The StarLNG™ family.
Linde’s portfolio for small- to mid-scale LNG plants.
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Securing future power supplies.

Need for cleaner sources of energy

One of the biggest challenges facing society today is the need to find more environmentally sound, future-proof sources of energy. This is being driven by rising demand for energy, dwindling fossil fuel reserves and growing climate change pressures. Stricter environmental regulations for pollutant emissions, especially in transport and shipping, are accentuating the need for alternatives to crude oil and diesel.

Natural gas is an increasingly important stepping stone on the journey towards a low carbon economy. As a raw material, it is almost as versatile as crude oil yet is significantly kinder to the environment. Burning methane, the principle component of natural gas, produces around 30% less carbon dioxide (CO₂) than crude oil, and almost 45% less CO₂ than coal. When combusted, it also releases around 91% less sulfur oxide, and 90% less nitrogen oxide than fossil fuels, and it emits no heavy metals or soot particles. In addition, advanced extraction technologies are unlocking new deposits all the time, especially in shale reserves.

Changing LNG landscape

Already today, natural gas meets approximately 30% of the world’s energy demand and this share is set to rise. Currently around 70% of the natural gas is delivered by pipeline as gaseous form, with the remainder transported overseas by huge LNG carriers and traded on a world scale. To date, this gas has been typically used for industrial processes, power generation and district heating.

Increasingly, however, natural gas is serving a much broader and smaller-scale application spectrum at local level. The trucking and marine transport industries are two good examples. This growing merchant market relies on state-of-the art liquefaction and transport technologies to deliver gas economically from remote deposits to the point of use.

Reflecting this shift, Liquefied Petroleum Gas (LPG), Natural Gas Liquids (NGL) and Liquefied Natural Gas (LNG) have become much more important in the world’s energy mix over the past two decades.

Offering value along the complete LNG value chain

At Linde, we have over 40 years of experience in the natural gas business. Our portfolio of energy-efficient, tailored plant solutions meets the needs of a wide market spectrum, from world-scale plants to smaller LNG terminals for regional markets. Linde Engineering is the only company in the LNG business capable of offering its customers a broad portfolio of liquefaction technologies, cryogenic core equipment as well as distribution infrastructures and services. In fact, we are the only equipment manufacturer to offer both coil-wound and plate-fin heat exchangers – equipment at the heart of most natural gas liquefaction plants.

Complementing this strong engineering portfolio, our process expertise covers the entire LNG value chain – from extraction through purification and liquefaction to distribution and regasification. Linde Gas operates more than 300 cryogenic processing plants around the world, including small-scale LNG plants and import terminals. We channel these valuable hands-on insights into the ongoing optimisation of our plant designs.

In addition to engineering services, we also offer commissioning, start-up and operational support as part of our turnkey packages. We even support our customers with training on site or at our premises.

Ground-breaking modular concept

Building on our strong track record in the successful execution of natural gas EPC (engineering, procurement, construction) projects on a lump-sum, turnkey basis, we have developed a flexible and modularised plant concept specifically for the emerging small- to mid-scale LNG market. StarLNG™ leverages our standardisation and modularisation experience in air separation to bring a variety of benefits to our customers.
StarLNG™ product family. How StarLNG™ was born.

Linde Engineering has been supplying individually designed LNG plants for many years. Today these plants are recognised worldwide as excellent LNG reference projects. To deliver the same level of quality at lower cost and in shorter timeframes, Linde Engineering has been transferring the standardisation and modularisation experience it has gained in air separation over decades to the LNG business. StarLNG™ was developed especially for the emerging small- to mid-scale LNG market and is designed as a process toolbox with configuration variations supporting about 90% of real-life LNG projects. In other words, the generic LNG plant design can be individually adapted to cope with most pipeline gas specifications as it covers a wide feed gas envelope and includes options for heavy hydrocarbon or nitrogen removal, for instance. It comes with modularised pre-treatment and process units, as well as main pipe racks. In addition, the StarLNG™ plant concept is adjustable within a wide liquefaction capacity range. Our engineers would be delighted to guide you through the available choices to find the plant concept best suited to your individual requirements.
Standardisation and modularisation started with air separation and have now progressed to LNG. In 2010, Linde formed a core team and invested more than 25,000 engineering hours in developing the StarLNG™ standardisation concept.

The StarLNG™ concept was originally developed for the typical small-scale capacity range of 100 to 600 tonnes per day (tpd) and was based on Linde’s proprietary single mixed refrigerant liquefaction process (LIMUM®) using plate-fin heat exchangers (PFHE). During concept development, the engineers recognised that many of the standardised design solutions and features can also be applied to LNG plants using other liquefaction technologies. Therefore the concept was extended to larger-scale plants up to 1 million tonnes per year (mtpa) using the LIMUM® process based on Linde’s proprietary coil-wound heat exchangers (CWHE). Recently the StarLNG™ family was completed by adding plant concepts using packaged proprietary nitrogen expander-based liquefaction processes, either for small-scale, highly modularised standalone LNG units or for integration into existing or new NGL extraction facilities.

The following figure gives an overview of the different members of the StarLNG™ family together with the applied liquefaction processes, refrigerants, compressor types and main cryogenic heat exchangers.

On the following pages, the various StarLNG™ family members are described in more detail.

The StarLNG™ family

The StarLNG™ concept was originally developed for the typical small-scale capacity range of 100 to 600 tonnes per day (tpd) and was based on Linde’s proprietary single mixed refrigerant liquefaction process (LIMUM®) using plate-fin heat exchangers (PFHE). During concept development, the engineers recognised that many of the standardised design solutions and features can also be applied to LNG plants using other liquefaction technologies. Therefore the concept was extended to larger-scale plants up to 1 million tonnes per year (mtpa) using the LIMUM® process based on Linde’s proprietary coil-wound heat exchangers (CWHE). Recently the StarLNG™ family was completed by adding plant concepts using packaged proprietary nitrogen expander-based liquefaction processes, either for small-scale, highly modularised standalone LNG units or for integration into existing or new NGL extraction facilities.

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Benefits of the StarLNG™ product family

Safe, simple, robust and highly efficient process design
• Strong focus on health and safety makes our small- to mid-scale LNG plants as safe as our world-scale plants
• Process design validated in dynamic simulations
• High reliability, robust design and ease of operation due to high degree of automation, remote control possible

Fast-track EPC time schedule
• Pre-engineered toolkit for process and plant design, standard documentation and modularised plant layout for shortest delivery time with minimum on-site construction effort

Lowest CAPEX
• Toolkit approach supports customisation, while benefiting from standardisation and production cost efficiencies of best-cost countries

StarLNG™ – a versatile toolkit

Overview of the members of the StarLNG™ family

[Diagram showing different members of the StarLNG™ family with their specific features and capacities]

The figure gives an overview of the different members of the StarLNG™ family together with the applied liquefaction processes.
StarLiteLNG™ refers to packaged compander units designed and manufactured by Linde’s fully owned subsidiary Cryostar, covering capacities between 28 and 125 tpd.

StarLiteLNG™ packaged units are based on Linde’s proprietary EcoRel system, used for on-board re-liquefaction of boil-off gas on LNG carriers such as the Q-Max (transporting world-scale LNG cargo from Qatar to the Far East).

At the heart of the StarLiteLNG™ refrigeration unit is the compander, a combination of compressors and expander in a single machine, with an integrally geared design driving a single nitrogen refrigeration cycle.

<table>
<thead>
<tr>
<th>Liquifier product</th>
<th>Typical capacity [TPD]</th>
<th>Configuration</th>
<th>Liquefier footprint w/o air coolers [m]</th>
<th>Specific power consumption kwh/kg</th>
<th>Rated power of compander [MW]</th>
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<tr>
<td>XS 28</td>
<td>2 Skids</td>
<td>15 x 15</td>
<td>1.1</td>
<td>0.8</td>
<td>1.5</td>
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<tr>
<td>S 50</td>
<td>2 Skids</td>
<td>15 x 15</td>
<td>2.2</td>
<td>0.8</td>
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<tr>
<td>M 88</td>
<td>ColdBox</td>
<td>15 x 15</td>
<td>3.5</td>
<td>0.8</td>
<td>3.5</td>
</tr>
<tr>
<td>L 125</td>
<td>ColdBox</td>
<td>15 x 15</td>
<td>4.5</td>
<td>0.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Key features of StarLiteLNG™

StarLiteLNG™ packaged units complete the StarLNG™ family at the lower end of the liquefaction capacity range, covering an LNG production rate from 28 to 125 tpd. The units offer the following main advantages to our customers:

**Low capital cost**
- Reduced equipment count and therefore simple operation
- Wide portfolio of standard compander sizes covering a wide range of liquefaction capacities
- Skid-mounted modules to minimize on-site construction

**Reliable and efficient equipment**
- Machinery designed, manufactured, assembled and tested in-house
- Proven plate fin heat exchangers (PFHEs) manufactured by Linde Engineering
StarLNG™ for liquefaction capacities up to ~0.3 mtpa per train.

The original StarLNG™ concept was developed for small-scale LNG liquefaction capacities ranging between 100 and 600 tpd.

Such plants typically consist of natural gas treatment (sour gas removal and dehydration) and liquefaction units, an LNG storage tank and an LNG truck filling station. The natural gas is cooled, liquefied and subcooled in a PFHE mounted into a coldbox using Linde’s highly efficient single mixed refrigerant cycle process.

Small-scale LNG plants have to meet the same high standards for safety, reliability, robustness and efficiency as mid-scale and world-scale LNG facilities. Linde’s small-scale plants thus comply with the most rigorous global standards.

Small-scale StarLNG™ using single mixed refrigerant process technology

The small-scale StarLNG™ concept uses Linde Engineering’s LIMUM® process, which is a single mixed refrigerant technology based on PFHEs manufactured at Linde’s own workshop in Schalken, Germany. The mixed refrigerant cycle uses four refrigerants: nitrogen, methane, ethylene or ethane (depending on availability) and butane. The pre-treated (dry and sweet) natural gas is typically liquefied in a single passage (“once through”) of the PFHE.

Small-scale StarLNG™ using nitrogen expander cycle process technology

We also offer an alternative process technology for small-scale StarLNG™ plants based on a double nitrogen expander cycle.

Key features

- N₂ refrigerant
- Vapour phase operation
- Brazed aluminium PFHE
- Electric motor drive
- Water cooling

In summary, the small-scale StarLNG™ concept offers the following main advantages to our customers:

- Lower complexity and equipment count compared to multiple refrigerant cycle based technology, but still high efficiency
- Most economical type of main cryogenic heat exchanger
- Part load capability of 50% or even less
- Minimised on-site installation works due to installation in road-transportable, workshop-assembled coldbox
Small-scale StarLNG™ includes a fully modular design enabling road transportation to many locations, while also aiming for minimum hook-up work on site and moderate crane capacity requirements. The modular design is based on a completely engineered generic 3D CAD model as shown in the picture below.

Road-transportable from 100 tpd liquefaction capacity

1 coldbox including up to 2 PFHEs, each with 400 tpd max. capacity

StarLNG™ for liquefaction capacities up to ~1 mtpa per train.

Mid-scale StarLNG™ was developed to extend the StarLNG™ concept to LNG capacity ranges between 600 and 3000 tpd (equivalent to approx. 1 mtpa). To avoid multiple parallel blocks of PFHEs, which results in complex piping arrangements, higher plot space requirements and which might lead to challenges with regard to flow distribution, Linde is applying for such capacities its LIMUM®3 liquefaction process using its proprietary CWHE. This type of heat exchanger is extremely robust and easy to operate, therefore also applied for the majority of world-scale plants.
Stick-built/customised large modules for liquefaction capacities up to 1 mtpa

1 x CWHE mounted into a steel structure for capacities above 600 tpd or 2 or more coldboxes incl. up to 2 PFHEs for each road-transportable CB module
Around the world, Linde Engineering customers secure valuable revenue streams by recovering ethane and propane from natural gas liquids. Linde Process Plants in Tulsa, USA and Linde Engineering headquarters in Pullach, Germany have jointly developed a process that integrates LNG production into NGL recovery plants.

The StarLNGL™ concept takes advantage of existing cryogenic conditions in an NGL plant, allowing customers to efficiently generate LNG and to increase the NGL production rate at the same time.

StarLNGL™ is an integrated NGL and LNG technology using Linde’s proven StarLNG™ design concept to generate LNG in existing or new NGL recovery plants.

The StarLNGL™ liquefaction facility gives NGL customers additional revenue from valuable LNG coupled with the added bonus of a very short payback period.

Features
- Add-on to existing NGL plants
- Tie-in via a cold vapour line
- 2-shaft compander
- Modified StarLiteLNG™ system
- N₂/CH₄ mixed refrigerant
- No HC make-up storage
- Small BOG compressor

The StarLNGL™ liquefaction facility gives NGL customers additional revenue from valuable LNG coupled with the added bonus of a very short payback period.

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**StarLNGL™ building on long-term in-house engineering and manufacturing know-how**

- NGL plant design by Linde Process Plants (CRYO-PLUS™ standard plant concept)
- Liquefaction with PFHE manufactured at Linde’s workshop
- Refrigeration with StarLiteLNG™ compander unit manufactured by Cryostar
- Overall plant design concept by Linde Process Plants in Tulsa, USA with support from Linde Engineering in Munich, Germany

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**Process flow of standardised StarLNGL™ plant (yellow dotted lines) integrated into NGL extraction facility (NGL plant)**

- Residue gas
- Feed gas
- Boil-off gas compressor
- Condensate
- Vapour
- Liquid
- Compressor module
- Cryo module
- NGL storage
- LNG storage
- LNG plant design (LPP)
- Refrigeration system (Cryostar)
- Plate fin heat exchanger (LES)
Key features of StarNGL™

- Lowers capital expenditure relative to standalone LNG unit
- Eliminates redundant infrastructure
- Integrates into new or existing NGL plants
- Integrates seamlessly with NGL technologies including CRYO-PLUS™, GSP* and RSV*
- Has zero impact on availability and reliability of the NGL plant
- Increases ethane recovery, propane recovery and plant throughput
- Comes in a compact modular design

* Gas Subcooled Process (GSP) and Recycle Split Vapour (RSV) process invented by Ortloff
Linde’s Engineering Division, a leading player in the international plant engineering business, covers every step in the design, project management and construction of turnkey industrial plants. Drawing on our extensive, proven process know-how, we set the standards for innovation, flexibility and reliability with ground-breaking concepts and a dedication to engineering excellence.

The success of our customers and partners around the globe is of primary importance. With a clear focus on efficiency, sustainability and growth, we develop customised solutions for projects of all sizes and degrees of complexity. We have already delivered more than 4,000 plants worldwide and always aim to find the best technical and economic solution for our customers.

Core competencies in plant engineering:
- Air separation plants
- LNG and natural gas processing plants
- Petrochemical plants
- Hydrogen and synthesis gas plants
- Chemical plants
- Adsorption plants
- Cryogenic plants
- Biotechnology plants
- Carbon capture and utilisation plants
- Furnaces, fired heaters, incinerators

Core competencies in component manufacturing:
- Packaged units and coldboxes
- Coil-wound heat exchangers
- Plate-fin heat exchangers
- Cryogenic columns
- Cryogenic tanks
- Air-heated vaporisers
- Water-bath vaporisers
- Spiral-welded aluminium pipes

Get in touch – find the best solution.

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