Collaborate. Innovate. Deliver.

Passion for Engineering.

"Our people, operational excellence and patented technologies empower us to deliver value to our customers."

Dr Marc Schier

Natural Gas Processing Plants

linde-engineering.com

Profile Linde Engineering

THE LINDE GROUP

Linde

COLLABORATE

INNOVATE

DELIVER

Linde Engineering.

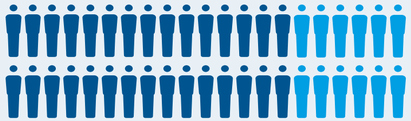
Facts and figures.

Our company.

100+ We serve our customers in over 100 countries worldwide

The Linde Group
~ 65,000 employees

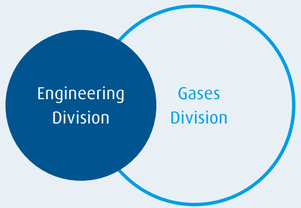
Engineering Division
~ 7,000 employees



Around 65,000 employees deliver value to our customers every day

Unique setup

Close to the customer with an integrated business model



Our business.

4,000+
plants have been delivered by Linde around the globe

3,000+
air separation units have been built in more than 90 countries

1,000 plants
are operated by
10
Linde Remote Operating Centres worldwide

600+
air separation, hydrogen and CO_2 plants are operated by Linde

50 %
of our research projects also aim to achieve an environmental benefit

1,000+
process technology patents bear testimony to our innovative powers

-50 °C to **+40 °C**
our plants withstand the most extreme climatic conditions

Our achievements.

55 million t
annual oxygen production capacity in Linde's air separation units installed since 2010

2.5 million tonnes in CO_2
savings since 2008 as a result of energy optimisation in our air separation units

5,500 t
of oxygen produced by our largest single air separation unit per day

25,000 m²
is the heating surface of one of our coil-wound heat exchangers

1,300 t
is the weight of one of our gigantic fully assembled coldboxes

The figures disclosed relate to 2015, unless stated otherwise, and are generally rounded.

Partnering with our customers.

Industrial process plants are among the most complex structures that people have ever built. Worldwide, there are only a handful of companies with the detailed know-how needed to successfully deliver turnkey industrial plants. Linde Engineering is a pioneer in the development of customised process solutions.

Customers in more than 100 countries around the globe partner with Linde because they trust in our specialist expertise. Whether they are located in a city, the desert or the Arctic; whether they need a small or world-scale plant; whether they want engineering, construction or operational support; our customers know they can rely on us to always deliver the very latest technologies.

After all, Linde Engineering holds around 1,000 process patents and we are constantly developing new processes to increase the efficiency, cost-effectiveness and sustainability of our customers' operations. Because we believe in trusted, lasting relationships, we also ensure that new technologies seamlessly integrate into existing plants. Worldwide, Linde Engineering has built over 4,000 plants to date. Moving forward, we continue to partner with our customers to collaboratively find the best solution along the entire lifecycle of plants.

Dr Christian Bruch
COO Linde Engineering

COLLABORATE

Achieving great things together.

Teamwork at its best: Smooth execution of something as technically sophisticated as gas plants requires on-the-ground collaboration between our many experts and our customers.

Teaming up for success.

The Jamnagar refining complex in Gujarat, India, is a record-breaking masterpiece of petrochemical engineering. In a global effort, Linde Engineering delivered multiple key facilities that will boost refining efficiency by substituting imported LNG and by integrating a petrochemical complex into the refinery.

"Our team collaborated globally and locally with the client to produce a world-scale project that pushed the boundaries of technical feasibility."

Dr Reinhart Vogel
Chemical and Petrochemical Plants

The district of Jamnagar in northwest India is home to the world's largest crude oil refinery. It currently boasts a processing capacity of 1.24 million barrels per day, which corresponds to 1.8 percent of the global refining market. This equates to a daily oil processing capacity of almost 80 Olympic-size swimming pools. Now in its third expansion phase, the Jamnagar complex is being equipped with the ability to generate its own synthesis gas as well as energy through the gasification of petroleum coke. Expansion plans include the integration of a petrochemical complex into the refinery. This step adds value to the production process flow by enabling petrochemical by-products to be captured. The Linde Engineering Division played a key role in delivering several of the plant technologies required to make this project a success.

Linde supported the gasification project by delivering five of the world's largest air separation units (ASUs). Experts from Linde Engineering and the refinery operator scaled up various plant component designs to take performance into uncharted territory. Each of the five ASUs is designed for an oxygen (O_2) production capacity of over 5,200 tonnes per day. The compressors required to operate the ASUs were modified in close collaboration between equipment suppliers and Linde process engineers. This cooperative effort contributed to a significant improvement in energy efficiency per tonne of oxygen produced. By teaming up with the customer and equipment manufacturers, Linde Engineering managed to optimise the plant configuration to leverage economies of scale and boost energy efficiency.

To treat the synthesis gas generated during the gasification process, Linde also delivered two RECTISOL® acid gas removal units. Services for this part of the project involved licensing, process design, detail engineering and procurement.

The design includes several coil-wound heat exchangers (CWHE), manufactured at Linde's fabrication shops in Schalchen (Germany) and Dalian (China) using proprietary know-how. Again, the different process units required close cooperation between Linde's engineering teams in Germany and India, the customer and the third-party equipment suppliers. In the end, this global partnership successfully realised the largest acid gas removal facility ever constructed.

Dr Reinhart Vogel

What was the biggest challenge with the Jamnagar project?

Scale-up was the most challenging step. When we planned the facility with the customer, we knew we were moving into uncharted territory. Production units on this scale have never been constructed before. But close collaboration and smart engineering made it possible.

What does this success symbolise for future engineering endeavours?

No matter where we are headed in the future, we have expanded our reference base. We can now reliably reproduce largest volume production capacities at the highest possible efficiency rates.

5,200 t
O_2 per day

Read more:
linde-engineering.com

It is complemented by a highly efficient sulfur recovery unit with four trains capable of recovering 99.98 percent of the sulfur components contained in various off-gas streams. Linde added significant value to the recovery design by combining state-of-the-art licensed sulfur recovery technology with Linde's proprietary burner design based on oxygen enrichment. The tail gas from the sulfur recovery unit is routed back to the Linde RECTISOL® unit using a special patented process step. This eliminated the need for the customer to invest in a separate tail gas treatment unit, which would have been necessary with conventional competitor designs for sulfur recovery.

In addition to the air separation and acid gas removal units, Linde delivered other plant components such as five large gas-fired heaters to superheat high-pressure steam as well as three pressure swing adsorption units to produce the high-purity hydrogen required to operate the refinery. Thanks to its multiple design and manufacturing facilities around the world, Linde was able to cover this extensive scope of delivery.

On all elements of this project, collaborative teamwork was so successful during the bidding phase that the required components were conceptually designed by the time the customer placed the final order. The success of the Jamnagar project is proof positive of one of Linde's core competencies: The ability to collaborate closely with customers and supply partners to realise even the most complex solutions on time and on spec, regardless of plant location and size.

Delivery of world's largest coldbox weighing 800 tonnes for Jamnagar, India.

With the HYDROPRIME® hydrogen generators, Linde is reacting to customer requirements.

Innovative hydrogen production.

Every day, vast amounts of hydrogen are used across a wide range of industries and applications. Many companies in the glass, chemicals, food and drinks, metals, electronics, photovoltaic and energy sectors rely on Linde's long-standing experience to meet their needs in this area. With a firm focus on concrete customer requirements, our experts work tirelessly to develop optimised solutions for the sustainable production of hydrogen.

Steam-reforming natural gas is currently the most cost-effective method of producing hydrogen. This proven technology is also at the heart of Linde's HYDROPRIME® product. Linde successfully launched this new line of fully modularised hydrogen generators in 2015 specifically to meet rising demand for compact, efficient and easy-to-install hydrogen solutions. The launch followed intensive testing by Hydro-Chem, a US-based affiliate of Linde's Engineering Division, which included demonstration of reliable operations in a variety of application scenarios.

These competitive, on-site production solutions are extremely reliable, environmentally friendly, safe and flexible as they can be easily relocated. Very high natural gas conversion rates and heat recovery technology keep operating costs low. The plants are also fully automatic, enabling them to be remotely monitored and operated. They produce high-purity hydrogen (up to 99.999 percent) at 13.8 bar (200 psi). For the majority of applications, the resulting gas does not require further compression.

As a leading global provider of hydrogen generators equipped with proprietary technologies, Linde has the expertise not only to deliver new turnkey plants but also to help industrial customers expand existing capacities. On request, Linde also offers HYDROPRIME® outsourcing models, saving customers investment and maintenance costs.

Single-train plant capacities of up to

120,000 Nm^3/h

Read more:
linde-engineering.com

30 %

increase in capacity with pure oxygen

Teaming up for optimum outcomes.

Hydrogen sulfide (H_2S) gas is highly toxic and extremely pungent. It is a by-product of oil refining, commonly occurring when low-value, sulfur-rich residue is converted into more profitable commodities such as petrol and diesel. The Claus process is generally used to quickly convert this chemical into a substance that can be safely and easily transported. This process uses several oxidation steps to convert H_2S into harmless sulfur. And that is exactly what the Lotos refinery in Poland does. However, Lotos was concerned that the four existing Claus units would cause a bottleneck in the refinery as they would be unable to handle the increase in H_2S volumes resulting from expansion plans. So Linde proposed a gas-enabled solution to debottleneck the refinery. The concept is based on the supplementary use of pure oxygen in the air oxidation step to increase H_2S processing capacity.

In summer 2014, application engineers from Linde ran a two-week trial on all Claus units at the Lotos refinery in order to verify the efficiency of oxygen enrichment. They used proprietary Linde hardware to meter and inject the oxygen with high precision. Linde's Chemical Development & Services team contributed to the test phase by supporting sampling and analysis of the Claus process gas. The trial confirmed not only the projected benefits of oxygen enrichment but also enhanced contaminant destruction capabilities – while enabling a 30 percent increase in capacity.

Successful completion of these proof-of-concept trials confirmed the customer's trust in Linde as the only company capable of offering the entire test phase from a single source. On examination of the test results, Lotos decided to integrate oxygen enrichment into regular operations. For this, Linde is delivering a containerised, turnkey Vacuum Pressure Swing Adsorption (VPSA) unit with a liquid oxygen backup solution. The on-site VPSA unit can generate three tonnes of oxygen per hour and is scheduled to go on stream in April 2017. It is envisaged that Linde will be looking after operation and maintenance as well as supplying the liquid oxygen for the backup solution. Lotos plans to connect its on-site unit to Linde's Remote Operation Centre (ROC) to monitor and manage the plants. The VPSA unit for the Lotos refinery in Gdansk is the fourth in a series of projects that Linde Engineering has successfully delivered to support on-site oxygen enrichment of Claus units in refineries.

Two of the four Claus units at the Polish refinery in Gdansk that are being engineered for increased capacity through oxygen enrichment.

Linde's specialists collaborate with customers on-site.

The air separation units at Cantarell (Mexico) were planned and built by Linde's Engineering Division.

Cooperating for record recoveries.

Innovative technologies are crucial in order to extract fossil fuels efficiently. Industrial gases such as nitrogen play a key role here. In the case of enhanced oil and gas recovery (EOR and EGR), nitrogen is injected into the reservoir at high pressure, enabling field operators to extract valuable natural resources and increase production and recovery rates. To meet this demand for nitrogen, Linde has designed and built some of the world's most impressive air separation plants in recent years. The Cantarell oil field in Mexico is a world-famous example. Located around 100 kilometres offshore in the Gulf of Mexico, this complex is one of the world's biggest oil fields. For a long time, it was the second most productive oil field in the world. Injecting nitrogen into the field has at times increased flow rates from one million to 2.2 million barrels a day. The strong rise in production started immediately after Linde had completed the land-based nitrogen complex in 2000. At the heart of this complex are four air separation units (five since 2004). To produce the gas, the plants first cool the ambient air to its liquefaction point. Rectification columns are then used to distil the liquid air into its constituent parts. Once the nitrogen has been separated in this way, it is transported around 100 kilometres in high-pressure, 36-inch pipelines to the offshore oil field, where it is injected into the reservoir.

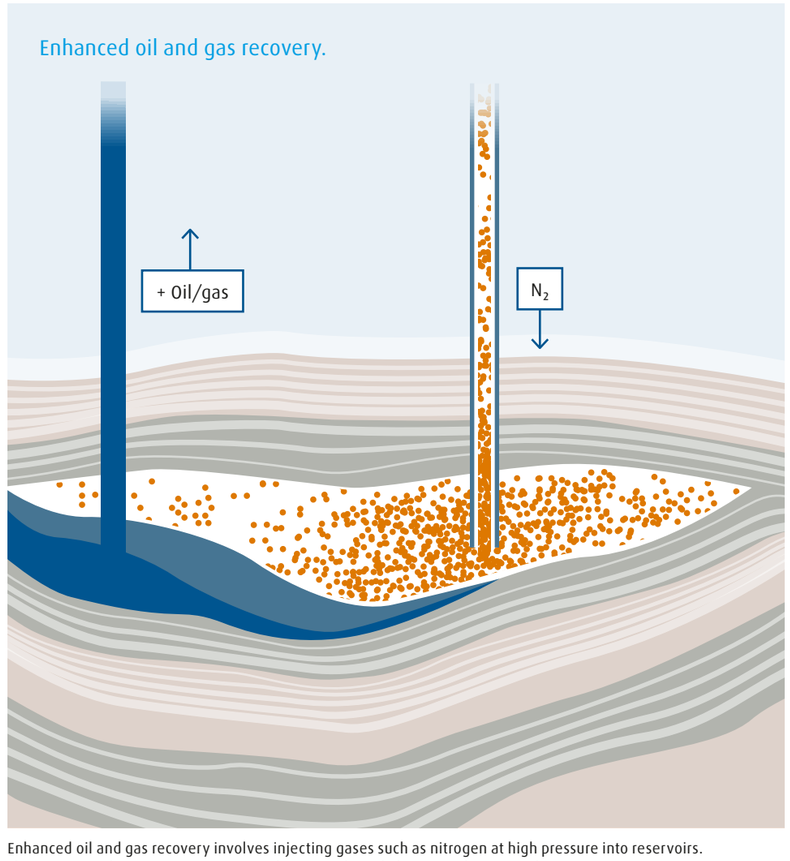
Based on positive experiences at sites like Cantarell, experts predict further growth for the global EOR and EGR market.

And Linde will continue to support Mexico's Cantarell field. The local operator has extended the supply agreement with Linde. Meanwhile, the Cantarell air separation plants are also supplying nitrogen to surrounding oil fields to increase their recovery rates.

+60 %

crude oil recovery thanks to nitrogen

Enhanced oil and gas recovery.



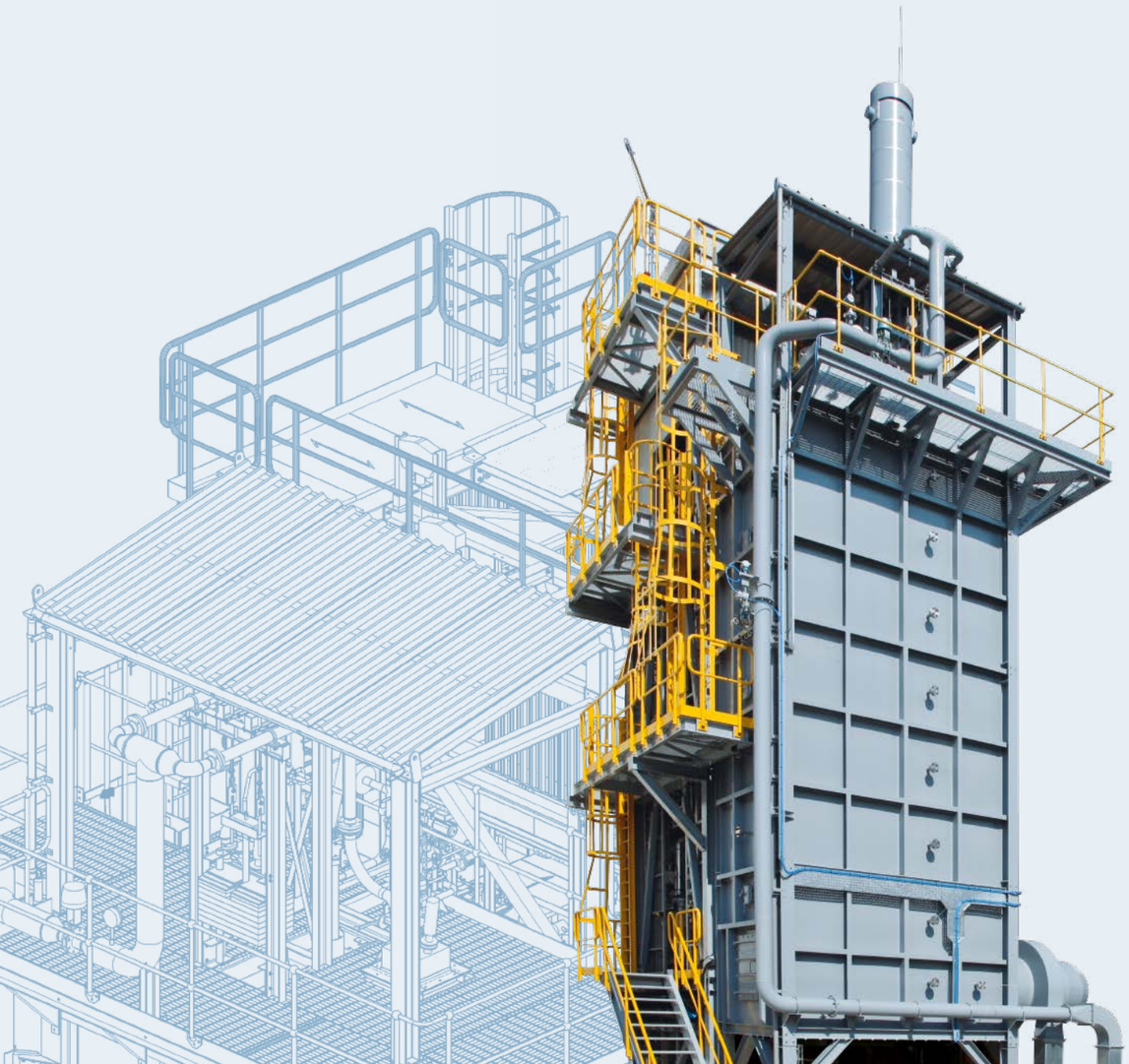
Enhanced oil and gas recovery involves injecting gases such as nitrogen at high pressure into reservoirs. This increases the reservoir pressure and can significantly boost production and recovery rates.

Read more:
linde-engineering.com

INNOVATE

Pioneering new processes.

Innovation is the key to success. As a pace-setter within the industry, we keep a finger on the trend pulse – and are already developing high-tech solutions for tomorrow's challenges.



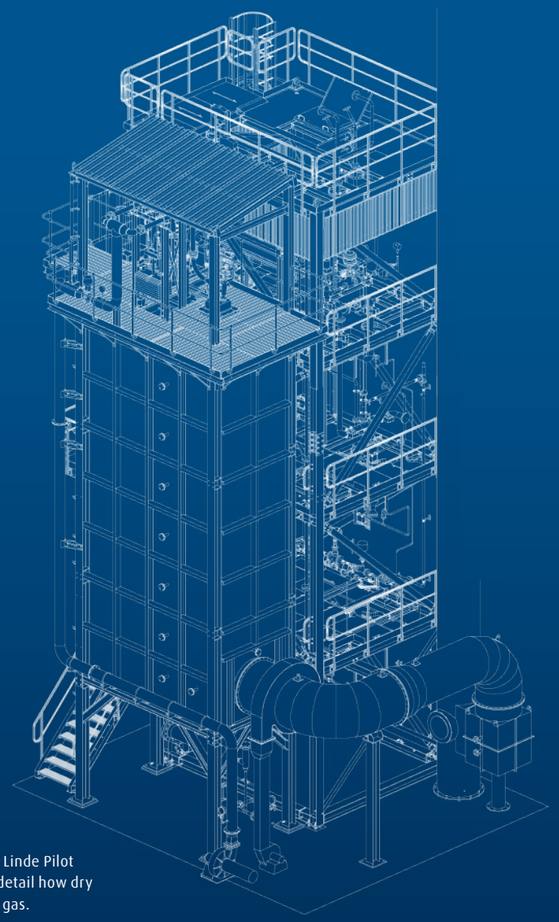
"Innovation is one of Linde's founding principles."

Claude Keller

Project Execution

Recycling CO_2 – the efficient way.

The Linde Pilot Reformer is demonstrating how an innovative dry reforming process can feed recycled carbon dioxide back into industrial applications. Not only does this process reduce carbon emissions, it also saves valuable energy.



From lab to industry: Engineers are using the Linde Pilot Reformer in Pullach, Germany, to analyse in detail how dry reforming can be used to generate synthesis gas.

"Innovation is all about getting the mix right – experience blended with fresh ideas; internal willingness to experiment with external impetus from universities and creative start-ups. It's the mix that takes innovation from the drawing board to reality."

Dr Nicole Schödel
Chemical Development and Services

A mixture of hydrogen and carbon monoxide, synthesis gas is used in many different chemical processes. For example, this gas mixture is a feedstock for many chemicals, polymers and fuels such as dimethyl ether. Linde has developed a dry reforming technology that feeds carbon dioxide (CO_2) into the synthesis gas production process, thus enabling industry to put recycled CO_2 to good use. To achieve this, experts from Linde collaborated with partners at BASF and its subsidiary hte as well as with researchers from the Karlsruhe Institute of Technology, the Technical University of Munich, the University of Leipzig and DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V. to develop an innovative technology capable of activating CO_2, which is an inert gas. Initially, the team developed two different catalysts to enable the chemical reaction. This involved converting natural gas, steam and carbon dioxide into hydrogen and carbon monoxide.

The innovative dry reforming process could be used at this plant in future.

Dry reforming saves energy

Once the reaction had been resolved, the experts focused on optimising the process flow. Temperatures can reach 1,000 degrees Celsius inside the catalyst-filled tube reactor. Despite this, the engineers were able to make the new process significantly more energy-efficient. This is because, depending on the product composition, the steam to carbon ratio is reduced to around one tenth of the ratio required for conventional steam reforming. And less steam means lower energy consumption. What's more, this process allows large volumes of CO_2 emitted by other production processes to be fed back into industry rather than being released. Linde's model calculations indicate that dry reforming has the potential to reduce CO_2 emissions by around 100,000 tonnes every year based on a dimethyl ether production plant with an annual capacity of about one million tonnes. This is the equivalent of 80 million car kilometres travelled. Using the pilot plant and its measuring technology, Linde experts are able to extensively test dry reforming processes and technologies, and collect data for future designs.

Dr Nicole Schödel

What benefits does Linde expect from the pilot plant?

This concept enables us to test various technological constraints so we can transition to industrial-scale deployment. We also have a lot of analytical flexibility across operating parameters and measurement technologies.

What were the greatest challenges you faced during development?

We had to choose the right catalyst and set the right process parameters to prevent carbon from forming during the reaction.

100,000 t
CO_2 reduction p.a.

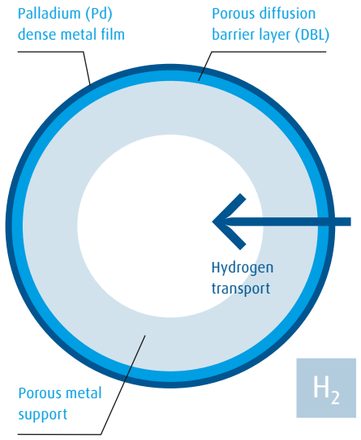
Read more:
linde-engineering.com

"Liquid Air Energy Storage (LAES) systems can be built quickly almost anywhere."

Storing power in liquid air.

Storage solutions are becoming increasingly important as the world's energy infrastructure moves towards renewable power sources. Liquid Air Energy Storage (LAES) is an innovative technology in this area that uses electricity to liquefy air. The liquid is stored in cryogenic tanks and converted back to electrical energy on demand in an expansion turbine. These tanks can hold between 50 and 600 megawatt hours of energy for anywhere between 4 and 20 hours. LAES offers a number of benefits over conventional, large-scale alternatives such as pumped and compressed air solutions. For example, LAES systems do not have special requirements; they can be built quickly just about anywhere; they do not pose any geological risks, and are unlikely to encounter public opposition. Linde has developed an LAES system in collaboration with a technology partner. This solution builds on technology components that already exist and is ready for demonstration. The company is also already working on its next, improved generation of LAES solutions.

Liquid Air Energy Storage (LAES) tank at an air separation plant in Leuna, Germany.



Palladium membrane reformer: The porous diffusion barrier layer is highly selective, resulting in a stream of pure hydrogen inside the tube (permeate side).

Making low-volume on-site hydrogen viable.

Producing small volumes of pure hydrogen when you need it, where you need it is no easy task – especially if you consume less than 300 standard cubic metres per hour. This is because conventional steam reformer technologies could not be operated cost-effectively on this scale in the past. To overcome this limitation, Linde teamed up with Austrian company Plansee SE and Germany's Karlsruhe Institute of Technology to develop the palladium membrane reformer. The innovative tubular membranes are made up of three layers: a porous metallic support, a ceramic diffusion barrier layer and an outer palladium layer. Natural gas and steam are fed into the reformer at temperatures of up to 650 degrees Celsius and converted into hydrogen after the catalyst reforming step. The hydrogen passes through the selective membrane on the tubes, which are also installed in the reformer, leaving the other gas components behind. The hydrogen that then flows through the centre of the tube is pure and does not require any further purification. All of which makes this innovative technology extremely efficient, compact and easy to use.

Highest value creation: Oxidative Coupling of Methane (OCM) pilot plant in La Porte, USA.

Technology innovation for petrochemicals.

For decades, technology innovators have had their sights set on the production of ethylene directly from methane, the main component of natural gas. This can be achieved through a catalytic process known as Oxidative Coupling of Methane (OCM). Now, in a bid to take this innovative process to industrial scale, Linde is working with Siluria Technologies, a company that developed a novel OCM catalyst and corresponding reaction section.

Siluria has set up a demonstration plant at Braskem's facility in La Porte (USA) in order to prove commercial maturity. Based on the vast experience it has gained in the production of ethylene from steam cracking, Linde is developing the concept for integrating Siluria's OCM process into the overall plant, including the required product separation and purification steps. This technology platform can be used for a wide range of applications at the front-end of the petrochemical process chain – from processing smaller volumes of natural gas in the mid-stream sector right through to large-scale production of ethylene for the polymer industry. The entire OCM process is designed to deliver the highest value creation to the customer.

Read more:
linde-engineering.com

"The CO_2-tolerant gas processing flow completely eliminates the amine scrubbing step."

World-scale LNG plant in Hammerfest, Norway.

The CO_2-tolerant plant.

Carbon dioxide (CO_2) has a bad reputation – especially in the natural gas business. Although this gas molecule generally occurs in low concentrations in gas reserves, developers need to remove it as quickly as possible. The reason is that a temperature drop below -57 degrees Celsius is all that is needed to convert pure CO_2 to solid dry ice, which settles in the processing plant and causes blockages. Operators usually avoid this problem with an upstream amine scrubbing step. At several million euros per plant, this chemical solution is extremely expensive, however. Now, Linde has developed and qualified an alternative solution to this problem – at no extra cost. Skipping the amine scrubbing step completely, Linde's approach is based on a CO_2-tolerant gas processing flow. In other words, concentrations of up to 0.5 percent of this otherwise problematic gas can now be tolerated in the natural gas stream without any risk of harmful solid deposits. The concept behind this new solution is ingeniously simple. The diluted CO_2 is maintained in a temperature range that is warm enough to prevent it from freezing. It may then remain within the final natural gas stream, where it is of no consequence in low concentrations. A Russian operator recently selected this innovative process technology for a plant currently under construction. Given the right configuration, Linde's solution has the potential to benefit many other natural gas processing customers by eliminating the need for an entire process step.

Coil-wound heat exchangers are the key to success.

Petrochemical, air separation and gas liquefaction units all have one thing in common – they need heat exchangers to process gases and liquids. Coil-wound heat exchangers in particular are used across a broad spectrum of cryogenic applications. Linde is a leader in this high-tech field, designing and building equipment to match individual customer specifications. To date, the company has successfully delivered more than 1,000 coil-wound heat exchangers (CWHE). These exchangers often weigh as much as 260 tonnes, are up to 7.5 metres in diameter and offer heating surfaces of over 20,000 square metres. Linde can also realise even larger, heavier models on request. What's more, the company is committed to continually evolving the underlying technologies. For example, to optimise operations and extend lifetime at an LNG plant in Stavanger, Norway, Linde engineered over 4,000 temperature measuring points in the CWHE bundle. This high-precision 3D temperature monitoring capability gives operators an exact overview of the process flow.

Coil-wound heat exchangers are used across a broad spectrum of cryogenic applications.

+1,000

coil-wound heat exchangers manufactured

Read more:
linde-engineering.com

DELIVER

Living reliability.

Our customers partner with us for peace of mind.
We deliver high-tech, economical plants on time and on budget.

"Great service is all about a true understanding of our customers, creativity and dedication."

Nicole Hocke

Health, Safety and Environment

Powerful solutions for extreme conditions.

From the desert to the Arctic, Linde delivers benchmark quality under the most extreme of conditions. Our large-scale petrochemical facilities in particular represent the perfect combination of expertise, experience and excellence in execution.

Ethylene unit in Ruwais, United Arab Emirates

"We build on our experience with every successful project. This ever-expanding know-how coupled with feedback from customers and valuable contacts we establish on-site open up new opportunities for the future and help us get even better at what we do."

Dr Harald Schubert
Global Project Management

Plastics are an indispensable part of our daily lives. Yet without petrochemicals, the plastics industry wouldn't exist. Complex petrochemical processes create the building blocks for a host of different applications and products. These starting materials include ethylene, propylene and butadiene, as well as aromatics. Obtained by steam cracking fossil fuel fractions, for instance, they are then further upgraded in downstream processes to create important base chemicals and plastics. The versatility of these building blocks is matched only by the complexity of the production facilities that create them.

Ethylene production facility delivers a total capacity of 4.5 million tonnes per annum.

As one of the world's leading technology contractors, Linde has the expertise to deliver these kinds of plants anywhere on the planet. The largest ethane cracker complex in the world, for example, is located in the middle of the desert in Abu Dhabi. From 2005 to 2014, Linde built three turnkey ethylene production facilities for a client at the Ruwais petrochemical hub, delivering a total capacity of 4.5 million tonnes per annum (tpa). Ruwais is a town on the Gulf coast, around 250 kilometres west of Abu Dhabi city. It is close to a large refinery and several petrochemical plants. In this part of the world, however, temperatures are extremely high all year round. Solar radiation and surface heat therefore had to be carefully factored into plant design, especially to protect the health and safety of workers. Linde rose to every challenge, delivering all three ethane crackers on schedule and without any hitches. As a leading provider of ethylene technology, Linde was thus able to play a key role in helping its customer realise what is currently the world's largest ethane-based polymer complex in Ruwais with a capacity of 3.9 million tpa. Delivering facilities that are a perfect match for individual needs is one of our core competencies, especially in the large-scale petrochemical engineering sector.

Dr Harald Schubert

Where – if at all – are the limits to plant engineering?

We can build and deliver tailored facilities anywhere in the world. Thanks to our global engineering, procurement and construction capabilities, we find the perfect fit for every plant – no matter where it is located.

What were the greatest challenges with the Ruwais project?

For me, it is crucial that we keep to the schedules and budgets we agree with our customers at the start of a project, while at the same time ensuring we deliver the highest levels of safety and quality.
During this process, it is fascinating to see how well people from all over the world work together to achieve this goal.

Surface temperatures on-site get as high as

+80 °C

Read more:
linde-engineering.com

Temperatures in Tobolsk (Russia) fall as low as

-53 °C

The geography and climate in parts of Russia can be equally challenging, especially in regions with permafrost. In the Western Siberian town of Tobolsk, for example, Linde is currently building one of the world's largest ethylene plants for a Russian petrochemical group. In contrast to Abu Dhabi, where plant components had to be insulated against the desert heat, the Tobolsk plant features a specially developed and highly sophisticated winterisation concept, balancing material cost with energy consumption for optimised management. The plant engineers also have to work with special types of steel that are extremely resistant to cold. Once complete, the facility in Tobolsk will produce around 1.5 million tpa of ethylene, 500,000 tpa of propylene and 100,000 tpa of butadiene – all of which are important feedstocks for the plastics industry. Linde is responsible for engineering, procurement and transport in this large-scale project. The company is also providing a number of consulting services for the customer on-site.

Linde's portfolio extends far beyond the engineering and design of petrochemical facilities, however. The company also offers procurement, construction and start-up services for these plants. In addition, customers rely on Linde for operational support in areas such as plant safety and energy optimisation. Linde is even offering full revamps of existing facilities. Whatever the challenge, whatever the location, Linde's engineers will find the right solution.

Even under extreme conditions like the Siberian permafrost, Linde delivers its plants reliably and safely.

Natural gas liquefaction plant in Stavanger, Norway.

"Linde has wide-ranging technology expertise in the field of small- to medium-sized LNG plants."

Supplying liquefied natural gas.

Liquefied natural gas (LNG) can be stored efficiently and transported long distances independently of pipeline networks – either by ship, truck or train. Over the last ten years, global demand rose annually by around 2.4 percent on average and this trend is set to continue. As an engineering and technology leader, Linde covers a large part of the entire LNG value chain from the source to the point of consumption.

Infrastructure on land plays a key role here. In the Norwegian city of Stavanger, for example, Linde built a particularly energy-efficient natural gas liquefaction plant for the company Skangass AS. The facility went on stream at the end of 2010 with an output of 300,000 tonnes of liquefied natural gas per annum. The plant design also includes the option of adding a second liquefaction train in future in order to double the facility's production capacity.

Small- to medium-sized natural gas liquefaction facilities like the plant in Stavanger are distribution hubs for the much-in-demand LNG. Unlike large-scale facilities, plants of this size can be located close to industrial parks and cities. They can also be planned and built to much shorter timescales. These smaller facilities are paving the way for companies to cost-effectively tap relatively small isolated reserves that previously would have been too difficult to develop. In addition to the actual liquefaction facility, these smaller plants also come with LNG storage tanks and LNG loading terminals so that the liquefied natural gas can be shipped out by tanker or truck. For LNG to be transported by ship at atmospheric pressure, it first has to be cooled to minus 162 degrees Celsius before being fed into the tanker's hold via an insulated pump system. Any LNG that evaporates during this process is recovered using special reliquefaction systems.

At present, natural gas meets around 25 percent of global energy demand. It also reduces carbon dioxide emissions by around 20 percent relative to crude oil. There are currently over 700 small- to medium-sized natural gas liquefaction plants in the world. Linde is ideally positioned in this market and offers almost all plant components from a single source. Our patented Linde Multistage Mixed Refrigerant (LIMUM®) process is just one example of our wide-ranging technology expertise in the field of small- to medium-sized LNG plants. This innovative liquefaction process is deployed at the plant in Stavanger, where it consumes significantly less energy than conventional nitrogen expander liquefaction processes.

Read more:
linde-engineering.com

"The six rectification coldboxes, with more than 2,000 tonnes of steel structure, were completed after only four months of work on-site."

Oxygen for mega GTL and CTL plants.

Conversion processes such as coal to liquids (CTL) and gas to liquids (GTL) require vast amounts of oxygen (O_2). More than can be provided by one plant alone. Linde offers cutting-edge, multi-train solutions for exactly these kinds of applications. An eight-train air separation facility in the Qatar desert is a prime example of the company's capabilities in this area. It is located at the site of the world's largest GTL plant to date, which went on stream after a planning and construction period spanning several years. Today, the plant produces 140,000 barrels of liquid fuels per day from natural gas. The eight identical air separation units provide the oxygen required for the conversion process.

Together, they generate 860,000 standard cubic metres (Nm^3) of oxygen every hour from the surrounding air. Weighing 470 tonnes and rising 60 metres up into the sky, the eight coldboxes can be seen from far afield.

Linde's process experts started planning the project long before it won the contract in 2006. The company leveraged its global supplier network to guarantee the highest quality levels at the best possible prices. Key components such as the aluminium plate-fin heat exchangers and rectification columns were sourced from Linde sites in Germany and China. The coldboxes were also fully assembled as packaged units at these locations. Preassembling the components in this way meant that Linde did not need to carry out complex assembly and construction work on-site. Which is a good thing in the desert. This kind of work would have been extremely difficult in an environment where temperatures can reach up to 50 degrees in the shade and sand storms and dust are part of daily life. As the main contractor, Linde was responsible over the entire project lifecycle for ensuring timely completion of the turnkey facility. Once the entire complex had been gradually brought on stream as planned, the company was able to officially hand over the eight air separation units after six years' construction.

Air separation units at the Pearl GTL complex in Ras Laffan, Qatar.

The success of this mega air separation reference project in Qatar resonated among the international engineering community. In China, for example, the market for CTL plants also requires very large, highly efficient air separation units. In March 2013, Linde won a major contract for a plant near Yinchuan City, in the mid-west of China. For this project, the company was commissioned to build a six-train air separation facility with a capacity of 630,000 Nm^3 of oxygen per hour. Linde built on the valuable experience it gained in Qatar to securely deliver these vast gas volumes cost effectively and reliably. Despite the remote location of the site, Linde was able to rely on its global and local network of partners to ensure a seamless execution of the project. Linde's engineering centres in Pullach (Germany) and Hangzhou (China) as well as its production sites in Schalchen (Germany) and Dalian (China) were all involved in the project. As a result, the six rectification coldboxes, with more than 2,000 tonnes of steel structure, were completed after only four months of work on-site.

Air separation units near Yinchuan City, China.

Read more:
linde-engineering.com

Collaborate. Innovate. Deliver.

Serving you better.

The Linde Group is a world-leading gases and engineering company with a rich and sophisticated technology and service portfolio. Regardless of your size or industry, this integrated business model brings you the benefits of a one-stop offering and synergised know-how.

Customers the world over rely on Linde to deliver the industrial and specialty gases and application technologies they need to support their business. At the same time, we excel in the planning, procurement, construction and operation of the plants and equipment used to produce and process these gases.

Collaborate

Our technologies play an indispensable role in process flows across the most varied of industries – from crude oil and natural gas extraction and refining to chemical and metal processing. But we bring a lot more than engineering excellence to the table. We value trusted, lasting business relationships with our customers. And so we listen carefully and collaborate closely with you to meet your needs.

Innovate

The connection with you inspires us to innovate process technologies. Often, these are designed in close collaboration with strategic partners and then delivered with true passion by our employees working in more than 100 countries worldwide.

This commitment to innovation has made us the world's leading supplier of air separation units, producing oxygen, nitrogen and argon in the volumes and purities you need. We have also developed innovative processes to capture and deliver rare gases such as krypton, xenon, helium and neon. Our petrochemical plants convert fossil fuels into olefins, which chemical companies then process into plastics and key base chemicals. Natural gas plants also rely on our technologies to separate the gas components and/or liquefy natural gas so it can be transported by ship, train or tanker and not necessarily by pipeline. Last but not least, our portfolio includes plants to generate hydrogen and synthesis gas, to separate CO_2 from off-gases, as well as cryogenic plants (for generation of very low temperatures and liquefaction of helium and hydrogen) and adsorption plants (separation and purification of process gases).

Deliver

Our customers often come to us with ideas and projects that have never before been realised on that scale. But our specialists are expert at overcoming everything from weather extremes to logistical challenges – and so they develop plant solutions that operate reliably and cost-effectively under all conditions. As general contractor, we manage the entire process flow to deliver a turnkey, state-of-the-art plant on time. From the desert to the Arctic, from small- to world-scale, from standardised to customised builds, from design to operations ... we ensure you get what you need, where you need it, when you need it.

Join us today on a collaborative journey to shape tomorrow's innovations and discover how we can contribute to your success by exceeding your expectations.

Visit **linde-engineering.com** for more information.

Published by:

Linde AG
Engineering Division, Dr.-Carl-von-Linde-Strasse 6–14
82049 Pullach, Germany
Phone +49.89.7445-0, Fax +49.89.7445-4908