constantly accumulate in the agricultural production of food, and which would otherwise not be used – such as cereal straw or maize stalks. In Europe, for example, cereal straw is the most used lignocellulose-containing feedstock. About 400 million tonnes of this is produced in the EU annually and at the moment only 20 to 30 percent is used industrially. If we were to start converting all the EU cereal straw today, we would be able to reduce petrol consumption in the EU by about 40 percent. Other feedstocks from the EU, rice straw from Asia, or waste sugar cane bagasse from Brazil's sugar production could also be used in the production of bioethanol. For this reason, we always match each production plant and each process to the material used, so that it works optimally and so that the maximum output of bioethanol can be derived from it.

↳ YOU WORK WITH ENZYMES, OR BIOCATALYSTS, TO PRODUCE ETHANOL FROM STRAW. WHAT ARE THE ADVANTAGES OF THIS COMPARED WITH OTHER METHODS?

For millions of years, enzymes have developed in nature, which can efficiently help decompose plant waste. They catalyse chemical reactions in all living organisms, converting chemical energy from sources such as sugar into kinetic energy. These natural catalysts require minimal energy use to work under very mild reaction conditions. And biocatalysts are being used more and more frequently in industry. As opposed to thermal or chemical methods, they frequently offer advantages such as less energy use and less by-products, as well as markedly lower investment costs for the systems.

↳ WHEN WILL THE FIRST COMMERCIAL SECOND-GENERATION BIOETHANOL PLANTS GO INTO OPERATION?

We're currently working with Linde to build a small-scale pilot plant in Munich, and we're already planning a larger pilot plant. That's the final step on the way to a production plant. The first commercial industrial plants that produce ethanol from straw will start operating in about three to five years.

ON THE MOVE WITH H_2

Linde technology for the set-up of a hydrogen infrastructure in Hamburg, Germany

Climate protection and business sense form a special alliance in Hamburg: Politicians, industrialists and other organisations all want to develop their Hanseatic city into a hydrogen metropolis. Linde engineers are participating in many of these hydrogen infrastructure-building projects – an infrastructure that could be a model for regions around the world.

↑ Author: Michael Kömpf
↓ Image source: Elbe&Flut Edition

Hamburg has a lot of water, H_2O, – and it will soon have a lot of H_2. The city-state is preparing to become a model region for the development of a hydrogen infrastructure. Today, the harbour city is already one of the most important European locations for hydrogen technology and fuel cell technology. "We began very early on in the fields of hydrogen and fuel cell applications", explains Heinrich Klingenberg, Managing Director of hySOLUTIONS GmbH. Founded in 2005 as a subsidiary of Hamburg's public transport operator – Hamburger Hochbahn AG – the company has now taken on the role of 'Cluster Manager'. The cluster's focus is on the hydrogen activities of both the Hamburg Senate and those of industry.

According to Christian Tuchel, Chemistry Project Manager in Linde Gas Germany's northern market region, this especially close collaboration between politicians, industry and other organisations is one of the determining factors contributing to Hamburg's prominent role in hydrogen supply. As a mechanical engineer, he looks after numerous H_2 projects in that city. "The conditions in Hamburg are optimal for testing hydrogen as an energy source in maritime applications, aircraft and road transport." The latest example is Project Zemships (zero emission ships) – an association of nine partners led by the Free and Hanseatic City of Hamburg's Department of City Development and the Environment. Since August 2008, a fuel-cell powered pleasure steamboat has been using hydrogen to carry its passengers across the River Alster. It receives its fuel from a hydrogen filling station provided by Linde.

The fuel cell on board the steamboat requires gaseous hydrogen. Linde engineers produce this by way of an evaporator. Using a screw compressor, the gas is then compressed to a pressure level of 25 bar. The second stage of compression – which then increases pressure on the hydrogen to a level of up to 450 bar – is carried out by two 'ionic compressors'. In this pressure-increasing procedure patented by Linde, an ionic liquid is used instead of the traditionally-used mechanical pistons (see also: text box – "Ionic Compressor for H_2 Filling Station"). This has enormous advantages: The compression process is very energy efficient; reduces the number of moving parts; and helps minimise noise as well as counterproductive heat generation. It therefore takes the Alster riverboat around twelve minutes to fill up with 50 kilogrammes of compressed hydrogen gas (CGH_2). "That should be enough for about three days", estimates Klingenberg. If the entire fleet of Alster steamers were to navigate Hamburg's canals powered by hydrogen, their CO_2 emissions would be reduced by 1,305 tonnes annually. The Zemships Project in Hamburg has a budget of approximately five million Euros – about half of which is sponsored by the EU.

The liquid hydrogen for the Alster riverboat is still delivered to Hamburg via tanker trucks from Leuna. "In the medium term, however, we aim to produce hydrogen for the region at the point of consumption", clarifies Tuchel. Its proximity to the coast and its local chemical industry grant Hamburg an especially favourable position. Green hydrogen can thus be produced by electrolysis performed on those electricity surpluses produced by offshore wind parks that cannot be fed into the grid. "With a pipeline network that supplies refineries with hydrogen, we could fuel road vehicles and ships", says Tuchel.

Hydrogen-powered fuel-cell busses have been driving through the city for Hamburger Hochbahn since as early as 2003. They are refuelled at a Vattenfall filling station. With a current total of six busses, it is one of the world's largest fuel-cell fleets. "But the technology is already outdated", says Klingenberg. From 2010, the first ten fuel-cell busses of the next generation will therefore be tested. More hybrid busses should then be ordered in the years thereafter. The Daimler subsidiary, EvoBus, would like to test the prototype of a vehicle fitted with a high-performance battery and wheel-hub motors as of 2009.

Hydrogen city of tomorrow: *Hamburg offers the optimal conditions to enable cooperation between politicians, industry and other organisations.*

H_2 infrastructure: *Thanks to Linde's hydrogen technology, it's not only the northern German metropolis' public bus lines and cruise boats that run on the environmentally friendly fuel. Fuel cells also power the baggage vehicles at Hamburg Airport.*

But in Hamburg, hydrogen doesn't only power busses. The Hamburg Car-Sharing Project's first two A-Class Mercedes are already cruising through the city, and are running on the promising fuel. "We want to test the technology in continuous operation at Hamburger Hochbahn and offer it to industry leaders for testing", clarifies Klingenberg. He also sees lifting equipment as a good application for hydrogen-powered propulsion. The KION group would like to gradually build up a small fleet of forklifts. The Hanseatic city also offers the perfect conditions for such a move. As part of HafenCity Hamburg – Europe's largest town planning project, located in Hamburg's harbour area – over 100 ocean-faring giants such as Queen Mary II will land at the city's cruiser terminal in the next few years. Fuel-cell powered forklifts would offer many advantages for loading and unloading cargo there. Problems such as high noise levels, exhaust fumes and long recharging times required by electric forklifts would be made irrelevant. Two baggage vehicles at Hamburg Airport and a forklift owned by Hamburger Hafen und Logistik AG (HHLA) are already fitted out with fuel cells. These vehicles are also supplied with fuel by Linde's mobile filling stations.

In order to be able to build up an economically viable hydrogen infrastructure in the medium term, Tuchel says that industrial clients are needed. "Once there are two or three larger hydrogen consumers in the region, it won't be long before cost-effective supply concepts are established for smaller quantities." The most cost-effective method of producing hydrogen is still based on natural gas. "But in the medium term, we'll have to switch to green hydrogen", says Tuchel. To do so, Linde will make use of renewable energy sources such as wind power, solar energy and biomass produced from composting plant materials and algae. Hydrogen could lead to enormous changes – especially in industries that process raw materials. "In many thermal processes, for instance, hydrogen can replace natural gas, thereby increasing effectiveness and also reducing CO_2 emissions," explains the mechanical engineer. He has already engaged in his first promising talks with companies in these industries in Hamburg. The Hanseatic city is thus on its way to becoming a hydrogen metropolis.

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LINKS:

www.hh2wasserstoff.de
www.now-gmbh.de
www.linde.com/hydrogen

BRIEF INTERVIEW:
"HAMBURG HAS MANY HYDROGEN BEACONS"

Hamburg, the Hanseatic city, is increasingly using hydrogen technology. "Linde Technology" spoke with Heinrich Klingenberg, Managing Director of hySOLUTIONS GmbH, about the city's transformation into a hydrogen metropolis.

WHAT MILESTONES DO YOU ENVISION ON THE PATH TOWARD A FUNCTIONING HYDROGEN INFRASTRUCTURE IN HAMBURG?

Revision of the technology is due by 2010. We now have to apply the lessons learnt from experiences in the technology that powers busses to a new generation of vehicles. We are also testing various components of the infrastructure. In 2013 we hope to take the final preparatory steps for continuous operation, so that we have a truly market-ready level of hydrogen technology as of 2015. Hamburg already has many exemplary hydrogen 'beacon projects' – in air and water transport, busses, cars and even in stationary systems for electricity and heating supplies.

WHERE DO YOU SEE THE GREATEST NEED FOR ACTION?

Many projects have proven that the drive technology has already progressed quite far. But now the supply needs to be secured. The questions that need to be answered are: How much hydrogen, from which sources and at what price are available where? Still lacking are sophisticated technical concepts for the standardised development of infrastructure – but we are already testing some of these in Hamburg. And in order to operate continuously, the infrastructure needs to be made capable of running 24 hours a day, 7 days a week. What we need above all is stronger communication between all participating industrial branches – between vehicle makers, energy providers and manufacturers of infrastructure components.

HOW DO YOU SEE THAT HAPPENING IN PRACTICE?

It's my view that the auto industry has to firstly agree on a technological concept that they wish to pursue. With the current indecision, we could miss the opportunity to gain important experiences that could then be applied elsewhere. It would be useful to develop a strategy under which someone provides the infrastructure, then the cars will be produced and the number of units can eventually be increased.

IS IT POSSIBLE TO APPLY THE HAMBURG HYDROGEN MODEL TO OTHER REGIONS?

That's absolutely possible, even though we have a clear advantage due to our proximity to wind energy. What we are primarily trying to achieve here is to provide an example of long-lasting, close collaboration between politicians, industrial representatives and leaders of organisations. The aim of this cooperation is to establish hydrogen technology as a sustainable energy supply, which unites quality of life with business commitments.

IONIC COMPRESSOR FOR H_2 FILLING STATION

Hamburg's Alster riverboat is fuelled by a very special innovation. Instead of using a piston, Linde's compressor operates using a so-called 'ionic liquid': an organic salt that is in liquid form at the desired temperature. Ionic compressors represent a quantum leap in gas compression: they work without any solid compression pistons. In the compression process, the ionic liquid behaves like a solid object – albeit with the properties of a fluid. This new structural engineering concept allows for an almost isothermal compression at a ratio of up to 1:30 in a single step, by way of an internal cooling mechanism. Its energy conversion efficiency is significantly higher than that of a conventional compressor. Ionic liquids also work to stop corrosion. And because there are no moving mechanical parts, there is also no wear and tear. This reduces the compressor's maintenance requirements. The liquid's density can be varied by variation in the choice of ions.

ENERGY MIX OF THE FUTURE

PROPELLED BY WASTE

Linde gas liquefier provides carbon-neutral fuel

At the moment, the world's largest biogas plant is being completed in California. It produces carbon-neutral biogas from the methane generated in a landfill. This liquid biofuel is expected to power 300 rubbish trucks. Within the scope of its joint venture with waste disposal company, Waste Management, the Linde Group provides the technology for the entire gas purification and liquefying process. The two companies are investing around 15 million US dollars in this promising project because: there will always be waste – and society is demanding biofuels.

↵ Author: Hubertus Breuer
↳ Image source: Waste Management, Inc.

California: The sunny 'Golden State' – a holiday paradise and the USA's environmental harbinger. Its governor, Arnold Schwarzenegger, has implemented green policies in the state. He wants to drastically reduce carbon emissions before everyone else. That is why he has made legal arrangements to reduce California's greenhouse gas emissions by a quarter by 2020, bringing them back to 1990 levels. The ex-actor is therefore promoting initiatives such as the plan to fit a million houses with energy-saving solar-panelled roofs. What is more, he has approved a plan, which financially supports fuels produced from biomass. And fledgling enterprise founders in Silicon Valley share Schwarzenegger's vision. They hope, for example, to press the oil out of algae, or to manipulate microorganisms in such a way that they produce petrol as a metabolic product.

But while some ambitious start-ups are still attempting to develop the fuel sources of the future in their laboratories, there have long been resources available that have only needed to be properly tapped. The sun is one of them – and biogas is another. In a place like California, this gas is emitted by over a thousand rubbish tips. In many of those, the gas is already being converted into electricity – which is fed into the state grid. But there is enough landfill gas left over to be converted into valuable fuel, as long as the right set-up is available. That is what has now motivated Linde and America's largest recycling and waste disposal service provider, Waste Management, to convert the gas emitted by composting rubbish in the Altamont landfill near Livermore, east of San Francisco, into liquefied natural gas (LNG). The Linde – Waste Management joint venture is building the world's largest plant of it's kind there. From 2009 onwards, 50,000 litres of liquid biogas are expected to flow through the tanks of 300 Waste Management rubbish trucks daily. Up until now, most of these heavy trucks have run on LNG produced from non-renewable pipeline natural gas.

THE CAPTURE AND PROCESSING OF LANDFILL GASES INTO AN ENVIRONMENTALLY FRIENDLY FUEL RELIEVES SOME OF THE BURDEN ON THE ENVIRONMENT AND REDUCES CO_2 EMISSIONS.

As part of the cooperation and drawing on a wealth of experience, Linde will build and operate the state-of-the-art gas liquefaction plant. For many years, the corporation has been advancing the development and environmentally friendly usage of fossil fuel alternatives. From extraction through to fuelling techniques, Linde offers technological solutions in the areas of LNG, biogas and hydrogen. "By capturing landfill gases and developing them into environmentally friendly fuel, we alleviate environmental pollution and reduce carbon emissions", explains Kent Masters, member of the Executive Board of Linde AG, responsible for the firm's North American business related to this new project.

And there is concrete evidence in the biogas joint venture to support this. "Waste Management estimates the project could reduce CO_2 emissions by approximately 30,000 tonnes annually", says

Powered by waste: *As of 2009, 300 of the company Waste Management's rubbish trucks will run on landfill gas.*

RUBBISH COLLECTED BY WASTE MANAGEMENT'S VEHICLES WILL BE USED TO FILL THE TANKS OF THE RUBBISH TRUCK FLEET.

Decomposition factory for bacteria:
By way of oxygen exclusion, microorganisms produce methane, which – when compressed and liquefied – fuels the rubbish trucks.

Steve Eckhardt, who manages LNG and biogas business development for Linde. This view is also welcomed by Schwarzenegger's administration. That is why his administration is providing support for the project in the form of around 1.5 million dollars – about 10 percent of the building costs. Linda Adams, a spokesperson for the Californian Environment Ministry, praises the enterprise. "We see this project as an important step toward meeting Governor Schwarzenegger's stipulated standards for low-polluting fuels." And even the usually critical Patricia Monahan of interest group 'Union of Concerned Scientists' admits that energy from waste is the "best possible scenario". And while on the subject of environmental impact, the biogas plant obviously provides Waste Management with a further selling point – the company can refer to the fact that this closes the loop in waste processing – rubbish collected by Waste Management vehicles is used to power those very same vehicles.

Landfill gases always accumulate in compost bins under the right conditions: oxygen supply is cut off and damp heat is present. That's when bacteria start on the decomposition process. They convert the organic waste chiefly into methane and carbon dioxide. Small amounts of alcohols, hydrogen sulphide and other hydrocarbons are also generated. The energy released in this process is contained primarily in combustible methane. One cubic metre of pure methane contains almost ten kilowatt hours of energy. The gas is at first collected in so-called gas reserves. To do this, the entire landfill is fitted out with horizontal filter pipes in which fans create a light vacuum effect that sucks up the gas. Using this method, about 200 cubic metres of landfill gas is collected in Livermore's reserves per tonne of waste. During this collection process, some air infiltration occurs and nitrogen and oxygen become a part of the gas. Until now, Waste Management has been sending this gas to a power plant that can produce about eight megawatts of electricity from it. That is at least enough power for 6,000 households, which the waste company supplies to the grid of Californian Pacific Gas and Electric Co. As more rubbish is added to the landfill, additional landfill gas is available and the waste company wishes to liquefy this biogas to produce LNG. And that too is now worth doing with technology from Linde.

Once at the biogas processing plant, the gas is initially compressed. This is followed by a purification process. The gas is desulphurised and carbon dioxide, nitrogen, alcohols, and other trace contaminants are removed. In one last step, using a mixed refrigerant process, the purified methane is cooled in a heat exchanger to a temperature of minus 160 degrees Celsius, and is thereby liquefied. The power required is also provided by landfill gas. It is burned and the heat this produces creates steam that operates a generator. The LNG is then stored in large liquid gas tanks that look like gigantic thermos flasks. The liquid methane is transported by tanker to the on-site gas filling stations at the landfill and other customer sites – and later used to run the fleet of rubbish trucks and other vehicles powered by natural gas.

This methodology displays its environmentally friendly usefulness very clearly – especially when combusted in engines. „As opposed to LNG from pipelines, biogas produced from rubbish tips is effectively climate-neutral", states Eckhardt. By converting the biogas into LNG, it is burned in a vehicle and flaring of the biogas at the site is avoided, as are those carbon emissions. In comparison to diesel, natural gas burns not only much more quietly, but also considerably more cleanly. Natural gas engines that use it release ninety percent less fine dust particles into the air, and both nitrogen oxides and sulphur dioxide are drastically reduced, compared to diesel engines. Biogas from landfills is a sustainable fuel source – and, as long as waste needs to be disposed of, there is an opportunity to productively use that biogas for LNG production.

In the United States alone, the potential is great for Linde's liquefaction plants. Waste Management has over 25,000 collection and transfer trucks at its disposal nationally and there are thousands of landfill sites. On top of this, the diesel fuel traditionally used by the company has recently become an enormous business cost, thanks to rising oil prices. It is therefore the long-term goal of Waste Management to improve its fuel efficiency by 15 percent by 2020, using gas liquefaction plants. Such potential for growth does not only exist in the USA, though. As of summer 2008, Linde is commissioning a plant at a rubbish dump in Albury, in Surrey, UK. Working together with the gas producer Gasrec, the plant is capable of extracting roughly 38,000 litres of LNG from landfill gas daily.

For the time being at least, the world's vehicles will continue to run on mostly fossil fuels. But in light of declining oil reserves, the world has to adjust to methods of securing its mobility by way of alternative energy sources. "The great advantages of biogas are that it's a renewable resource, it's readily available and domestic, and it provides a significant reduction in carbon emissions", says Eckhardt. In his opinion, biogas will be one of many energy sources that will replace oil long-term.

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LINKS:
www.wm.com
www.adelaide.edu.au/biogas

ENERGY MIX OF THE FUTURE

Linde provides conciliatory fuels from Canada's oil sands boom

SULPHUR-FREE WITH HYDROGEN

The world's largest oil sand fields are in Canada. Linde is using reliable plant technology to lay down the basis for environmentally friendly fuel.

Fort McMurray in the northern part of Alberta, Canada used to be a sleepy pioneer town. The locals now jokingly refer to their little metropolis as "Fort McMoney" – since businesses have been investing huge sums in the remote region over the past few years. It's expected to amount to over 80 billion dollars in the coming years alone.

Oil companies have discovered a treasure beneath the Canadian forests, that has in fact been known about for quite some time: oil sands – also known as bitumen. The sand looks like heavy, black earth and smells like diesel oil. Deposits of it can be found in an area that stretches out over approximately 194,000 square kilometres – an area greater than Florida. Experts estimate that there is enough bitumen in Alberta to produce 179 billion barrels of oil – one barrel is equivalent to 159 litres. Presuming that only ten percent of this amount can actually be extracted, this still represents the second-largest oil reserve in the world after Saudi Arabia. In Fort McMurray you can smell these riches. The breeze that blows from the oil fields carries the faint scent of sulphur, because the precious raw material carries much higher levels of this close companion than in conventional crude oil.

However, sulphur is an unwanted element in fuels. Without special treatment, tar oil from Canada is therefore not suitable as auto vehicle fuel. But there is a solution to the problem: hydrogen. This strips the sulphur from tar sand oil. And demand is growing for the gaseous cleaner. In order to meet the rising hydrogen demand, Linde engineers are building H_2 plants near the large refineries. These 'hydrogen factories' produce the coveted cleaning material on site.

OIL SHEIKS IN THE LAND OF THE MAPLE LEAF

Canada's oil industry is booming: After Saudi Arabia, the country is home to the world's second-largest oil reserves. Canada produces 2.75 billion barrels of crude oil daily, 1.2 billion of which come from oil sands. The rest comes from traditional oil wells. The Canadian Association of Petroleum Producers (CAPP) estimates that the land of the maple leaf will jump to fourth place in oil production by the year 2015. By 2020, a production rate of 4.5 billion barrels a day is expected. About 3.5 billion of those should be produced from oil sand deposits.

Black gold: *Bitumen contains precious oil. Breaking down the viscous mass is an elaborate process requiring heavy machinery.*

↳ Author: Hubertus Breuer
↱ Image source: ThyssenKrupp

However, extracting valuable oil from the tar mass is a complex affair. While conventional crude oil can be pumped out of the earth in a transportable form, oil sands are viscous. They consist mostly of silica sand, clay minerals and water. Only about ten percent is made up of gooey 'bitumen' – a heavy oil mixture that can only be converted into synthetic crude oil via robust technology. It needs to be initially extracted from the open pit using heavy equipment such as earth-movers that can scoop up amounts of up to 100 tonnes at a time and trucks that can carry loads of over 400 tonnes. Such a load can eventually produce about 200 barrels of crude oil after it is extracted, cleaned and liquefied.

Before this oil makes it out of the oil sand fields and into the refineries, petroleum companies have to process the thick mass in several production steps. Firstly, the clumps of oil sand are crushed, mixed with water and pumped to extraction plants. Once there, the oil is extracted and treated with solutions so that it can be pumped through pipelines. It is then further processed into synthetic crude oil, which will be transported to refineries in the south of Canada and in the USA.

One such pipeline should soon start pumping the oil to Toledo, Ohio. That is where, even before their merger in 2005, BOC and Linde established a hydrogen plant near two oil refineries from Sunoco and BP. Today up to 132 million standard cubic feet per day – that's 3.54 million standard cubic metres (Nm^3) – is supplied by Linde's largest hydrogen plant with a connection to refineries. The conglomerate has also supplied other ready-to-use plants in the USA – such as in Lemont near Chicago, Illinois, in Salt Lake City, Utah and in Mobile, Alabama. Terry Phipps, Head of the HYCO Cluster, Toledo at Linde Gas USA, is in charge of some of these plants, whose numbers are constantly increasing. "Refineries used to self-produce the hydrogen needed for desulphurisation as part of their own refining process", explains the expatriate in an unmistakable British accent. "But faced with new legal limits and the high sulphur content in heavy fuel oil, externally operated plants run by gas experts can meet demands significantly more economically, more efficiently and with higher security of supply."

Hydrogen treatment for crude oil

Linde produces the hydrogen in so-called on-site plants in the same location as the refineries. During Linde's hydrogen production process (steam reforming), natural gas is often used as feed stock. It is provided in part by BP and Sunoco. In the plant – aptly called a steam reformer – certain by-products from the oil refinery are also used, such as methane and butane. At temperatures of 900 degrees Celsius, the natural gas reacts with introduced steam in the Linde plant, producing hydrogen and carbon monoxide. In a second step, the hydrogen yield is increased by combining the carbon monoxide with more steam, thereby transforming it into hydrogen and carbon dioxide. The hydrogen is later extracted from the mixture and purified. The result: gaseous hydrogen in gas form with a purity of 99.9 percent.

The pure hydrogen is then delivered to the refinery via pipes so that it can be used to desulphurise the crude oil. But before this can occur, the oil also has to undergo certain processes. It is thus desalinated on arrival in the refinery. Then, by way of 'fractional distillation', the liquid is separated into the chemical precursors of petrol, diesel, heating oil, lubricants, asphalt and plastics. The substances are then desulphurised in the hydrotreater. For this purpose, the high-purity Linde hydrogen will firstly be preheated, and then heated up to about 360 degrees Celsius in an oven before finally being sent to a reactor. Once there, the hydrogen reacts with petrol or diesel at a pressure of up to 80 bar in a catalytic chemical reactor. The sulphur contained therein is thus separated out from the hydrocarbons while forming hydrogen sulphide. This can simply be divided off and reprocessed to elementary sulphur. "That is how we end up with low-sulphur fuel, which does less harm to the environment and to catalytic converters in auto vehicles", explains Phipps. But before the fuel starts its journey to the petrol stations, it is processed even further. By 2015, it is hoped that up to five million barrels a day can be mined around the Athabasca River.

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LINKS:
www.oilsands.alberta.ca

Spanish sun catcher:
Mirrored parabolic troughs intensify the sun's rays and heat special oil in dark-coloured absorbent pipes to 393 degrees Celsius.

ENERGY MIX OF THE FUTURE

Linde subsidiary builds storage systems for solar heat

SOLAR POWER AT NIGHT

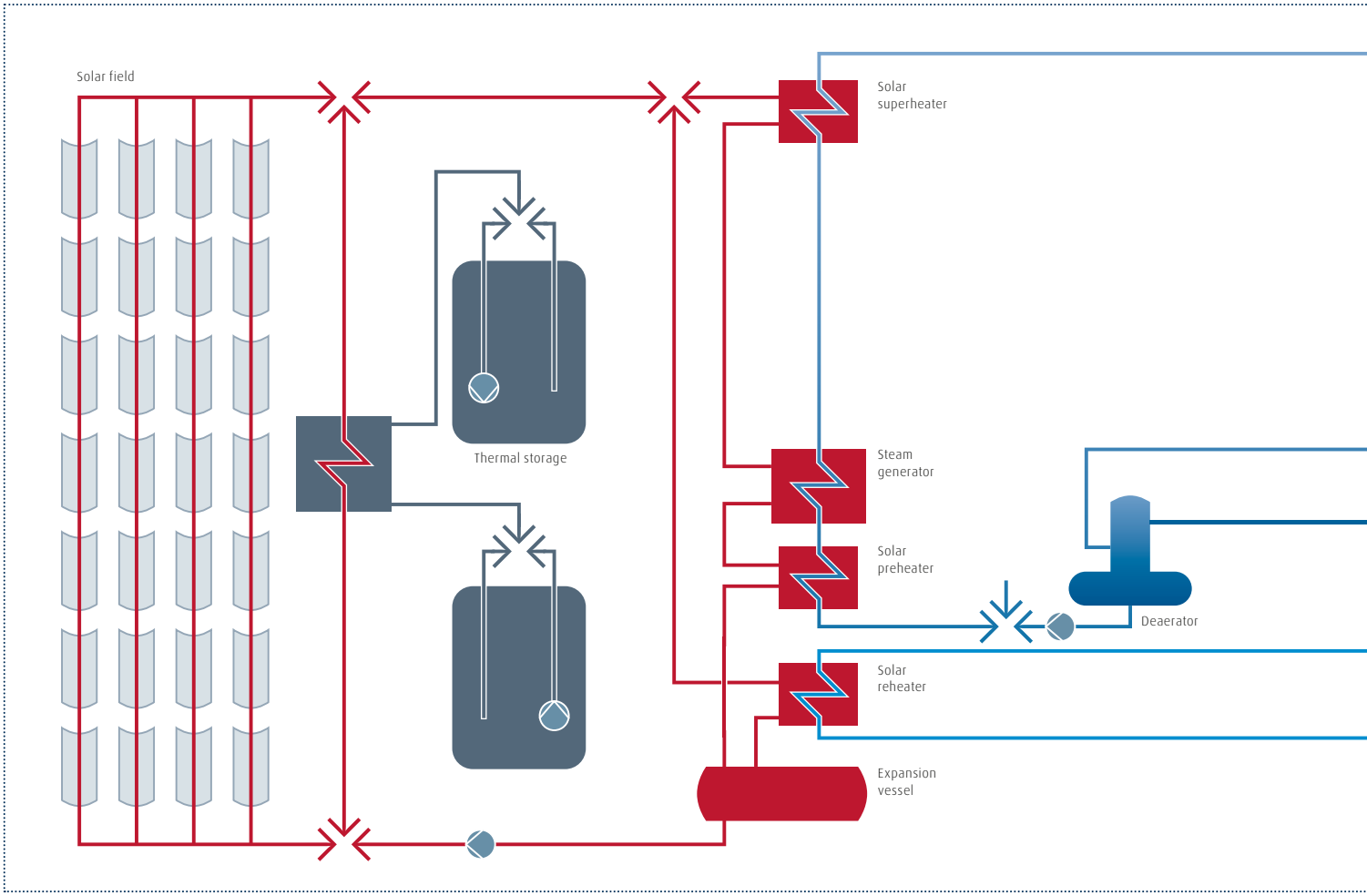
Solar thermal power stations play a decisive role in the future scenarios outlined by many energy experts. Storage systems will be required so that they are still capable of supplying electricity when the sun doesn't shine. A prime location for their design, supply and construction is at the premises of Swiss Linde subsidiary, Bertrams Heatec AG.

↑ *Image source: Solarmillenium*
↓ *Author: Frank Frick*

Spain boasts sea, countless tourists, white beaches – and sun in abundance. In the country's south, the sun shines for more than 3,000 hours per year. But the sun doesn't make Spain attractive only to tourists. It also attracts scientists, engineers and investors who want to tap into a clean and inexhaustible energy source, using gigantic, mirrored power stations. There is also a second reason why the Iberian Peninsula has become an El Dorado for these people. The government pays almost 27 cents per kilowatt hour of renewable energy fed back into the electricity grid – and that's guaranteed for the next 25 years. Opposed to this, experts project that the cost of energy production from thermal solar power plants should add up to a maximum of 15 cents per kWh. This would make solar power still more expensive than the current price of producing energy from coal or gas, but nevertheless worthwhile for the power plant operators.

After two years of construction, Europe's first parabolic trough power station has recently begun operating in Andalusia. "Andasol 1" features mirrors covering a surface area of 0,5 square kilometres (or 500,000 square meters) – that's equal to 70 football fields – and supplies enough solar power for up to 200,000 people. Like a magnifying glass, the power station intensifies the sun's rays. Parabolic troughs concentrate the sun's heat rays onto dark-coloured absorbent pipes. A special oil circulates through those pipes, which reaches a temperature of 393 degrees Celsius. This in turn heats water via a heat exchanger, which evaporates into steam that drives a turbine with an attached generator.

This technology has been successfully proven over more than 25 years in the USA. Originating in the 1980s, nine parabolic trough power stations have since been generating power in the Mojave Desert. Over twelve billion kilowatt hours of solar power have already been supplied by the "Solar Energy Generating Systems" (SEGS), which translates to enough electricity for about twelve million people for one year. Even if Andasol 1 and its future Spanish sister plants currently in construction – Andasol 2 and 3 – were to produce energy by the same principle developed in California, they would still differ in one significant way: The Andasol plants possess thermal storage systems that allow them to supply green power at night.

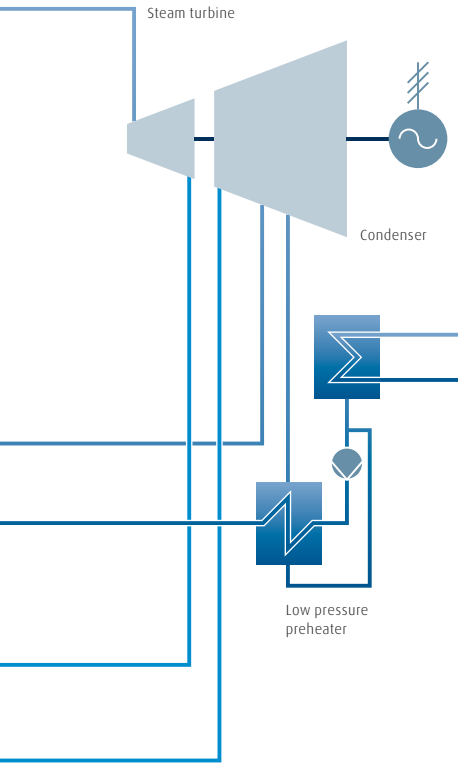


Liquid salts transfer heat

And the thermal storage systems are in greater demand than ever before. “Almost everyone who is currently interested in solar heat power stations with thermal storage systems turns to us for advice”, says Steven Koning, Chief Sales Officer and Board Member of the Linde subsidiary, Bertrams Heatec AG, which is based in Pratteln, near Basel. The Swiss firm is the global number one in the design, supply and construction of molten salt systems for heat transfer in the chemical industry. These systems are needed for the production of such products as melamine and aluminium oxide. It is precisely this experience with molten salt systems – which Bertrams has been gathering for over 60 years – that makes the company the global premier address in thermal storage systems for solar heat. The most vital components of these storage systems are two tanks, one of which is filled with liquid salt that has a temperature of at least 292 degrees Celsius. At this stage, the second tank remains at a minimum level. Over the course of the day, the salt is pumped from the cold to the hot tank through a heat exchanger train, where it is heated to a maximum temperature of 384 degrees Celsius via hot thermal oil. In the evening, the system is reversed. Overnight, the hot salt flows back into the cold tank, returning the stored heat to the thermal oil and generating steam.

Despite the seemingly simple principle, such a storage system requires quite a lot of expertise. It begins with the selection of cost-effective salt mixtures, with a reliable constant melting temperature over time. Roughly 30,000 tonnes of salt would be required for the storage system for a 50-megawatt power station that either collects or releases heat for shifts of more than eight hours at a time. For such quantities, the price of the salt is a considerable factor in determining how much money needs to be invested in the storage system. About three months go past before the storage system begins operation. “The system set-up demands much experience in dealing with the properties of molten salt. For example, the salt dissolves graphite seals or creeps along the pump shafts”, explains Andrew Lochbrunner, Process Engineer with Bertrams Heatec.

The Swiss firm offers the entire storage system from one source – from the planning stage through to installation. The system’s individual components, such as heat exchangers and pumps are not produced directly by Bertrams Heatec. The company has frequently worked in cooperation with its suppliers in the field of conventional molten salt systems over many decades. And this business model can already record it’s first success story: Bertrams Heatec has the exclusive assignment of planning a thermal storage system for a Spanish 50-megawatt parabolic trough power station. “We are confident that we will be able to complete delivery of this contract in 2008”, says Steven Koning.



TURNING LIGHT INTO STEAM

SOLAR POWER PLANTS

Parabolic mirrors capture solar energy and concentrate the heat radiation onto dark-coloured absorbent pipes, through which a special oil flows. The heated oil makes water evaporate via a heat exchanger. This steam drives a turbine with an attached generator. In order to be able to also use solar power at night, molten salt masses are integrated in the system. They are especially good at storing heat and they allow oil to be permanently heated.

EXPERTS IN MOLTEN SALT

At temperatures of well over 500 degrees Celsius, molten salt is a suitable heat transfer medium in various chemical processes – for instance in the production of melamine and aluminium oxide, or the concentration via evaporation of sodium or potassium hydroxide. The Linde subsidiary, Bertrams Heatec AG, is a leading specialist in the design, supply and construction of systems that reliably transfer process heat. Among other things, the Swiss firm utilises salt mixtures with a melting point of 142 degrees Celsius (when new). These then remain liquefied under operating conditions. The company had a turnover of about 32 million Swiss francs in 2007 – which is roughly 20 million Euros.

The German Aerospace Centre (DLR) predicts that renewable energy will largely replace fossil fuels in Mediterranean countries by 2050. As part of this phenomenon, thermal solar power plants should supply twice as much power as wind, photovoltaic, geothermal and biomass combined. American scientists have also outlined a detailed concept for their country to meet about 70 percent of its electricity demands using solar power by 2050. Until then, every newly-built solar power plant will help the Earth's climate by reducing greenhouse gases. For each 50 megawatts of output at a solar plant that replaces a conventional gas and steam turbine plant, around 95,000 tonnes less carbon dioxide will be released into the atmosphere.

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Frank Frick holds an advanced chemistry degree and works as a freelance science journalist in the Bonn area. His work has appeared in the "Frankfurter Allgemeine Zeitung", "bild der wissenschaft" and "Handelsblatt".

LINKS:

www.desertec.org
www.bertrams-heatec.com

Spanish sun farm: *In Granada Province, parabolic mirrors supply up to 200,000 people with solar power.*

Using heat optimally: *The heat recovery boiler's pipelines heat both liquid and gaseous media to high temperatures.*

Interview: Dr Johannes Lambertz on brown coal, CO_2 scrubbing and the future of fossil fuel energy supplies

"BROWN COAL IS VITAL TO THE ENERGY MIX"

RWE Power is working with BASF and the Linde Group to develop new methods of separating CO_2 out of the combustion gases produced by coal power plants. As part of this current collaboration they intend to build and operate a pilot plant at RWE's Niederaussem brown coal power plant site. "Linde Technology" spoke to Dr Johannes Lambertz, CEO of RWE Power AG, about the prospects for CO_2 scrubbing and about the energy supply of the future.

Image source: RWE Power AG

Energy policy is one of the issues being publicly debated most fiercely at the moment. The German energy agency, dena, predicts that in accordance with a current study, around 12,000 MW of required capacity will be lacking in 2020. Can this gap be breached? And if so, when?

You're right – energy policy is attracting stronger interest than almost ever before. This has a strong, direct effect on large energy suppliers.

Many debates are however conducted very emotionally. So, first of all, I see it as a great challenge to make the discussion objective once more. It shouldn't be about spreading panic. But anyone who has legitimately dealt with the subject, as the dena agency has, can't help but realise that we will be confronted with problems in the foreseeable future. The 12,000 MW of power plant capacity required, as stipulated by dena, equates to the output of between 12 and 15 large power plants.

That means that sooner or later, if we don't build any new power plants, we could see capacity bottlenecks. As an energy producer, RWE Power stands for efficiency, sustainability, the development of environmentally friendly technologies and a broad energy mix. This mix, which guarantees both clean and reliable electricity supplies, has powered Germany very well in the past. We will therefore do well to also stick to this strategy in future.

At the moment, RWE is building a new brown coal power plant in Neurath, called BoA 2 and 3. How is this project compatible with the EU's climate protection targets and the minimisation of CO_2?

The EU and Germany have set themselves ambitious climate targets. As the largest energy provider in Germany, RWE is aware of its responsibilities. We want to contribute to making these targets achievable. Yet enormous investments are needed for this purpose – and only financially strong companies that also possess the necessary expertise are capable of transactions on such a scale. We are doing our part and will continue to do this in future. In Germany alone, we will invest about five billion euros in the construction of new power plants by 2012. The new double turbine unit plant in Neurath counts as the most modern brown coal power plant in the world. With over 43 percent efficiency, the 2,200 MW plant saves about six million tonnes of CO_2 annually in comparison to older plants, while producing the same amount of electricity.

Why is RWE sticking with brown coal as an energy source?

As I already mentioned, we advocate a broad energy mix, especially with respect to the compatibility of economic efficiency and climate protection. Brown coal is the only local, subsidy-free source of energy. It secures 50,000 jobs in Germany and reduces our dependence on imports. This is an aspect that plays an increasingly important role in current global raw material trade developments. This is also the reason why we see brown coal – which secures 25 percent of German electricity supplies – continuing to be a vital component of the energy mix. In order to fulfil the climate protection demands, we have to further optimise the methods of power generation from coal. RWE has many such projects in place. One example is in fluid bed drying, called FBD for short. We have built our first prototype unit to dry out brown coal at our Niederaussem location. FBD methods alone have increased our efficiency by about 4 percent to a rate of 47 percent. That's a brand new dimension of power generation from brown coal.

Energy expert:
Dr Johannes Lambertz,
CEO of RWE Power AG

CO_2 scrubbing: *A CO_2 capture pilot plant should start operating in 2009 at RWE Power's Niederaussem lignite power plant.*

Nevertheless, CO_2 is still produced during power generation. What do you do about that?
To be able to reach the climate targets stipulated in policy, it's imperative that we separate, capture and store CO_2. RWE is taking the lead in this kind of action. We have just recently announced that we want to build the first industrial power plant featuring built-in coal gasification, CO_2 capture, transport and storage (CCS) facilities in Huerth – near Cologne. With our ambitious timeline, we intend to be finished by the end of 2014. This technology would then be ready for the start of production as of 2020.

You are now going to build a pilot plant for CO_2 scrubbing in Niederaussem along with BASF and the Linde Group. What are the aims of this collaboration?
We begun with the pre-construction provisions and arrangements this past summer. Operations should begin next year, once the pilot plant is connected to the generating unit. Comprehensive tests are planned for further process optimisation. The pilot phase is scheduled until 2010. After that we should be able to give the green light to build a large demonstration plant. Pilot and test installations serve to facilitate the industrial development of CO_2 scrubbing. I'm very happy to have found a competent, medium-sized company in Linde-KCA Dresden (part of the Linde Group), which will build the pilot plant. It's our aim to work with the Linde Group and BASF to be able to retrofit existing generating units and bring carbon sequestration technology into operation.

How can one imagine the CO_2 scrubbing process?
At the new pilot plant, CO_2 will be separated from the flue gas by chemically binding it to a liquid at low temperatures. In a device known as a desorber column, the CO_2 is then released out of the scrubbing liquid by way of an increase in temperature. After that, the CO_2 is available in its pure form. This is how we would like to reduce the proportion of CO_2 in flue gases by 90 percent.

How much has been invested in the development project?
RWE Power has allocated a budget of roughly 80 million euros to the entire development project, including the construction and operation of both the pilot plant and the demonstration plant.

What are the advantages of CO_2 scrubbing?
This technique would open up the opportunity not only for us, but also for developing countries with their own coal deposits, to convert coal into electricity more efficiently and in a more environmentally friendly way. CCS technology is an effective tool for climate protection that is not only applicable to power plants. With the relevant modifications, this technique could be used in all industrial processes that are associated with high CO_2 emissions. Some examples are the steel industry, the cement industry or the chemical industry. I believe it's important that energy providers and industry join together to lead the way by advocating the development and implementation of CCS technology. RWE is already laying out all its modern coal power plants in such a way that they can be retrofitted with CO_2 capture and storage facilities.

The so-called CCS method sounds very promising. As yet however, no underground CO_2 storage options have been found. Therefore, what are you doing with the greenhouse gas at the moment?
According to current plans the CO_2 separated at the pilot plant will be put back into the BoA's normal flue gas flow. Since the Niederaussem pilot plant is only experimental and not a production plant, there are no possible uses for the CO_2. On the other hand, the CO_2 that will later be captured in the demonstration plant will be stored underground as soon as the necessary storage infrastructure is available.

What kind of government support do such projects receive?
In order to implement ambitious projects like these, financial incentives are necessary – especially during the pilot plant and demonstration plant phase – so that companies can continue to invest in research and development. Our ambition to make the CCS method's technology market ready by 2020 satisfies the targets set by the European Commission and the German Federal Government. So the Federal Ministry of Economics and Technology is sponsoring the CO_2 scrubbing pilot plant in Niederaussem to the value of around four million euros. We are happy that the federal government is prepared to actively champion the further development of CO_2 capture and storage, as evidenced by the allocation of this funding. For RWE, this technology is the key to climate compatible power generation from coal.

Sensitive patients: *A stay in hospital or a visit to the doctor provokes great fear in many children, who are afraid of needles or painful treatments. By using a special mixture of gases for the treatment of pain in children, it's possible to break the cycle of fear in a simple way.*

Technique for pain relief in children

A MIXTURE TO REDUCE FEAR

No one likes pain, and children are often especially afraid as soon as they see a doctor with a needle. But for many, therapies that include hypodermic needles, catheters, rehabilitation procedures, blood tests or wound dressings are unavoidable. Linde Gas Therapeutics is now helping to increase interest in a pain-relieving agent that is probably underused in children: LIVOPAN®, a 50/50 mixture of nitrous oxide and oxygen. Medical studies have shown that LIVOPAN® is a safe and effective therapy, as optimal administration alters pain pathways within the body.

↑ Image source: Corbis
↓ Author: Cornelia Stolze

They bump into the corners of furniture, fall off the swings or off their bikes – for children, small aches are part of everyday life. However in many children's lives there is intense pain, which can be an ongoing burden. Each year, all over the world, hundreds of thousands of boys and girls endure painful procedures in clinics, surgeries and emergency situations: for instance, broken bones may need manipulation or doctors may have to subject severely ill patients to bone marrow or spinal fluid extractions, repeatedly perform injections or take blood samples.

Despite advances in medicine, pain is by no means always optimally alleviated – even in industrialised countries. One of the reasons for this, according to paediatrician Raymund Pothmann of the Centre for Child Pain Therapy in Hamburg, is that "children's pain is often not taken seriously, is considered over-exaggerated or not abnormal and therefore deemed unnecessary to treat". The consequences of this can be that many children develop strong fears of ongoing treatments, some of them consistently trying to avoid doctors, injections, or surgery, all of which may be vital for a healthy recovery. In order to be able to carry out the treatment in spite of these fears, doctors and nurses sometimes take drastic measures. Many hold the children down or otherwise restrain them until the procedure is over. Such measures have long been known to be a contributing factor in a vicious cycle of fear and pain in which many patients become caught up. The result is pain memory due to the nerve cells of the affected children becoming hypersensitive. Experiences that usually only result in minor pain, such as a small sting, will then produce a greatly exaggerated pain sensation.

WHENEVER CHILDREN HAVE ALREADY HAD AN EXCRUCIATING EXPERIENCE DURING MEDICAL PROCEDURES, THE FEAR OF RENEWED SUFFERING IS OFTEN WORSE THAN THE PAIN ITSELF.

In many such cases, one simple, non-invasive and safe procedure can break the cycle. In the past few years, several studies have shown that a short treatment using a specific medical gas mixture from Linde Gas Therapeutics not only relieves the pain that young patients experience during medical procedures but also eliminates the fears of most of those children. The gas mixture, LIVOPAN® (known as ENTONOX®, in some countries), is made up of equal parts of nitrous oxide (also known as laughing gas) and oxygen, and its administration can be controlled by children on their own once they understand and have been shown how to use the gas properly.

Low pain sensation with LIVOPAN®

In a study of the use of a 50/50 nitrous oxide/oxygen mixture in children having painful procedures, pain scores, as noted by the children themselves, were very low with a median score of only 9 out of 100. In addition, 93 per cent of the children who had inhaled the mixture during treatment later reported that they were prepared to undergo further treatments if they were needed. "It is possible to undertake many treatments that are necessary, but would otherwise be very difficult because the subjects would just be too afraid and feel too much pain during them", explains

Easing the pain:
The LIVOPAN® gas mixture (also known as ENTONOX® in some countries) consists of equal parts nitrous oxide – also called laughing gas – and oxygen. After receiving instructions, even primary-aged children are able to independently control its supply through a mouthpiece, thus relieving the dreaded pain of such things as needles.

Dr Martin Jöhr, anaesthetic specialist at the Kantonsspital hospital in Luzern, and author of a textbook on child anaesthesia.

A U.K. based specialist, Dr Vaughan Thomas, has had the same experience many times at the Southampton General Hospital. He employs nitrous oxide/oxygen mixtures in the treatment of over 300 patients annually. It doesn't matter whether the procedure is to remove a catheter from the chest after a heart-lung operation, or to aid physiotherapy to re-mobilise a leg that has been operated on, Thomas notes that "whenever children have already had an excruciating experience during medical procedures, the fear of renewed suffering is often worse than the pain itself."

Takes effect after a few breaths

There are several equally important reasons as to why LIVOPAN® is especially useful for pain relief in children. The gas is not only easy to administer, it also works very fast. In a matter of minutes after the child begins inhaling the gas through a mouthpiece or face mask, it passes from the lungs, through the bloodstream and into the brain. After four to five breaths the gas begins to work and after a few minutes maximal pain relief occurs so that pain is reduced, the child relaxes and becomes sleepy, but is still conscious. Its effect can also be stopped just as quickly. As soon as the child stops inhaling, the body begins to expel the gas, again via the lungs. A few minutes later the effect of the gas has dissipated and the patient is completely back to their usual conscious state.

Other drugs are available to provide sedative effects and reduce anxiety during procedures, however their effect cannot be as well regulated as LIVOPAN® and they do not specifically provide pain relief. Their sedative effects, in some cases, should disappear within five to ten minutes after stopping administration, but the fact remains that they all have to be administered intravenously. This is an added unpleasant experience that the children can be spared via the use of a non-invasive technique involving the simple inhalation of LIVOPAN®.

The history of nitrous oxide use in medicine

The first doctor to use it as an analgesic was the American dentist Horace Wells. He administered the gas as a painkiller while extracting teeth in 1844 and so the foundations were laid for its use in clinics throughout the world with many hospitals having a permanent pipeline supplying nitrous oxide to their operating theatres.

In 1965, BOC, which is now part of the Linde Group, brought a ready-to-use mixture of equal parts of nitrous oxide and oxygen onto the market. The ready-to-use product was available to doctors and nurses and allowed nitrous oxide, as a premix, to be used outside the operating theatre, in the treatment of outpatients, during which the patients stayed awake and could regulate the gas inhalation themselves. Since 1965 in Britain, millions of women have given birth with the assistance of a nitrous oxide/oxygen mixture. For many people who have had to undergo otherwise uncomfortable examinations, such as a colonoscopy or painful bandage changing after being severely burnt, LIVOPAN® has made these procedures bearable.

Nitrous oxide use, for many years in decline, is now experiencing a resurgence in popularity as a safe and effective analgesic for patients of all ages when used appropriately, according to instructions and for a short time. The medicine is inhaled only a few times, and only for the length of the procedure, usually about 10 minutes. Some critics fear that daily contact with it could be detrimental to people such as healthcare personnel and there are in fact indications that large amounts of nitrous oxide, above recommended exposure levels, can have effects such as changing the metabolism of folic acid, which can cause specific changes in the blood count.

With the introduction of improved intravenous anaesthetics, this classic from the 19th century seemed to have run its course in

"WITH LIVOPAN® IT IS POSSIBLE TO UNDERTAKE MANY TREATMENTS THAT ARE NECESSARY, BUT WOULD OTHERWISE BE VERY DIFFICULT BECAUSE THE SUBJECTS WOULD JUST BE TOO AFRAID AND FEEL TOO MUCH PAIN DURING THEM"

Dr Martin Jöhr, anaesthetic specialist, Kantonsspital hospital Luzern, Suisse

the eyes of many anaesthetists, relates Dr Martin Jöhr. "In the past few years, many a young, dynamic head doctor has therefore simply torn the nitrous oxide pipes right out of his or her clinic or just turned them off." This phenomenon proves that even medical procedures are subject to fashion. "Laughing gas certainly did not become superfluous", says Jöhr, "but for many doctors it had suddenly become old-fashioned."

However the critical discussions took place more than twenty years ago and many of the issues of the day have long been solved by technological advancements. The introduction of special breathing masks and mouthpieces, which only release the gas mixture when the patient actively inhales, has led to the possibility of using the gas on children from the age of four, when children are generally accepted as being able to understand and follow instructions. Practitioners are trained to ensure that the child is guided and instructed in how to use the gas and to explain how the treatment will progress so that he or she is allowed to stop breathing the gas at any stage if it becomes uncomfortable.

In addition to these advances in administration, for the past few years both permanently-installed and mobile aspiration systems have been developed, which capture the nitrous oxide exhaled by patients so that it can later be put into a catalytic chemical reactor, where it is then separated into its harmless elements: nitrogen and oxygen.

In Sweden, where Linde Gas Therapeutics recently completed a one-year pilot project featuring targeted training for medical practitioners, many sceptics have already discarded their earlier reservations about the use of nitrous oxide. "The resonance with the participating doctors and nurses was extremely positive", says Anders Frummerin, Product Manager for the Northern European Region at Linde Gas Therapeutics in Lidingö, Sweden. "We will therefore soon be able", he asserts, "to start projects in many other European countries in order to also improve pain relief in paediatrics there."

AUTHOR:

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LINKS:

www.chw.edu.au/parents/factsheets/nitrousj.htm
www.rch.org.au/kidsinfo/factsheets.cfm?doc_id=11149

Linde welding technology for highly stressed steel components

THE WARM-UP EXPRESS FOR WIND ENERGY PLANTS

Wind energy plants are constantly generating higher outputs. Offshore operations are particularly exposed to high stress situations, which demand massive structural components. In order to be able to weld the thick parts, they must be carefully pre-treated and post-treated. Development engineers from Linde have now designed a quick and efficient heat treatment system for the gigantic steel parts.

← Author: Tim Schröder
→ Image source: Getty Images

The gale blares and thrashes. Huge waves build up, forming breaks as high as houses. They violently crash against the slender, white tower that protrudes 80 metres above the water's surface. The steel vibrates, but it holds. Offshore wind energy plants have to withstand enormous loads. In a few years' time, several hundred wind turbines will be operating in German waters – each with a capacity of up to five megawatts. In summer 2008, work already began on building the world's first deepwater offshore wind farm north of Borkum. At least another 20 projects have been licensed for the North Sea and Baltic Sea. High quality steel and the most up-to-date production methods are necessary for wind farms operating under such harsh conditions. In this context, welding becomes particularly important, because the steel towers and mighty support stilts that the giant turbines are composed of, are manufactured from several steel segments. A faulty weld seam on a single component can have catastrophic consequences. Cracks or dangerous saltwater corrosion could lead to the enormous steel components' rupture. The seam must therefore be perfect.

HIGH QUALITY STEEL AND THE MOST UP-TO-DATE PRODUCTION PROCESSES ARE NECESSARY FOR OFFSHORE WIND PARKS.

Fine flames for steel weld seams

However, welding is a complicated affair. To begin with, the thick metal pieces need to be pre-heated; if this is not done, the large, cold steel plates will lose heat too quickly, and the metal will not be completely melted in the welding zone. A secure connection is thereby impossible. Pre-heating will also prevent the build-up of cold cracks, which can occur due to hydrogen exposure or internal stress in the component. This is particularly important when treating high strength steels. After the weld, these materials therefore need to be post-heated for around two to three hours. This way, any rogue hydrogen atoms in the weld seam can be diffused.

In the case of freight containers, fully automatic systems for the heat treatment of weld seams have been in place for some time already. But for segments of wind turbine towers – steel plates which are up to four meters wide and 12 centimetres thick – such systems are as yet nonexistent. The Rostock steel experts, EEW Special Pipe Constructions, therefore turned to Linde in Munich for assistance. Heat treatment systems have long been developed there. "For manufacturers who have to maintain a fast production speed, it is vital that they quickly reach a pre-heated temperature of greater than one hundred degrees Celsius", says Ronald Steusloff, Project Leader at Linde in Munich, "In this way they save time." The experts aim to construct an especially large system which heats seams of several metres in length in no time at all. Steusloff uses special burners with the oxy-fuel gas acetylene to carry out this express warm-up. This is because – as opposed to a propane gas flame, for instance – this gas burns with a very precise, pointed, so-called 'primary flame cone', which drives the heat directly into the metal. Furthermore, the flame temperatures that can be reached with the oxy-acetylene torch used – approximately 2,400 degrees Celsius – are significantly higher than those achievable using other oxy-fuel gases in

WIND ENERGY ON THE HIGH SEAS:

The European Wind Energy Association (EWEA) estimates that by 2010, 10,000 megawatts of offshore energy output systems will be installed in Europe, increasing to 70,000 MW by 2020. According to the EWEA, by the end of 2007, the turbines of wind energy plants were already rotating off the coasts of Denmark, Sweden, the Netherlands, Britain and Ireland, with a total output of almost 1,100 MW. The German Federal Environment Ministry anticipates that in the year 2030, offshore wind energy installations with an output of up to 25,000 megawatts will be achievable in German marine territories.

combination with air. The new burner can thereby heat the steel up twice as fast as conventional methods.

Gas burners according to the modular principle

Similar to one on a gas stovetop in the kitchen, the burner developed for Rostock has several burner nozzles. But these nozzles do not form a ring; they are rather placed on a five-metre-long pipe, out of which a flame shoots at intervals of a few centimetres. The challenge for Steusloff and his colleagues: They had to design the long burner in such a way that the same amount of gas comes out of each nozzle, allowing for a uniform temperature throughout. It was also important to keep the number of gas feed pipes low, in order to reduce complexity in construction. In collaboration with gas flow experts from the Technical University Dresden, the experts at Linde designed a unit assembly system comprised of segments for almost any burner length. This special design facilitates the steady flow of gas.

For the Rostock plant, the Munich team has designed a burner suited to so-called longitudinal welds, as well as a curved segment burner for circular steel segments (circumferential welds) – with a diameter of up to seven metres. "Most companies work on pipes with a maximum diameter of 1.2 metres. At our Rostock facility we start at 1.6 metres", says Steusloff. Both machines are operated fully automatically. This is primarily necessary for the post-weld heating, which should begin immediately after the welding. The new Linde acetylene burners are fitted with several temperature sensors, which regulate the heat precisely. In addition, the burners automatically turn on or off, keeping the temperature within the desired range during the post-heating process. Benefits of such precise process controls include not only the required quality assurance, but also a more economical use of acetylene as a fuel gas.

EEW Special Pipe Constructions has long delivered components for offshore construction in the gas and oil industries. The order books are so full, that the technicians at Linde have to install their acetylene burners while the plant is running. Moreover, Udo Niepel, Technical Head at the Rostock plant, expects a boom in wind energy system segments in 2009. "We anticipate very large production runs. That is why we depend on a particularly fast and reliable system for pre- and post-heating." Niepel is convinced that the Linde system's massive specifications will cope with the challenge.

AUTHOR:

Tim Schröder is a freelance science journalist from Oldenburg. He writes about natural science and related research for the "Financial Times Deutschland", "Frankfurter Allgemeine Sonntagszeitung", "Neue Zürcher Zeitung" and "Mare".

LINKS:

www.dewi.de

www.gl-group.com

Freezing for biotechnology: *The International Space Station, ISS requires special cooling equipment to store biological samples and perishable materials. This is the purpose served by MELFI – a special refrigerator using Linde technology.*

REFRIGERATOR IN ORBIT

Linde technology for scientific space missions

↑ *Image source: NASA*
↓ *Author: Bernd Müller*

It's cold in space – but not cold enough for the Herschel infrared observatory. That's why Linde is building a cooling unit to cool the sensitive measuring instruments to temperatures near absolute zero. There is also a Linde freezing system on board the international space station, ISS. It keeps organic samples fresh at temperatures of less than minus 80 degrees Celsius.

Electronic controls, automatic ice makers and maybe internet access coming soon – modern refrigerators come with all the trimmings. But none of these high-tech household fridges can reach temperatures near minus 100 degrees Celsius or keep working at zero gravity to boot. Such a refrigerator is useless for the average consumer, unless he or she is an astronaut currently working on scientific experiments who lives on board the International Space Station, ISS. Because since July 2006, the freezer named MELFI (Minus Eighty Degrees Laboratory Freezer for the ISS) has been inside the ISS and has been orbiting 350 kilometres above the Earth once every 92 minutes. The 'cosmic cooler' was transported there aboard the Discovery space shuttle and the German astronaut Thomas Reiter and his colleagues activated it, so that samples from biological experiments could be stored there.

Two kilometres of pipes for nitrogen

MELFI was developed and built by the Linde Engineering Division and the EADS space technology company, Astrium, on behalf of the European Space Agency (ESA) – and has nothing in common with the fridge in your kitchen. Instead of a large door, MELFI contains four cylindrical cooling chambers that, like thermos flasks, are insulated against the heat in the space station by way of a vacuum wall, thick insulating layers and a round bayonet lid. Each of these four chambers has a volume of 75 litres and in turn contains four drawers, which are pushed into the cylinder like oversized pieces of cake. The four cylinders, the electronics and a spare parts compartment are mounted on a shelf that's only one metre wide and two metres high – the standard measurement of all ISS fixtures.

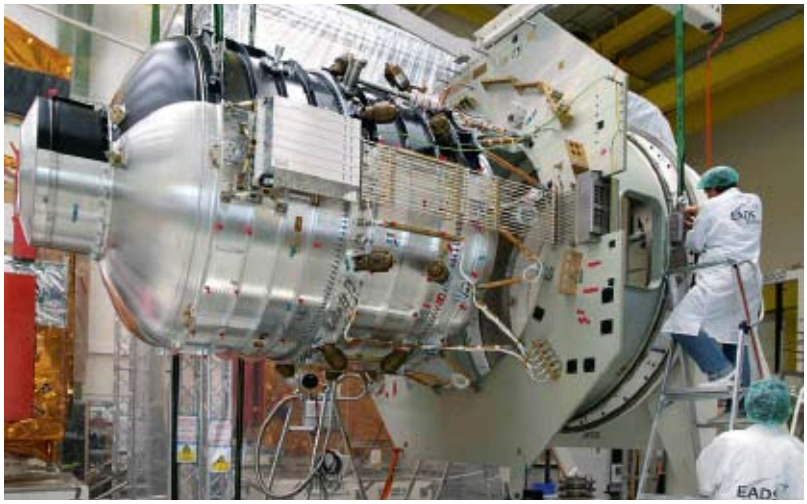
At the core of every refrigerator is its cooling unit. It compresses a gas that emits energy via a heat exchanger and refrigerates via expansion. This may be something that has become commonly available technology on Earth since the refrigerator was developed by Carl von Linde more than 130 years ago, but in the case of MELFI, it's a high-tech product at the limit of what is technically possible. The reason for this is that space-specific demands come with many special problems, first and foremost, weightlessness. But they also demand extreme resilience and low energy use in a restricted space. A practical example of this is the cold box, which contains a refrigerator that works according to the thermodynamic 'Brayton cycle' and pumps high-purity nitrogen through a 2,200 metre long pipe system.

THE MELFI FREEZING SYSTEM IS DESIGNED FOR 15 STARTS AND CAN ORBIT IN SPACE FOR A MINIMUM OF FIVE YEARS.

"The electric drive runs in absolutely contact-free gas bearings to avoid abrasion and wear, which would contaminate the gas cycle and reduce its life expectancy to less than the planned 15 years", explains Horst Rüdiger, who is in charge of development work for the MELFI space mission at the Linde Engineering Division, Pullach. The compressor and a turboexpander are coupled to the motor shaft, which rotates at up to 90,000 revolutions per minute. The cryogenic nitrogen flows through four-walled concentric pipes into four so-called 'cold fingers' within the cold storage cells, and then transports heat from the frozen goods back the same way. "The 'cold finger' trick is necessary because at zero gravity, there is no convection current as there is in a conventional refrigerator, which could distribute the cold air inside the fridge", says Rüdiger.

The biggest technical and manual challenge that was faced by engineers at Linde was the manufacture of the process heat exchanger. It consists of 480 stainless steel pipes, measuring 2,200 meters in total length, but with a diameter of 3 mm and wall thickness of only 0.15 mm – as thin as straw. These little pipes are coiled around a cylinder containing the Brayton machine at its core. It took three months to wind and weld the "stainless steel straws". The tech-

HERSCHEL: THE INFRARED OBSERVATORY



HERSCHEL FACTS

The telescope will orbit in space about 1.5 million kilometres outside the Earth's orbit.

CARRIER ROCKET:
Ariane 5 ECA (along with the Planck satellite)

MISSION DURATION:
3 years (with a possible extension of 1 year)

TOTAL MASS OF THE SATELLITE:
at launch: approx. 3,300 kilograms

TELESCOPE DIAMETER:
3.5 metres

EXTERIOR DIMENSIONS OF THE SATELLITE:
Height: 9 metres
Diameter: 4 metres

nicians weren't allowed to make any mistakes because even the tiniest leak would interfere with the vacuum and thus impair its cooling efficiency. Despite its delicate inner construction, MELFI is extremely sturdy and designed to withstand 15 starts, a ten year life span and at least five years of continuous operation in orbit.

Genetic testing at zero gravity

MELFI's four cooling chambers can be set to different temperatures independently from one another. The Linde refrigeration system can even reach much lower temperatures than the minus 80 degrees Celsius demanded. Astronauts enthusiastically report that it has reached minus 97 degrees. The crew regularly freezes blood and urine samples in MELFI or stores cotton buds with swipe samples from their skin and from objects in the space station. In doing so, they wish to verify which bacteria exist on board the space station. In a NASA experiment, the astronauts spent months investigating genetic changes in living cells under conditions of weightlessness. So that they don't defrost, the perishable goods were put into individual drawers with cold packs before the flight back to Earth.

There are now three MELFIs, two of which were delivered to NASA and one to the Japanese space agency, NASDA (now known as JAXA). "MELFI has become a coveted item for exchange between the various international space research partners", says Rüdiger. Because in return for the ESA providing access to the Linde freezing system, the Americans allowed the Europeans to use the ISS before they were able to use their own Columbus laboratory – which was docked to the ISS in February 2008. The Japanese will in turn deliver the equipment for the ISS's further assembly. Coldness therefore brings space researchers together outside the Earth's boundaries.

In the far-flung parts of the universe, it's much colder than it is inside MELFI. If astronomers want to observe objects whose temperature is only a few degrees above absolute zero – such as gas or dust clouds – they can't simply look through a telescope. Because such matter usually emits no visible light, but only weak, long-wave infrared radiation. Since the view of this is blocked by the water vapour in the Earth's atmosphere, the stargazers have to move their observation equipment to space if they wish to observe such phenomena as the formation of galaxies. The peak of these ambitions will be achieved by the Herschel infrared observatory, named for the German-British astronomer, Frederick William Herschel, who discovered infrared radiation in 1800. The telescope, which is meant to record wavelengths between 60 and 670 micrometres, is set to begin its four-month voyage to its operation site in April 2009, when it is due to depart with an Ariane V rocket from the CSG spaceport near Kourou, French Guiana. It will then orbit the sun at a distance 1.5 million kilometres outside the Earth's orbit – or about five times as far as

HERSCHEL'S MISSION

The wavelength range covered by Herschel, the European infrared observatory, closes the gap between the light spectrum visible from the ground and that which has been covered by previous space missions. Within this spectral range lies the maximum radiation of so-called 'black bodies' with a temperature between five and 50 degrees Kelvin. Since Herschel is going to investigate this wavelength range for the first time, a plethora of new discoveries are expected.

Technology for star gazers:
Astronomers want to use the Herschel infrared observatory to observe objects in space whose temperature lies only a few degrees above absolute zero. Cooling technology from Linde will help the telescope achieve its extraordinary precision in space.

MELFI: THE HIGH-TECH FREEZER

Freezer:
Samples from biological experiments will be stored in there.

the moon. From its position there, it will deliver findings on the formation and development of stars and galaxies located billions of light years away. While doing this, Herschel will always remain under the protection of the Earth's cool shade and a large metal shield mounted in front of the 3.5-metre mirror made from silicon carbide. "Because when observing cold objects, one must block out distracting sunlight. And in this way, the astronomy satellite will also be protected from excessive thermal impact", says Rüdiger, who also looks after the Herschel mission at the Linde Engineering Division.

Helium for cool optics

But even the telescope itself, its energy supply and instruments radiate heat. This would register as disturbing signal noise, lowering measurement sensitivity and thereby negating all measurement efforts. The design engineers at ESA have therefore come up with the solution of cooling parts of the apparatus with helium, and thus eliminating noise. For this purpose, Herschel contains a 2,200-litre tank from which about 2 milligrams of the minus 271-degree Celsius liquefied helium will evaporate each second.

Supplied with helium for three years

A small helium tank, which carries out the cooling on the ground, has to be emptied shortly before takeoff. That's taken care of by a Linde heating element, which brings the helium to ambient temperature without any danger of freezing.

The smallest but most necessary part of this apparatus is the so-called phase separator. It ensures that tiny amounts of gaseous helium flow out of the tank to cool the optical components, while the liquid helium remains inside the tank.

If everything goes to plan, the helium supply should last for three years – or as for the ISO mission – even longer. The astronomers will make intensive use of the given time frame in order to gain as many insights as possible into the formation of new galaxies.

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Bernd Müller is a freelance technology journalist in Esslingen. Amongst other work, he regularly writes for "bild der wissenschaft" and "Focus".

LINKS:
www.esa.int
www.sci.esa.int/science-e/www/area/index.cfm?fareaid=16

HOT FURNACES, EFFICIENTLY LIT

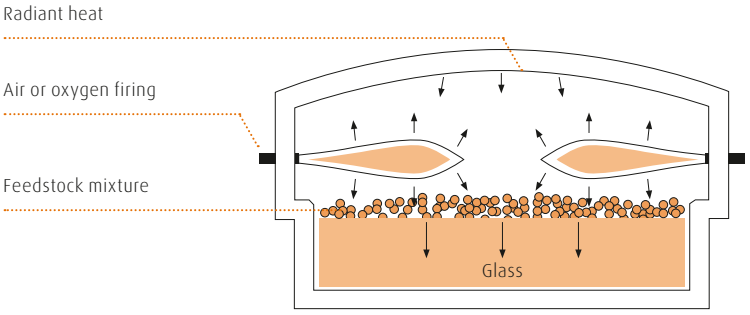
New melting technology makes glass production more cost-effective

Glass is a growth market: Demand for it is dramatically increasing worldwide. But its production is energy intensive, and therefore cost intensive. Linde's engineers have developed a firing system for glass melting furnaces which allows the sought-after material to be produced more quickly while saving energy.

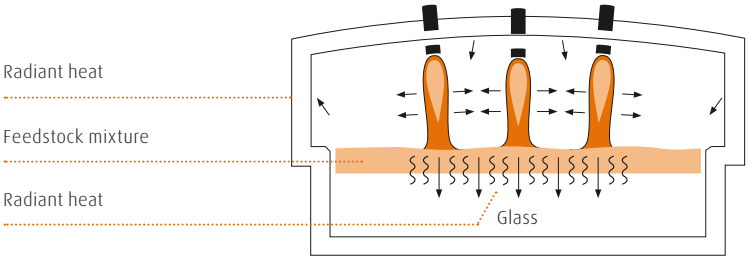
Glass "goes through hell" during its manufacture – through blazing flames, all-consuming heat and sizzling containers. What seems like a horror scenario is actually the birthplace of window panes, bottles and high-quality lenses: a glass melting furnace. In fireproof stone furnaces with tops as high as houses, flames metres high transform a mixture of sand, soda and chalk into white-hot, glowing molten glass at temperatures of around 1,500 degrees Celsius. The furnace inferno must be well-calculated so that this synthesis succeeds and the continual process doesn't stall. On one side of the furnace, conveyer belts are constantly delivering new 'ingredients', and on the other side, the molten glass flows out through a gutter system and is cooled to 1,000 degrees Celsius to shape it into the desired form. Depending on which fabrication steps are then taken, the clear material can end up as container glass, plate glass or specialty glass. A large plate glass manufacturing plant produces up to 700 tonnes of glass per day. And that requires energy – lots of energy. The usual requirement is approximately 4 to 9 gigajoules per tonne of glass – depending on the size and efficiency of the furnace. And just as in many other manufacturing processes, there is also great potential for energy savings to make glass production more efficient.

This was one of the starting points that led the engineers at Linde to design efficient burners for glass furnaces, which have now developed into a real success story. Instead of being built into two opposite side walls, as in the past, the new model has burners built into the furnace roof. They are thus capable of shooting their flames directly onto the raw materials to be melted into glass. "This way,

Classic horizontal burner installation



CGM™ Vertical burner installation



INNOVATIVE GLASS MANUFACTURE

Glass melting plants operate more effectively, more economically and to a higher standard with the new CGM™ melting technique (Convective Glass Melting). This is the first time burners have been installed in the roof of the furnace's heating chamber, which then aim the oxy-fuel flames directly at the feedstock mixture in the furnace. This melts the glass faster than conventional firing from the sides. CGM™ was developed by BOC – now part of the Linde Group – and has been on the market since 2004.

INNOVATIVE CGM™ TECHNOLOGY FOR THE GLASS INDUSTRY

↑ Author: Andrea Hoferichter
↱ Image source: Schott AG

heat is conveyed especially effectively. It saves energy and shortens the production process drastically", says Hans Mahrenholtz – who has many responsibilities in the Linde Gases Division, one of which is glass melting technology – as he lists the advantages of this new method. While the feedstock mixture used to be heated only by the radiant heat of the flames and by the heated furnace walls, the heat is now transferred directly. "After all, if you touch the flame of a lit match, it's also considerably hotter than if you just hold your hand next to it", offers the Linde engineer to illustrate the difference. Furthermore, due to a larger temperature difference between the upper and lower layers, molecules from the forming molten glass move steadily, intermingling better and thereby transferring the heat to the colder layers of the molten mass faster. These so-called convective components of the heat transfer gave the patented process its name: 'Convective Glass Melting' or CGM™ for short.

Another determining factor of the burners' efficiency is the gas mixture that fuels them. Instead of operating the burners with the traditional mix of fuel gas and air, engineers at Linde swear by a mixture of fuel gas and pure oxygen. "On the surface of it, using oxygen may appear more expensive, however it pays off fast because the method is more effective", explains Mahrenholtz. After all, air contains about 79 percent nitrogen by volume, which is unused in the melting process, but which nevertheless must still be heated to the temperatures required for the melting process. That's not only energy intensive – it also creates a large amount of polluting nitric oxides. With this new technology, such emissions can be reduced by more than ten percent. Removing the nitrogen without substitution leads to an overall lower level of gas pressure in the furnace. This reduces mechanical stress on the furnace, thereby increasing its operational life. Many glass-melting furnaces can only stay in good condition for five years before already requiring repairs. Mahrenholtz names one further advantage of CGM™ technology: "As opposed to the prevalent side brackets for the burners, installing them in the furnace roof allows room for up to four burners." That way, the melting process can be sped up even more. Glass producers can increase output by up to 25 percent in this manner. And high production rates in glassworks are in high demand. Because glass is a growing industry and global demand is enormous. Over 125 million tonnes of glass are produced annually worldwide.

The global plate glass market alone produces volumes of around 34 million tonnes a year. About 70 percent of this is destined for use as windows in buildings. Ten percent is used in vehicles and the rest is used for furniture and other indoor applications.

"At the moment, demand for glass is increasing by five to six percent each year in Europe and North America alone", reports Volker Häckh, who manages the metallurgy and glass market segment of Linde's Gases Division. And Linde's engineers are certain that production quantities will continue to increase dramatically in the coming

THE NATIVE AMERICANS' GLASS BALCONY

GLASS APPLICATIONS:

It's been possible to marvel at a spectacular glass application in the US since March 2007 – the glass observation deck called Skywalk. It belongs to the Hualapai tribe of Native Americans and offers a spectacular view of the Grand Canyon. Its floor consists of a total of 46 pieces of laminated safety glass. Both sides of the platform are each lined with a 100-metre long, curved, parapet wall which is also made from glass. The Skywalk can carry a load of almost 500 kg/m² and is supposed to withstand earthquakes measuring 7 on the Richter scale and wind speeds of up to 160 km/h. Each visitor is provided with special felt shoes, in order to avoid scratching the floor.

years – most markedly in Eastern Europe, Russia and India. Currently, because of a lack of furnace capacity, glass prices are constantly on the rise, which explains why the price of a jar of mustard or honey already depends more on the cost of the container than on the cost of the contents.

More time for glass refinement

However, the new furnace design doesn't only offer greater output, but also the ability to increase the quality of the molten glass at no extra cost. The glass required for use in modern panorama car roofs, for instance, has to be particularly high-quality, as does the glass used in large-scale, designer glass sheets and curved glazing for buildings or the glass used to make basins for particularly trendy bathrooms. "Since using CGM™ technology saves so much time in the actual melting process, glass manufacturers can spend more time on the refining process", explains Häckh. The purpose of refinement is to remove gas bubbles created during synthesis, which would otherwise reduce the glass's stability. To achieve this, the molten glass is kept at temperatures of about 1,000 degrees Celsius until no more gas comes out.

The idea to direct flames straight at the feedstock in order to increase the effectiveness of the heat transfer may have already existed for decades, but for a long time, methods were irreproducible and knowledge of advantageous flame shapes and angles was insufficient. Yet more than 40 years ago, engineers at BOC – which is today part of the Linde Group – began experimenting with furnace design by building a test furnace with a floor that could be pushed up. This height adjustment option allowed for the testing of variable distances between the flame and the glass mixture. In addition, they developed suitable simulation models that they kept comparing with their results and adjusting accordingly. Today, these simulation programs have been engineered in full detail and now help to optimally configure both pre-existing and new furnaces to suit a CGM™ burner set-up. Aside from this, Linde's furnace experts can use this sophisticated mathematical tool to develop completely new concepts that are perfectly suited to the new burner technology and to the needs of glass producers. Linde has already designed a hybrid furnace for glass manufacturers who perhaps wish to profit from CGM™ technology but want to continue using a fuel gas/air rather than fuel gas/oxygen combination for the refinement process. It features a front section fired with pure oxygen and back section fired with air.

According to Häckh, conventional glass furnaces could easily be converted to accommodate the new technology – and this could be done during operation without interrupting glass production. More importantly, such a conversion would pay off very quickly. "Because of the resulting higher production rates and energy savings, the new technology can pretty much pay for itself within six months", says the Linde glass specialist. The conversion is comparatively simple. Firstly holes have to be made in the furnace roof up above the glowing molten glass and the flames from the conventional burners. Fireproof bushings are then installed for mounting the CGM™ burners into. A tool specially developed by the engineers at Linde makes this assembly work easier to carry out.

Although the new technology's advantages are clear, its engineers have had to wait a long time for a breakthrough. "What finally led to CGM™ technology's acceptance was the combination of

"I HAVE ALWAYS HELD THAT THERE ARE MORE IMPORTANT THINGS THAN GOLD. FOR EXAMPLE, I FIND GLASS MUCH MORE USEFUL."

(Theodor Fontane)

Hot job: *When manufacturing glass components, such as a mirror mount for a telescope, the molten mass that flows into the mould measures more than 1,500 degrees Celsius.*

Heat wave: *Open flames are still often used in the production of purpose-built ampoules.*

stricter environmental protection standards, higher energy costs and a switch to new, harder-to-melt materials in the glass fibre industry", reports Linde engineer, Dick Marshall, who was instrumental in the development of CGM™ technology at BOC. Last but not least, the new furnace design has also benefitted from Linde's worldwide presence, thereby gaining access to key markets in Europe and the Middle East. Marshall concludes that, "It took a few years, but our faith in the new technology has finally paid off."

Indeed. Today there are already more than 35 glass melting furnaces worldwide that are fitted with the new technology, and their operators are more than satisfied. "We were able to increase production without any loss of quality, and to an even higher rate than what we had expected", reports Jean-Pierre Bocquet, CEO of Saint-Gobain Conceptions Verriers – the French company that is one of the world's leading glass producers. Other glass producers, such as LG, Philips Displays, and Owens Corning, as well as the well-established company, Pilkington, are also using CGM™ technology successfully. And in 2006, a licence was granted to the French company, Stein Heurtey SA – one of the world's leading suppliers of glass melting and glass manufacturing plants – which has since had equipment fitted out with CGM™ burners on offer throughout the world. And the engineers at Linde have still more irons in the fire, with ideas for innovative, custom-made furnace concepts up their sleeves that several glass manufacturers are already warming up to.

AUTHOR:

The chemistry graduate, Andrea Hoferichter, works as a freelance science journalist and is based near Braunschweig. There is no hot furnace heating her office; instead, her desk sits by a south-facing window.

LINKS:

www.glassonline.com
www.stein-heurtey.com
www.feve.org

Better protection against allergies with cleaning technology from Fred Butler®

FIGHTING MITES WITH CARBON DIOXIDE

More and more people are battling allergies, especially dust allergies. There is now a remedy in sight. And it can be applied right where the cause feels most at home. Mites and the like can be effectively eliminated long term with Deep Cleaning by Fred Butler®.

↑ Author: Caroline Zörlein
↓ Image source: Getty Images, Agentur Focus GmbH

They may be tiny, but they rob many people of their sleep. Up to 4,000 dust mites can live in one gram of bed dust. And this makes night time especially tough for hay fever sufferers. They react to the arachnids' protein-containing residues with tears, coughing and sneezing. But now these invisible pests are in for it! Working under its dry cleaning brand, Fred Butler®, the Linde subsidiary – Cleaning Enterprises – has now developed a new deep-cleaning method using carbon dioxide. This Deep Cleaning method annihilates the annoying mites – fast. It combines CO_2 cleaning with a mild wet cleaning process at 35 degrees Celsius. Tests performed by Fred Butler® along with research societies Eurofins and Allergon, have proven the effectiveness of this special wash. In the tests, the minute bed occupants were lastingly removed.

Sewn into fabric pockets, the Deep Cleaning method confronted the dust mite cultures. The trapped creatures' optimal living and growth conditions were subsequently interrupted. Even 72 days later, no living mites, eggs or larvae could be detected. "This combination of methods is especially effective. First the carbon dioxide breaks down the mite culture, and then a mild, wet cleaning procedure rinses the allergens out of the fibres", explains Moritz von Kunowski, Engineer and Director Technical and Business Development at Fred Butler®.

Although the special washing machines exert pressure of about 50 bar, this method is still easy on the textiles. They are only minimally spun, therefore only slightly stressing their fibres. "The liquid carbon dioxide that we use in the process is lighter than water and soaks gently into the fibres, because the surface tension is very low", says von Kunowski. The method is not only effective against dust mites, but also mildew – which is another well-known cause of allergies.

UP TO 4,000 DUST MITES CAN LIVE IN ONE GRAM OF BED DUST.

CO_2 is also an intelligent choice of cleaning product for difficult-to-clean items of clothing – such as shoes and leather jackets. "We clean all the difficult fabrics such as silk and cashmere, which other textile cleaners are unable to manage", says Andreas Klensch, Managing Director of Cleaning Enterprises. "That way we expand the textile cleaning market and a new market is formed outside the normal realm of competition." Even these fabrics emerge deeply cleaned from the carbon dioxide wash. "Leather needs to be entirely regreased after its CO_2 bath", says Klensch. The textile cleaners with the penguin logo are also certified by the Blue Angel label as "eco-friendly". That is because the carbon dioxide used is then not only 98 percent recycled, but there are also attempts to use waste heat from the process efficiently.

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