Making our world more productive

LNG Technology

Optimised solutions for small- to world-scale plants

Introduction.

Natural gas is one of the world's most important sources of energy. Today, approximately 30% of the world's energy needs are met with this gas. Most of it is supplied in gaseous form by pipeline. However, over the past two decades, Liquefied Petroleum Gas (LPG), Natural Gas Liquids (NGL) and Liquefied Natural Gas (LNG) have become much more important in the world's energy market. Natural gas and LNG in particular are expected to play an essential role in the world's transition to cleaner sources of energy.

Approximately
30%
of the world's energy needs are met with natural gas

Liquefied Natural Gas

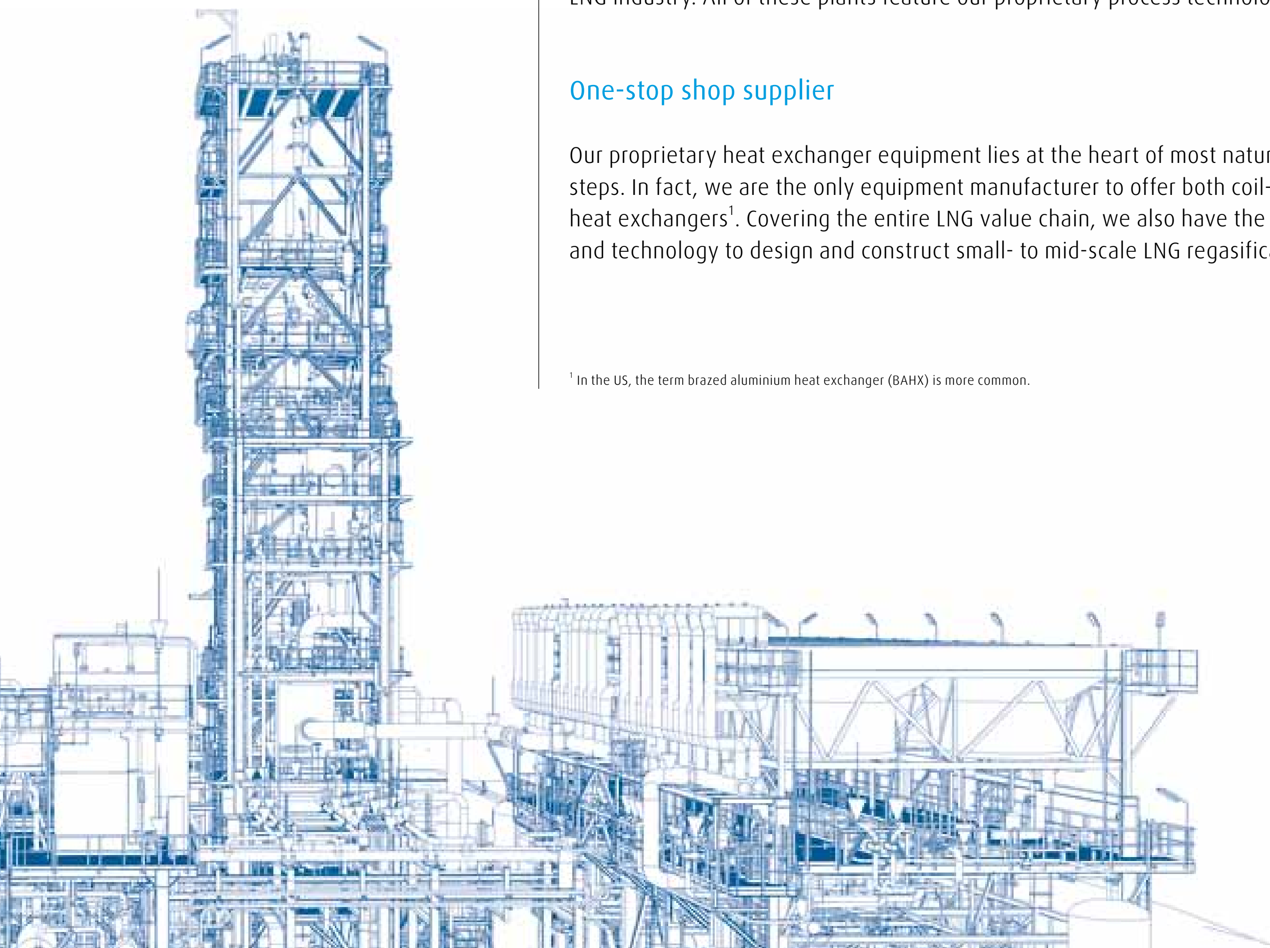
LNG is natural gas in liquid form. In order to liquefy natural gas, it must be cooled to cryogenic temperatures of approximately –160°C. As a liquid, natural gas occupies only 1/600 of the volume of natural gas (at atmospheric pressure) in gaseous form, making LNG more economical and practical to store. Natural gas is typically transported in liquid form when vast distances, geological conditions or political dynamics make pipeline construction impractical.

Linde Engineering has developed and patented liquefaction processes for LNG production plants ranging in size from 10,000 tonnes per annum (small scale) to up to 10 million tonnes per annum (baseload, world scale). Having developed, built and commissioned over 30 LNG plants worldwide since 1967, Linde Engineering has a strong and proven track record in the LNG industry. All of these plants feature our proprietary process technologies.

One-stop shop supplier

Our proprietary heat exchanger equipment lies at the heart of most natural gas processing steps. In fact, we are the only equipment manufacturer to offer both coil-wound and plate-fin heat exchangers[1]. Covering the entire LNG value chain, we also have the know-how, capacity and technology to design and construct small- to mid-scale LNG regasification terminals.

[1] In the US, the term brazed aluminium heat exchanger (BAHX) is more common.



Pretreatment and separation of natural gas.

Pretreatment of natural gas

Natural gas pretreatment typically consists of mercury removal, gas sweetening and drying. Depending on the downstream processing steps and the hydrogen sulfide (H_2S) and carbon dioxide (CO_2) concentration in the natural gas, it may be necessary to remove H_2S and CO_2 from sour natural gas. Scrubbing processes such as MDEA, Benfield or SULFINOL are used for this step. If the H_2S concentration is low, the sour components and water can be removed by means of adsorption. Mercury guard beds are recommended to protect people and equipment. Natural gas is typically dried in molecular sieve adsorbers.

Separation of natural gas liquids

NGL, LPG, condensate and the pure components methane, ethane, propane and butane often have a higher sales value than pipeline gas. This makes it financially appealing to extract and fractionate these products in processing plants tailored to regional market requirements. NGL and LPG, for instance, are ideal feedstocks for steam crackers producing olefins.

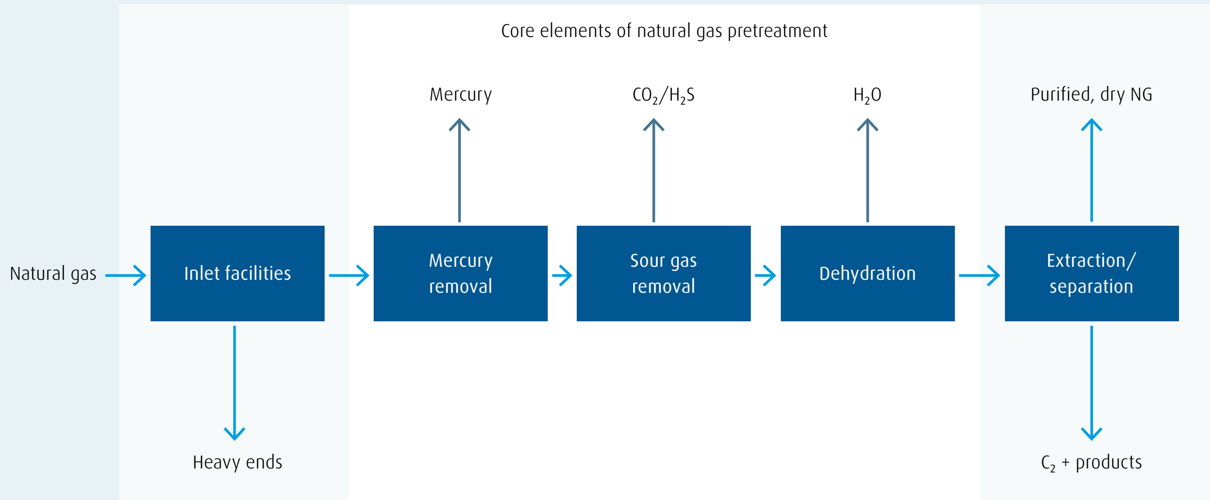
In addition to supporting all natural gas pretreatment processes, we also have the technologies and expertise to extract NGL, LPG, nitrogen and helium.

Extraction of non-hydrocarbons

Natural gas is a mixture of gases, with hydrocarbons being the main component. However, raw natural gas also frequently contains the inert gas nitrogen. Nitrogen lowers the heating value of natural gas and increases transport volumes. Pipeline specifications for nitrogen vary. Typically, however, no more than 3–4% nitrogen is allowed in most specifications.

More information:
linde-engineering.com/ngl

Pretreatment of natural gas



PSA unit in Leuna, Germany.

Nitrogen rejection units

More information:
linde-engineering.com/nru

LNG should not contain more than 1% nitrogen to avoid storage problems. Some state-of-the-art, world-scale LNG plants thus feature a nitrogen rejection unit (NRU) for the safe and economical rejection of nitrogen. This is required, for instance, if surplus nitrogen cannot be sent to gas turbines. Not only does the rejection of nitrogen reduce transportation volumes, it also increases the heating value of LNG. Alternatively, an NRU can be used to recover methane from tank return or end-flash gas.

We offer nitrogen rejection units with tailored process technology to ensure the highest levels of cost and operational efficiency. Our portfolio includes designs with single columns, single partitioned columns, double columns and double columns with enrichment processes, with configurations tailored to the individual composition of the gas.

Helium recovery

Liquefaction and production of high-purity helium

>99.999%

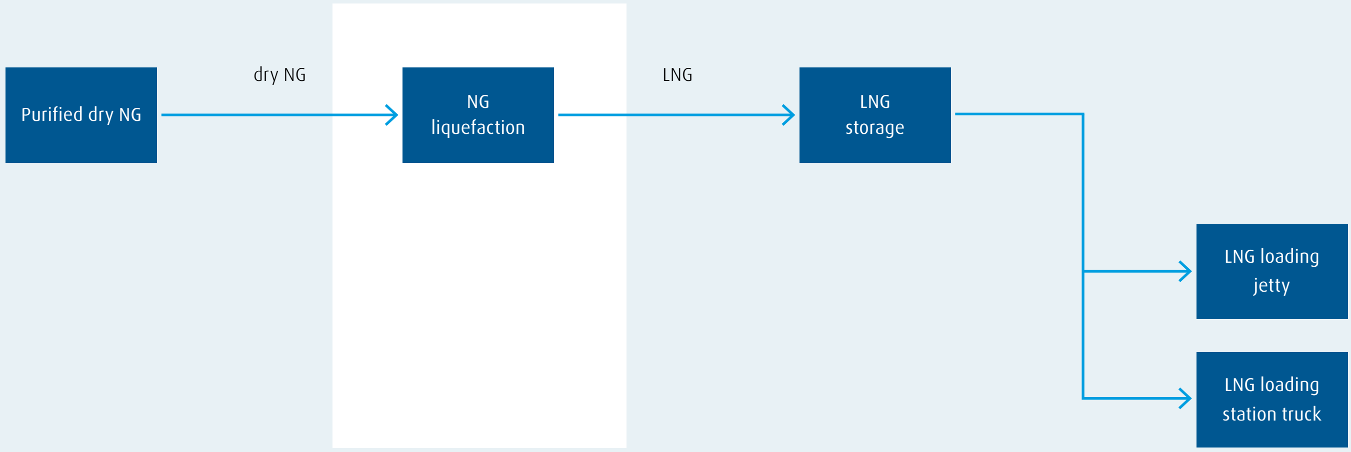
Helium is a rare gas and highly valued in the market, making its recovery – even in small amounts – from natural gas and subsequent liquefaction an attractive option. It is used, for example, in the space industry, MRI and NMR equipment (superconducting magnets), welding and shielding processes, lasers and optical fibre manufacturing.

So, if helium is also present in the natural gas stream, nitrogen rejection is typically combined with the recovery of helium. High-purity helium is obtained by combining cryogenic and pressure swing adsorption process steps.

We offer field-proven processes and plants for the cryogenic recovery of raw helium from natural gas, the purification of the raw helium in pressure swing adsorption (PSA) units, the liquefaction and production of high-purity helium (>99.999%) and its storage at temperatures of around –270°C. Our technologies cover each step in the helium value chain, enabling us to offer complete plants on a turnkey, lump-sum basis. Our wide range of process technologies is tailored to the capacity and helium concentration in the feed gas for optimum recovery results.

Main process units of an LNG production plant.

Typical block diagram of an LNG production plant



Linde process solutions for different gas field types

Onshore
Small- to mid-scale LNG production
(up to 1.5 mtpa liquefaction capacity per train)

Single mixed refrigerant cycle
→ Linde multistage mixed refrigerant (LIMUM®) or nitrogen expander process
→ StarLNG® process family

Onshore
World-scale LNG production
(minimum 3 mtpa liquefaction capacity per train)

Dual or triple refrigerant cycle
→ Mixed refrigerant cycle process
→ Mixed fluid cascade (MFC®)
→ MFC family

Near- and offshore
Mid- to world-scale LNG production
FPSO (Floating Prod. Shore & Offshore)
GBS (Gravity Blended Structure)

Dedicated liquefaction process
→ LIMEN™ (Linde methane nitrogen)

Small- to mid-scale StarLNG.

"Small- to mid-scale LNG plants do not compromise on safety, reliability, robustness or efficiency in comparison with world-scale LNG facilities, while execution risks and time as well as capital requirements are significantly reduced."

Targeted at small- to mid-scale LNG production plants, StarLNG 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 pretreatment and processing units, as well as main pipe racks. In addition, the StarLNG plant concept is adjustable within a wide liquefaction capacity range.

Thanks to the toolbox concept, StarLNG offers a number of compelling benefits to our customers. First and foremost, all StarLNG units leverage the safety and operational experience we have gained building world-scale plants and are designed to the same rigorous safety and reliability standards. This reduces execution risk and capital investment over a wide capacity range for our customers. Our excellent track record in safety performance is reflected in the fact that we have obtained construction permits for plants located close to urban developments in some of the world's most highly regulated geographies.

In addition, the advanced level of standardisation and modularisation, combined with well-referenced equipment sizes, means that we can draw on a large pool of vendors to offer customers more competitive pricing. Moreover, standard agreements with suppliers for long-lead items and design blueprints enable us to accelerate lead times from tendering to commercial production. Compared with world-scale projects in particular, this translates into huge time savings, not only for small-scale but also for mid-scale plants.

Mid-scale is scaling out.

In the past, the LNG market typically differentiated between small- to mid-scale production facilities and world-scale plants. Whereas the small- to mid-scale segment usually produces up to 0.5 million tonnes per annum (mtpa), world-class plants have liquefaction capacities of anywhere between 3.5 and almost 8 mtpa. According to our estimates, the small- to mid-scale sector currently accounts for around 10 to 15 percent of global liquefaction capacity. However, that may be about to change.

Recently, the market is seeing growing demand for a new class of LNG plant, namely "large" mid-scale facilities producing between one and two mtpa. Operators of these plants are looking to combine the benefits of large-scale plants (processing natural gas directly from the field and exporting the LNG to high-value markets in large "parcels") with those of small- to mid-scale plants (processing of pretreated feed gas from a pipeline).

Hence the market demands more flexible and cost-effective construction models for large mid-scale plants, offering fast time-to-solution – especially in remote areas or in environments where construction work is difficult or costly. Similar to the "smaller" mid-scale sector, the key to meeting these demands lies in standardised machines, equipment and instrumentation. Prefabricated modules can significantly reduce on-site construction effort and accelerate lead times from tendering to commercial production.

40

years of experience in the natural gas business

Extended mid-scale StarLNG®.

The time, cost and flexibility advantages of "larger" mid-scale units is fuelling demand for this class of plant. To meet this need, Linde developed a concept for a new class of mid-scale LNG production plant with a liquefaction capacity of between 1 and 2 mtpa. This concept offers economies of scale relative to smaller LNG plants while still benefitting from components of well-proven sizes that do not stretch technical limits. Furthermore, it has the potential to reduce construction costs, especially in remote areas or high-cost countries, by applying a fully modularised approach.

"Lowest CAPEX with plant solutions standardised for all climatic conditions."

Mid-scale StarLNG plant with up to 0.8 mtpa liquefaction capacity in Bintulu, Malaysia.

StarLNG family members.

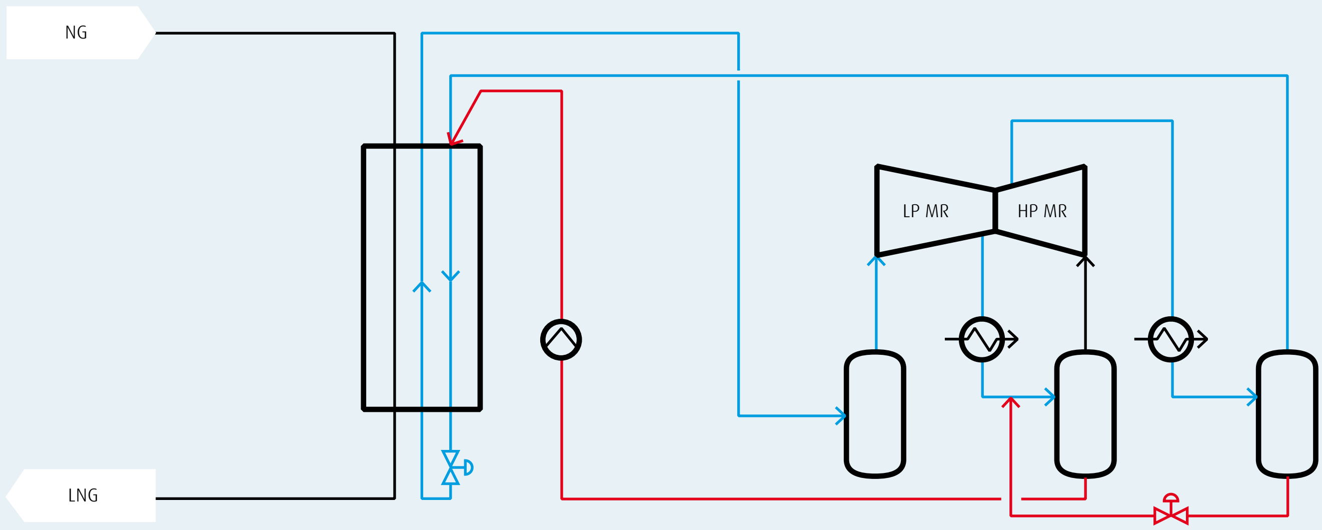
Small-scale StarLNG

The StarLNG concept originally targeted small-scale LNG liquefaction capacities ranging between 100 and 600 tpd (tonnes per day). 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 sub-cooled in a plate-fin heat exchanger (PFHE) mounted in a coldbox using Linde's highly efficient single mixed refrigerant cycle process, LIMUM®1. This mixed refrigerant cycle uses four refrigerants: nitrogen, methane, ethylene or ethane (depending on availability) and butane. As an alternative to the LIMUM1 process for small-scale StarLNG plants described above, Linde can also offer a well-proven nitrogen double expander cycle process, which offers particular advantages if the mixed refrigerants required for LIMUM1 are not available.

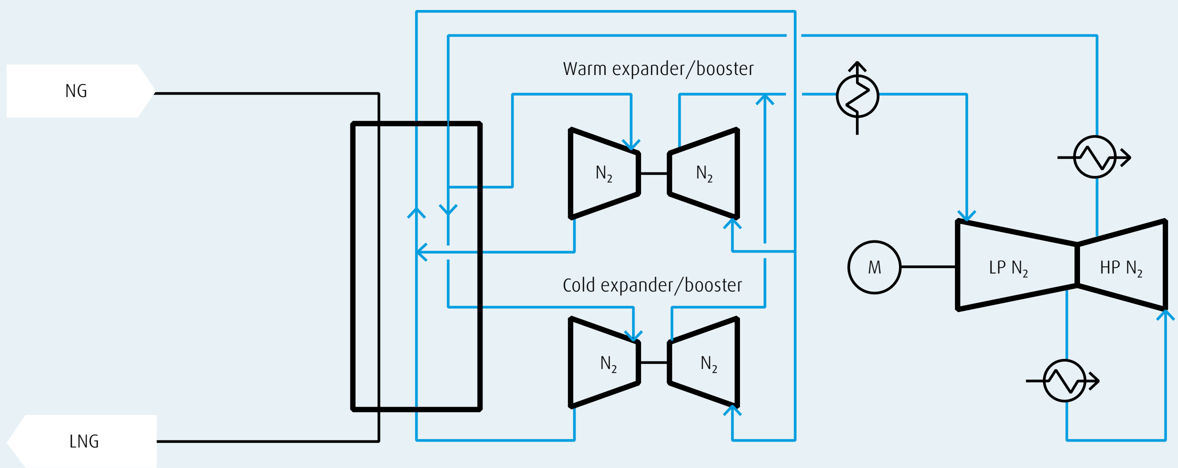
Key highlights

- Proven PFHEs manufactured by Linde Engineering
- Once-through liquefaction of pretreated (dry and sweet) natural gas
- Alternative process technology based on a double nitrogen expander cycle also available
- Compact modular design

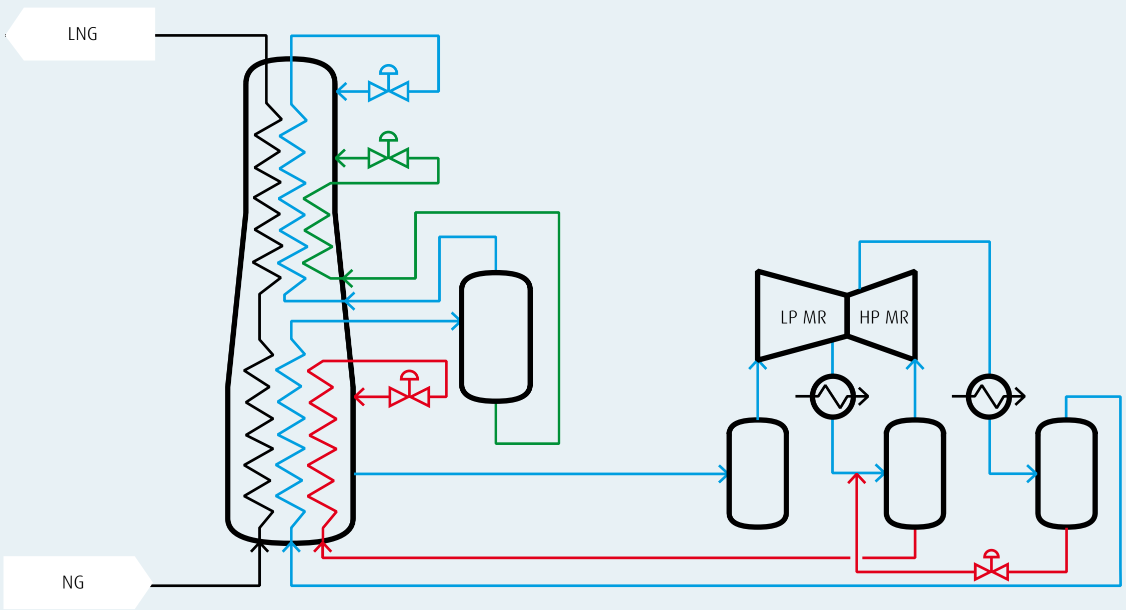
Small-scale StarLNG® process with single mixed refrigerant cycle LIMUM and PFHE (coldbox)



Small-scale StarLNG® process with nitrogen double expansion cycle and PFHE (coldbox)



Mid-scale StarLNG® process with LIMUM®3 liquefaction process using CWHE



Mid-scale StarLNG

Building on the StarLNG concept, the mid-scale LNG designs support capacities ranging from 600 to 3000 tpd (equivalent to approx. 1 mtpa). Here we use our LIMUM3 liquefaction process based on our proprietary coil-wound heat exchangers (CWHEs). This avoids multiple parallel blocks of PFHEs, which can result in complex piping arrangements, higher plot space requirements and flow distribution issues.

Key highlights
- CWHEs offering extremely robust design and ease of operation
- Same exchangers as those used for most world-scale plants
- Extended for liquefaction capacities >1 mtpa per train
- Three separate refrigerant fractions provide refrigeration power separately for the pre-cooling, liquefaction and sub-cooling cycles
- Part load capability of less than 31%

Extended mid-scale StarLNG

Based on its mid-scale StarLNG plants, Linde has developed a concept for a new class of mid-scale LNG production plants with 1–2 million mtpa liquefaction capacity. These plants are becoming increasingly attractive for the international LNG market as they combine the strengths of both mid-scale and world-scale plant types and markets. The concept offers economies of scale relative to smaller LNG plants while still benefitting from components of well-proven sizes that do not stretch technical limits. Furthermore, it has the potential to reduce construction costs especially in remote areas or high-cost countries by applying a fully modularised approach.

Highlights
- Reduced processing effort for pretreated feed gas
- Economies of scale relative to small-scale LNG plants, with reduced construction costs
- Proven components and dimensioning without stretching technical limits
- Multiple sourcing flexibility with no supplier lock-in or cost component qualification programmes
- Significant reduction in overall project risk and complexity compared with world-scale projects
- Compact modular design

Extended class
of mid-scale LNG plants with 1–2 mtpa liquefaction capacity

References for small- to mid-scale LNG plants.

Natural gas liquefaction plant in Bergen, Norway

Client	Naturgass Vest
Process	LIMUM® closed mixed refrigerant cycle process with plate-fin heat exchanger
Capacity	120 tpd
Scope of work	Engineering, procurement, construction, start-up supervision
Start-up	2003

Natural gas liquefaction plant in Kwinana, Australia

Client	Wesfarmers Gas Limited
Process	LIMUM closed mixed refrigerant cycle process with plate-fin heat exchanger
Capacity	175 tpd
Scope of work	Engineering, procurement, construction, start-up supervision
Start-up	2008

Natural gas liquefaction plant in Montreal, Canada

Client	GazMetro
Process	N_2 expander with coldbox
Capacity	390 tpd
Scope of work	Basic engineering, detail engineering, procurement, module construction, start-up assistance
Start-up	2017

Natural gas liquefaction plant in Shanshan, China

Client	Xinjiang Guanghui LNG Development Co. Ltd.
Process	LIMUM closed mixed refrigerant cycle process with coil-wound heat exchanger and gas turbine to drive MRC compressor
Capacity	1,300 tpd (430,000 tpa)
Scope of work	Engineering, procurement of main equipment, construction supervision, start-up supervision
Start-up	2004

Natural gas liquefaction plant in Stavanger, Norway

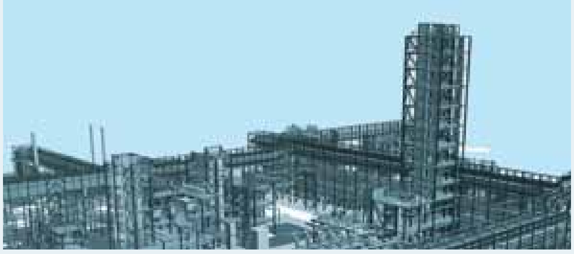
Client	Lyse Gass AS
Process	LIMUM closed mixed refrigerant cycle process with coil-wound heat exchanger
Capacity	900 tpd
Scope of work	Engineering, procurement, construction, start-up supervision
Start-up	2010

Natural gas liquefaction plants in China

Client	Several clients
Process	LIMUM closed mixed refrigerant cycle process with coil-wound heat exchanger
Capacity	0.28–0.5 mtpa
Scope of work	Engineering, procurement of main equipment, construction supervision, start-up supervision
Start-up	2013–2018

Natural gas liquefaction plant in Portovaya, Russia

Client	Gazprom (SRDI O&G Peton)
Process	LIMUM with coil-wound heat exchanger
Capacity	2 x 0.75 mtpa LNG storage 42,000m^3
Scope of work	Engineering, procurement, construction, start-up supervision
Start-up	expected 2021



Bintulu boil-off gas (BOG) reliquefaction plant, Malaysia

Client	MLNG (Petronas)
Process	BOG reliquefaction with proprietary LIMUM process and coil-wound heat exchangers
Capacity	Up to 0.8 mtpa
Scope of work	Engineering, procurement, construction, start-up supervision
Start-up	2015

World-scale LNG production.

< 250 KWH/T

MFC® process concept results in lowest energy consumption at the Hammerfest LNG plant.

LNG is traded on the global market, generally based on long-term contracts. World-scale natural gas liquefaction plants export the gas, and it is imported by world-scale terminals, where it is regasified to feed national pipeline grids. These world-scale plants have liquefaction capacities of anywhere between 3.5 and almost 8 mtpa.

The Hammerfest LNG story

In 1996, Linde AG and Statoil ASA started developing a new process for natural gas liquefaction. The resulting Mixed Fluid Cascade (MFC) process was successfully commercialised at the Snøhvit plant in Hammerfest (Norway) with a 4.3 mtpa LNG capacity. The plant has been running successfully beyond its design capacity since early 2009 and has passed all performance tests.

The main features of the Hammerfest LNG concept include

- → MFC process with three cascaded mixed refrigerant cycles
- → Direct sea water cooling for all compressor coolers and the main refrigerant condenser
- → All-electric concept with power generated by highly efficient aeroderivative gas turbines
- → Full sequestration of CO_2 contained in the feed gas
- → High-purity nitrogen (99.99 vol%) rejection from end-flash gas
- → Waste heat recovery from gas turbines

Total energy consumed by the liquefaction plant is as low as 243 kWh/tLNG, which is unsurpassed by any other baseload LNG plant worldwide. This low carbon footprint makes an impressive contribution to overall plant efficiency.

MFC world-class process family.

Several years ago, Linde set out to develop a portfolio of next generation processes capable of satisfying more diverse needs. The aim was to allow smooth operation in different climates, offer a variety of drive concepts, support different heavy hydrocarbon (HHC) and NGL extraction schemes and enable a range of liquefaction capacities.

The resulting MFC family includes processes with two refrigeration cycles (MFC1 and MFC2) or three refrigeration cycles (MFC3 and MFC4). For each of these base topologies, designs with propane (C_3H_8) pre-cooling (for warm climates) and mixed refrigerant (MR) pre-cooling (for cold climates and space-constrained applications such as floating LNG operations) are available. All processes have been patented and are at different phases of commercialisation. MFC4 has been selected, for instance, for Novatek's Arctic LNG 2 project.

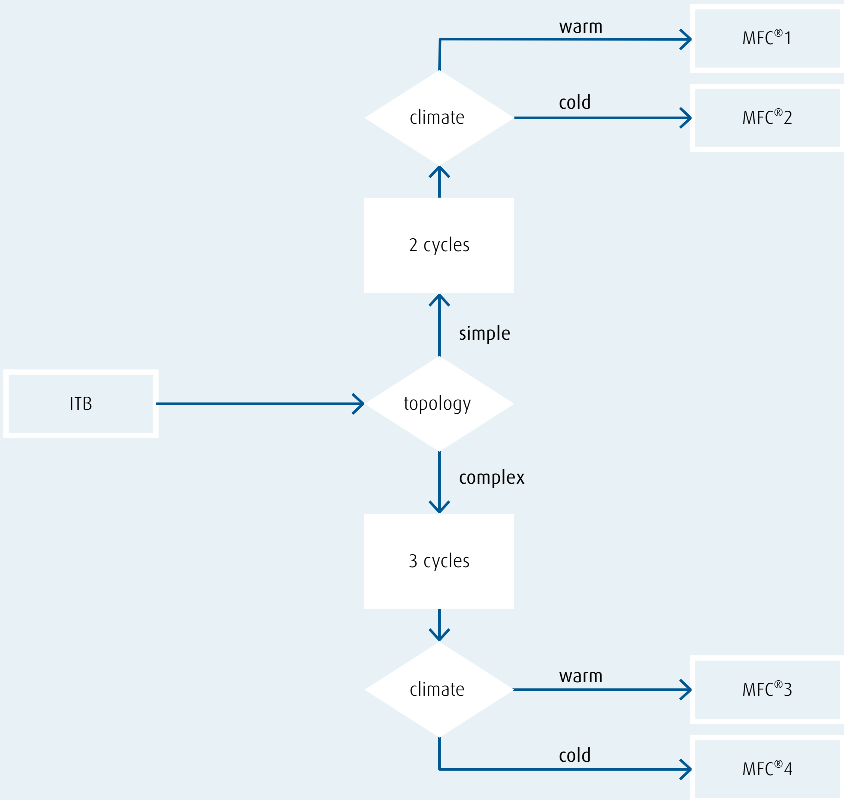
Design flexibility

If a very compact modular design is required, for instance for a floating LNG plant, the mixed refrigerant pre-cooling process is more cost-effective when the safety measures required for a large propane pre-cooling inventory are taken into consideration.

Cost-effectiveness

due to compact modular design

Process topology for land-based, stick-built world-scale LNG plants



MFC1 process.

The patented MFC1 process is a modern interpretation of the well-known propane pre-cooled mixed refrigerant process. It uses rotating and static equipment with an operating pressure of up to 100 bar. Decades ago, when the C3MR process was introduced, this pressure range was considered highly unusual in the absence of suitable or cost-effective equipment.

Reducing operating expenses

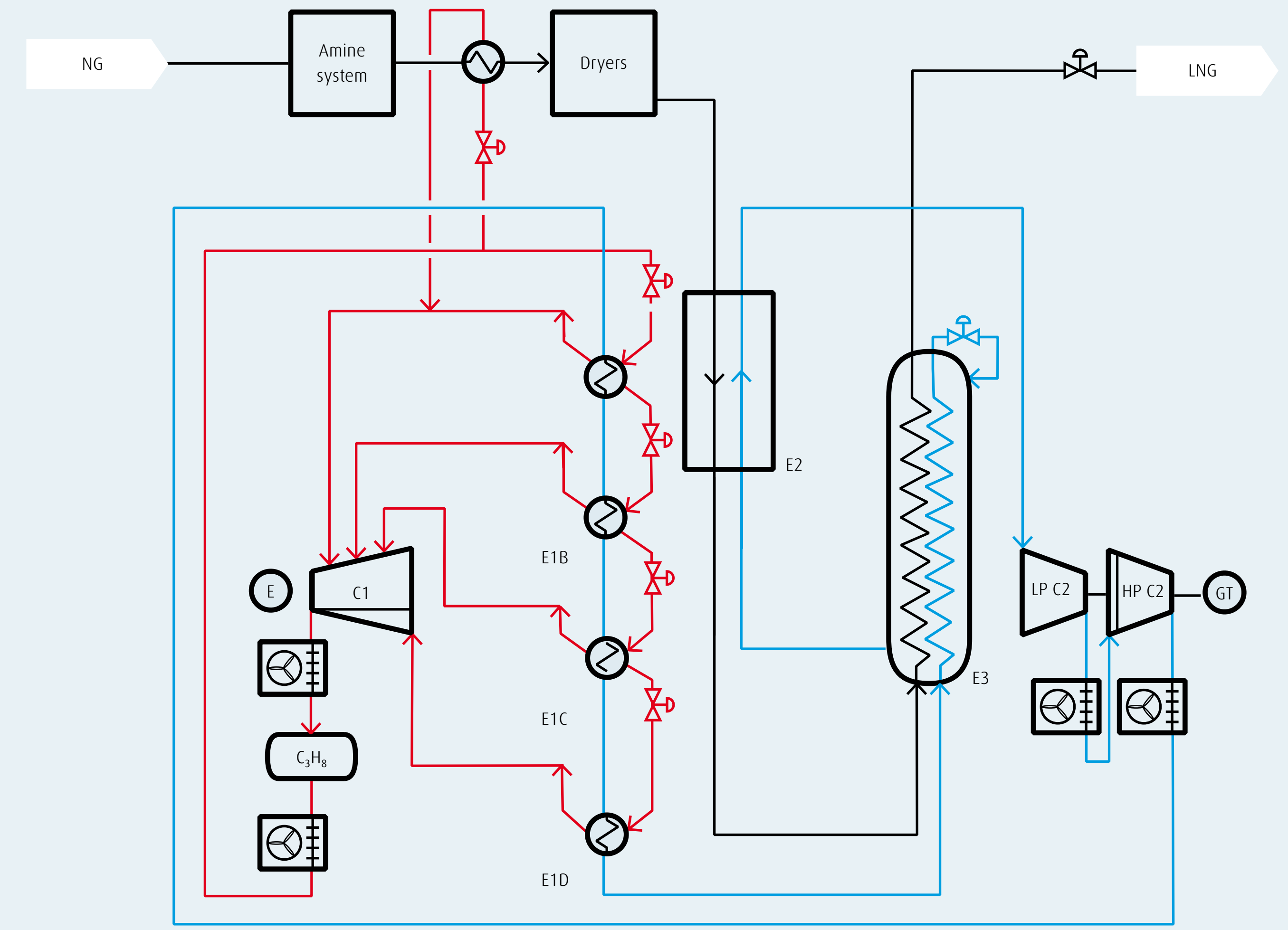
The C3 pre-cooling cycle is used to cool and condense the HP mixed refrigerant stream in a series of heat exchangers E1A to E1D, which can be either conventional shell and tube kettle-type heat exchangers or block-in-shell heat exchangers consisting of a large PFHE installed in of a vessel. In a warm climate, feed gas chilling down to almost the hydrate formation temperature reduces operating expenses. This feed gas chiller can be integrated into the propane cycle.

Lean design

The mixed refrigerant cycle compressor C2 has a high compression ratio higher than a factor of 20. The vaporised mixed refrigerant from the CWHE E3 is superheated in a PFHE E2 against the warm feed gas. This eliminates the need for another set of bulky and expensive propane vaporisers and eases the operation of the MR compressor, as the suction temperature is now at around ambient temperature, so no longer in the region of −40°C. Furthermore, a cold MR separator is no longer required. The HP design of the MR cycle reduces the circulating refrigerant flow rate and improves the thermodynamic efficiency.

Even though the integration of a conventional scrub column is feasible, the preferred process setup is based on separate HHC/NGL extraction with subsequent lean feed gas compression. In this configuration, up to 6 mtpa LNG capacity can be attained if two large gas turbines act as drivers for C1 + HP C2 and LP C2. If a lower capacity range down to 3 mtpa is required, a configuration with an electric motor for C1 and a gas turbine for LP + HP C2 is recommended.

MFC®1 process (patented as LIPROM)



MFC2 process.

The patented MFC2 process is an alternative to the MFC1 process more suited to cold climates or space-constrained plots (e.g. FLNG or GBS), which exclude the large-scale storage of liquid C3+ hydrocarbons for safety reasons.

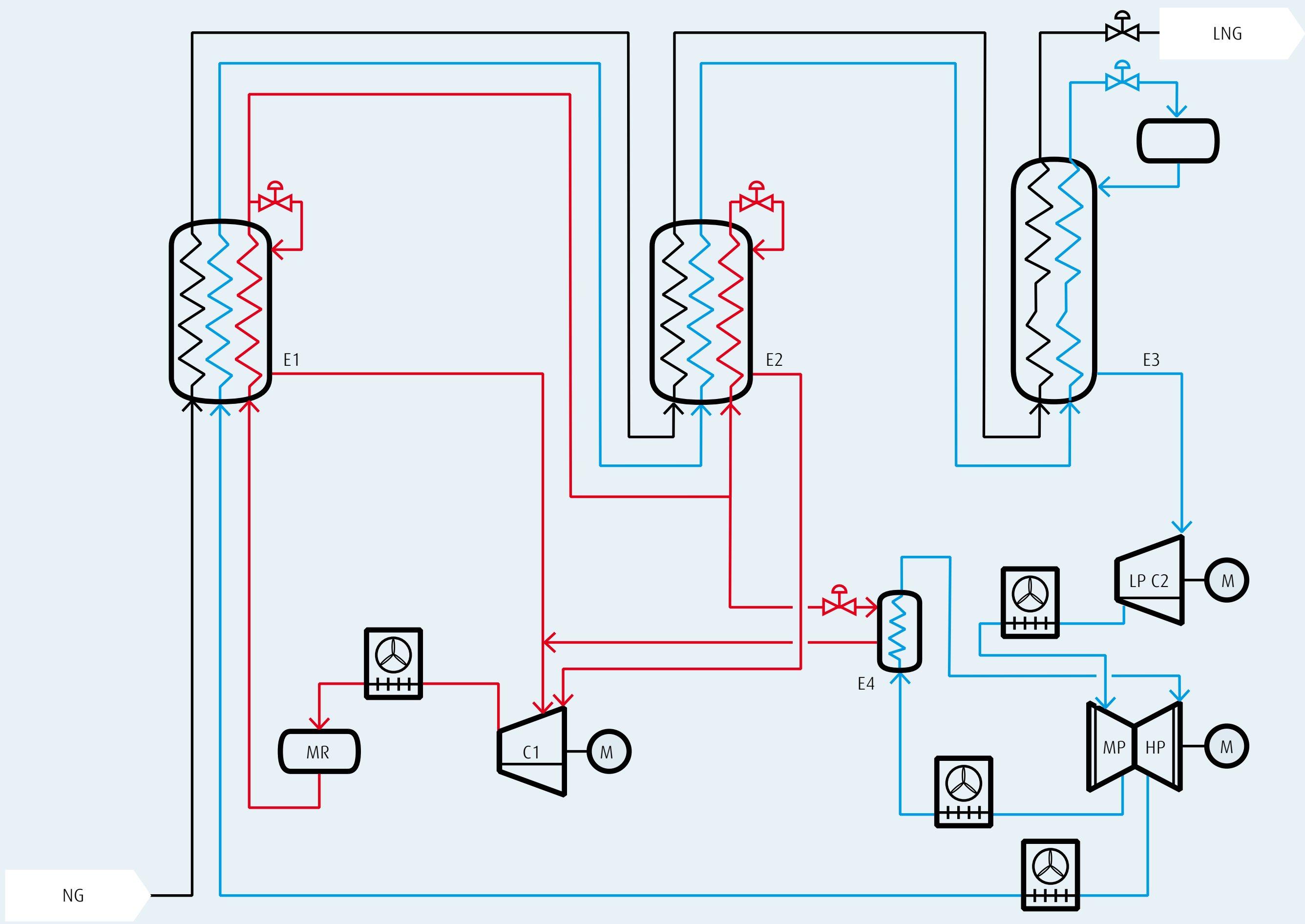
The pre-cooling cycle is designed as a mixed refrigerant loop with vaporisation of the fluid at two different pressure levels in E1 and E2. This design relieves the LP suction side of compressor C1 and helps to achieve large LNG capacities without parallel rotating equipment.

High compression ratio

The mixed refrigerant cycle compressor C2 has a high compression ratio higher than a factor of 20. A cold MR separator is not required. The HP design of the MR cycle reduces the circulating refrigerant flow rate and improves the thermodynamic efficiency. Two intercoolers are implemented in the cold MR compression, and they are supported by a side stream of warm MR used for interstage chilling in E4. In addition, E4 supports start-up of the cold suction LP C2 compressor so it quickly reaches cold suction conditions from ambient temperatures.

The preferred process setup is based on separate HHC/NGL extraction with subsequent lean feed gas compression. In this configuration, up to 7 mtpa LNG capacity can be reached in cold climates if two large gas turbines act as drivers for C1 + HP C2 and LP + MP C2. Alternatively, three electric motors (see sketch) with identical power ratings can be implemented.

MFC®2 process (dual mixed refrigerant)



MFC3 process.

The patented MFC3 process is a warm-climate adaptation of the MFC process already proven in the Hammerfest LNG plant. It has been licensed for several projects in the Middle East and in South America.

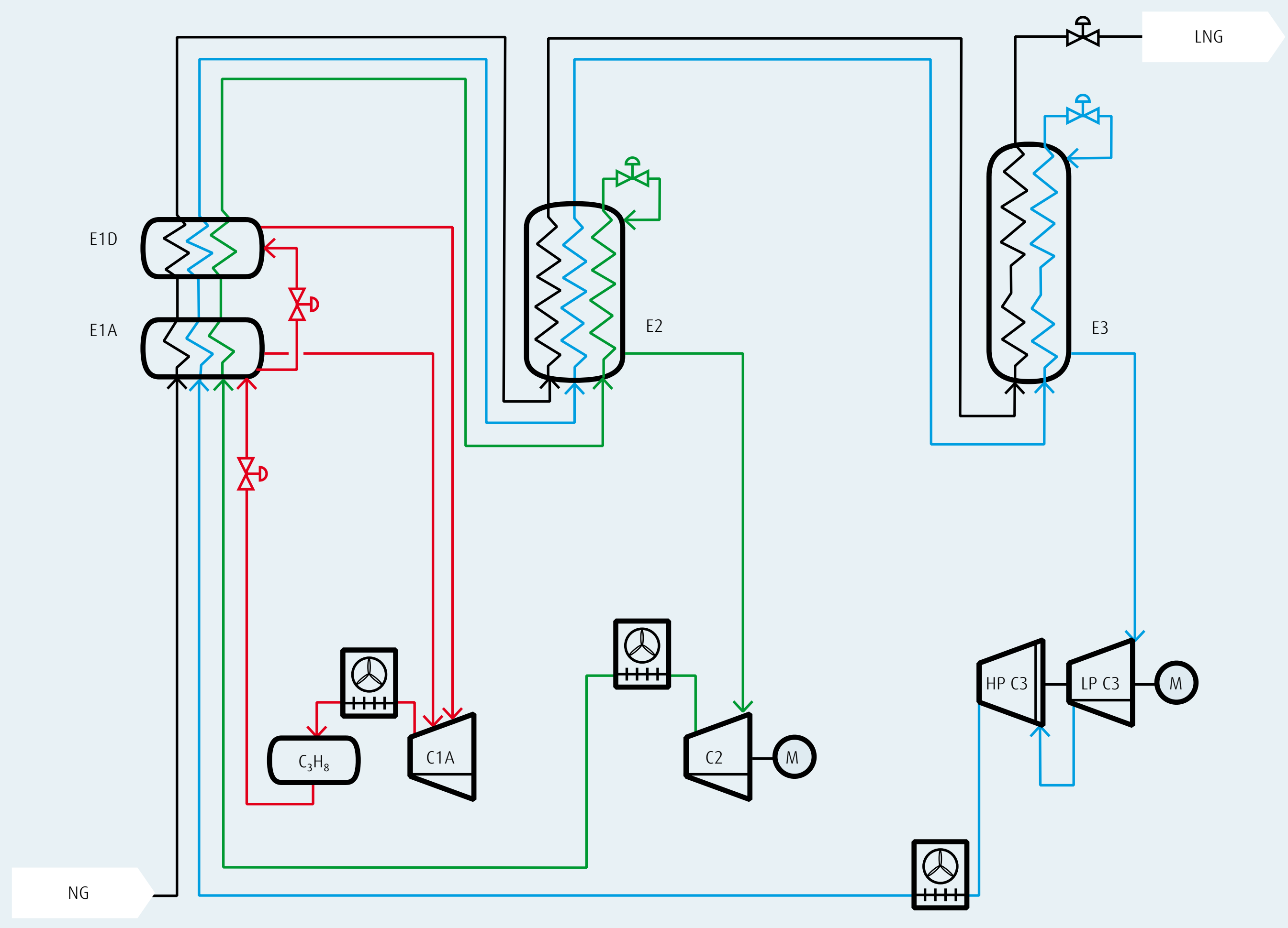
The C3 pre-cooling cycle is used to cool feed gas and the two mixed refrigerant fluids in a series of heat exchangers E1A to E1D (only partly shown in the sketch), which can be either conventional shell and tube kettle-type heat exchangers or block-in-shell heat exchangers consisting of a large PFHE installed in vessel. In a warm climate, feed gas chilling down to almost the hydrate formation temperature reduces operating expenses. This feed gas chiller can be integrated into the propane cycle.

Different feedstock compositions

The mixed refrigerants for the liquefier E2 and the sub-cooler E3 are fully independent. The operating parameters can be fine-tuned to match different ambient conditions and feedstock compositions.

The preferred process setup is based on separate HHC/NGL extraction with subsequent lean feed gas compression. In this configuration, up to 10 mtpa LNG capacity can be attained if three large gas turbines act as drivers for C1, C2 and LP + HP C3. Alternatively, three electric motors (see sketch) with identical power ratings can be implemented.

MFC®3 process



MFC4 process.

The patented MFC4 process is an alternative to the MFC3 process more suited to cold climates or space-constrained plots (e.g. FLNG or GBS), which exclude large-scale storage of liquid C3+ hydrocarbons for safety reasons. The MFC4 process has been licensed for Novatek's Arctic LNG II project.

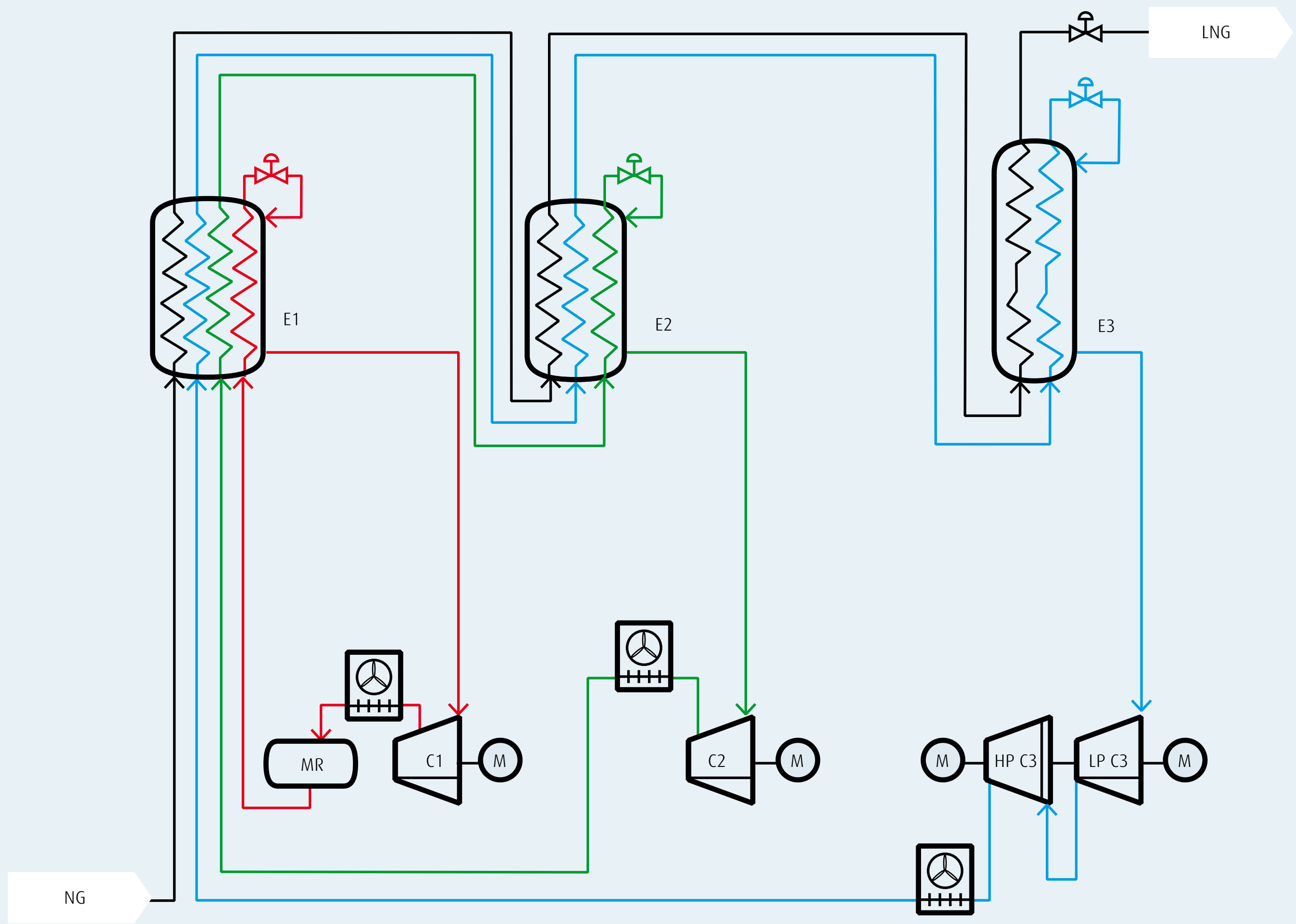
Achieving large LNG capacities

In contrast to the MFC2 process, the warm cycle is split into two independent cycles, which supply refrigeration to E1 and E2. This design reduces the load to the MR compressors C1 and C2 and helps to achieve large LNG capacities without parallel rotating equipment.

The mixed refrigerant cycle compressor C3 has a high compression ratio higher than a factor of 20. The HP design of the MR cycle reduces the circulating refrigerant flow rate and improves the thermodynamic efficiency.

The preferred process setup is based on a separate HHC/NGL extraction with subsequent lean feed gas compression. In this configuration, up to 7 mtpa LNG capacity can be reached in cold climates if two large gas turbines act as drivers for C1 + C2 and LP + MP C3. Alternatively, four electric motors (see sketch) with identical power ratings can be implemented.

MFC®4 process



LIMEN – process for floating LNG operations.

LIMEN

newly patented FLNG process technology

Floating natural gas liquefaction (FLNG) projects are still quite rare and are clearly outnumbered by the hundred-plus mid- and world-scale onshore LNG trains with at least 1 mtpa capacity.

The CAPEX of these floating operations can be reduced by increasing the liquefaction capacity to capitalise on economies of scale. However, not all concepts that are proven on shore translate into optimal FLNG solutions. In many cases, operability is more important than efficiency. This offers new opportunities for expander-based liquefaction processes.

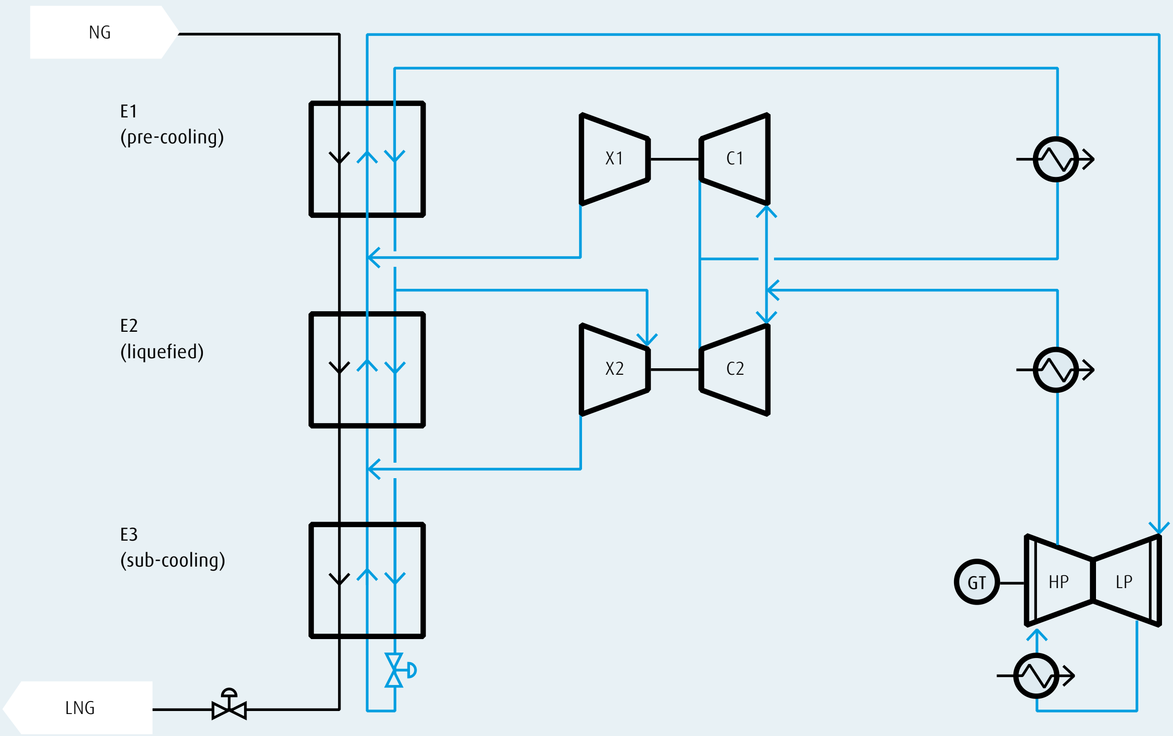
LIMEN (Linde Methane/Nitrogen) process

Our patented LIMEN process relies on proven building blocks, combined in a novel and sophisticated manner. The simple and clean process layout builds on cLNG process features. A methane/nitrogen mixture as the refrigerant and a phase-change step in E3 (see figure below) offer the following benefits:

- In E3, sub-cooling is provided by efficient condensation/vaporisation similar to that provided by well-known mixed refrigerant processes
- The operating range of the cold expander X2 is shifted from the sub-cooling service to a warmer range, where more refrigeration can be used efficiently
- With the correct feed gas settings, similar or even identical X1 and X2 shaft power can be achieved at the optimum thermodynamic conditions (in other words, with minimum energy consumption)

LNG tanker Arctic Princess docked at LNG plant in Hammerfest, Norway.

Schematic diagram of Linde's new symmetric methane (CH_4)/nitrogen (N_2) expander process (LIMEN™)



High-capacity expander process with excellent safety.

The refrigerant inventory is present in a vapour or dense phase for the entire process except for a short line between the JT valve at the cold end of E3 and its feed point back into E3. As this volume is negligible compared with the LNG streams, no relevant safety risk is added to the liquefaction process due to the use of a refrigerant, which contains the flammable component methane.

The novel LIMEN process can be used to design FLNG processes with a total capacity of up to 2.5 mtpa based on two 1.25 mtpa trains. It thus significantly reduces equipment count and plot requirements relative to competing technologies. The thermodynamic efficiency matches that of a well-designed N_2 expander process. The rotating equipment supplied by Cryostar, a member of The Linde Group, is one of the key success factors for the LIMEN process.

FLNG process
with up to 2.5 mtpa
capacity


Linde

Innovating service delivery through digitalisation.

We combine the experience and hands-on insights we have gained through our engineering and operational references with the latest digitalisation technologies to create truly innovative customer experiences.

We have been rolling out digital technologies across all business lines for a number of years now, as evidenced by our five Remote Operation Centres (ROC) tasked with the remote management of around 1,000 industrial plants around the world. We are using the huge trove of digital data that we already possess from these plants to accelerate the development and delivery of new products and services for our customers.

For example, thousands of sensors in hundreds of Linde plants across the globe have been gathering extremely detailed data on the status and health of components for many years now. We are using this information to develop predictive maintenance capabilities that allow us to accurately predict when a component is likely to fail so we can take appropriate proactive measures in good time. This information can also be channelled into the optimisation of component design.

Virtual training platform

Our gold mine of digital data includes detailed CAD files for every project we have executed. We use this data to create impressively detailed 3D simulations of large-scale plants, known as "digital twins". A virtual reality application uses these digital twins to train operators before a plant has even been constructed.

This VR application can also be used to visualise design changes during the planning phase. Operators of what will be one of the world's largest gas processing complexes can already take a virtual tour of the Svobodny plant near Belogorsk in the Amur region, for instance. All they need is a VR headset, a laptop and a hand-held controller, and they can explore all of the module's platforms and study its valves and compressors from every angle. They can even step inside process components such as coldboxes – so they are thoroughly familiar with the plant's inner workings by the time it goes on stream.

This service means that plant operators can accelerate the start-up process on completion of the plant as the staff is ready to spring into action. It can also save operators millions by ensuring that staff are trained to deal with critical or dangerous situations before they even arise.
In addition, virtual training avoids unnecessary travel expenses to attend classroom-based training courses. Looking beyond the logistical benefits, studies indicate that VR technology makes the learning process 15 times more effective than classroom-based training, with learning curves accelerating by 33 percent.

"Up to 15 times more effective than classroom training."

Emerson study

Top-to-bottom competence for your peace of mind.
LINDE PLANTSERV.

"All-round, full-lifecycle support for your plant – from training and parts management to repairs and revamps."

Performance you can trust

With our LINDE PLANTSERV portfolio, we deliver a broad range of services spanning every step in the plant lifecycle – from operational support through maintenance and repairs to modifications and revamps. You can even rely on LINDE PLANTSERV for complementary services such as training and spare parts management – delivered through innovative digital platforms for maximum convenience.

TCO optimisation

Not only does LINDE PLANTSERV give you a single point of contact for all your service, maintenance and modernisation needs, it also helps to minimise your total cost of ownership (TCO). Looking beyond the initial upfront investment, which our experienced engineers have already optimised through cost-effective technologies, modularisation and global sourcing capabilities, LINDE PLANTSERV focuses on also reducing your running costs.

Experience has shown that operating costs account for the lion's share of total outlay. Although energy costs play a large role here, so too do downtime, maintenance work, repairs and spare parts management. Regular maintenance, predictive repairs, timely modernisation and efficient spare parts management can reduce both the time and cost involved in maintaining smooth operations.

More information:
http://portal.linde-plantserv.com/

Execution excellence – every step of the way.

At Linde, we have a strong focus on and excellent track record in quality, health, safety and environmental (QSHE) protection. This has always been a top priority when planning and building our plants all over the world.

Long-standing experience in cryogenic plant design

We have a large engineering and project execution workforce for the implementation of engineering, procurement and construction (EPC) projects worldwide. Project managers with extensive experience in complex multinational/multi-partner projects supported by advanced tools and methods for project control are the best way to ensure the success of your project.

Manufacturing excellence – made in-house

We design and manufacture all key and proprietary cryogenic components required for NG plants in our own fabrication workshops.

Key components for NG plants manufactured in house include:

- Coil-wound heat exchangers (CWHEs) and plate-fin heat exchangers (PFHEs)
  Linde Engineering is the only manufacturer to specialise in both types of cryogenic heat exchanger typically deployed in industrial-scale LNG plants – coil-wound and plate-fin models – both produced at our Schalchen (Germany) plant
- Cryogenic pumps, manufactured by Linde Group member Cryostar.
  Highlights include submerged cryogenic pumps to export LNG from storage tanks to regasification or filling stations
- Coldboxes
  Also manufactured at our Schalchen plant, our coldboxes scale from pre-packaged, pre-tested models that are ready to operate to customised equipment assembled on site
- Expanders
  Also manufactured by Linde Group member Cryostar – world quality leader in radial inflow expansion turbine technology, pumps and LNG boil-off gas compressors, having also developed a range of small-scale LNG or liquid biogas plants for onshore natural gas or biogas liquefaction projects

Profitability matters

Worldwide staffing and training, global procurement and fabrication capabilities and a broad partner ecosystem bring maximum flexibility and cost efficiency to your project. At every stage of the project – from your very first query to turnkey handover – our service-focused engineers are there to support you. You can rely on our team to deliver the project development services you need to make the best investment in natural gas processing technology and maximise your return on that investment.

Talk to our experts today.

Global reach

100+

We are represented in over 100 countries worldwide.

Read more:
linde-engineering.com

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Your partner for the production and processing of gases

Delivering reliable process plants for maximum capital efficiency
Linde has been optimizing gas processing technologies for 140 years, successfully delivering more than 4,000 plant engineering projects around the globe. Favoring trusted, lasting business relationships, the company collaborates closely with customers to enhance plant lifecycle productivity and innovate process flows. The company's proven gas processing expertise plays an indispensable role in the success of customers across multiple industries – from natural gas and oil refining through petrochemicals and fertilizers to electronics and metal processing.

Operational excellence along the entire plant lifecycle
We work closely with our customers to gain an in-depth understanding of individual needs. Building on the unique synergies of Linde as an integrated plant operator and engineering company, Linde offers innovative process technologies and services to exceed our customers' reliability and profitability expectations. This commitment to innovation extends along the entire plant lifecycle. The LINDE PLANTSERV® service team supports customers every step of the way – from maintenance and repairs to full revamps. Leveraging the latest digital technologies to offer on-site and remote operational and support services, we consistently take asset performance to the next level.

Making the impossible possible
From the desert to the Arctic, from small- to world-scale, from standardised to customised designs, Linde's engineering specialists develop solutions that operate under all conditions. The company covers every step in the design, project management and construction of gas processing plants and components. Customers can always rely on Linde to deliver the plants, components and services that fit their needs best – anywhere in the world.

Discover how we can contribute to your success at www.linde-engineering.com

Get in touch with our natural gas plants team:
Phone +49 89 7445-3434, inquiry: www.linde-engineering.com/contact

Core competencies at a glance

Plant engineering
- Air separation plants
- LNG and natural gas processing plants
- Petrochemical plants
- Hydrogen and synthesis gas plants
- Adsorption plants
- Cryogenic plants
- Carbon capture and utilisation plants
- Furnaces, fired heaters, incinerators

Component manufacturing
- Coldboxes and modules
- Coil-wound heat exchangers
- Plate-fin heat exchangers
- Cryogenic columns
- Cryogenic storage tanks
- Liquefied helium tanks and containers
- Air-heated vaporisers
- Water bath vaporisers
- Spiral-welded aluminum pipes

Services
- Revamps and plant modifications
- Plant relocations
- Spare parts
- Operational support, troubleshooting and immediate repairs
- Long-term service contracts
- Expert reviews for plants, operations and spare part inventory
- Operator training

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