THE CRYOSTAR GROUP

CRYOSTAR is a cryogenic equipment manufacturer with more than 600 employees including 150 engineers. With its headquarters located in France, the company operates five production sites and is present worldwide through eight business centers and 16 business partners.

Founded in 1966 the company has over 40 years experience with LNG and has become the world leader for boil off gas compressors and on-board liquefaction units for LNG carriers. The company has delivered thousands of cryogenic pumps for liquid hydrocarbon applications (including methane, ethylene, ethane, etc.)

CRYOSTAR’s engineers continuously innovate with patented solutions for various applications throughout the LNG supply chain such as small scale liquefaction, LNG transportation, LNG/LCNG vehicle refueling stations and LNG bunkering.

SAFETY AND STANDARDS

Safety is an integral part of CRYOSTAR’s management and manufacturing commitments. For each new development or project, the company performs a risk analysis using approved techniques such as HAZOP (Hazard and Operability) and FMEA (Failure Mode and Effects Analysis). CRYOSTAR’s equipment and solutions comply with most stringent machine and safety regulations such as the Pressure Equipment Directive 97/23/CE (Module H and H1) and ATEX.

FACTORY AND ON-SITE ACCEPTANCE TESTS

CRYOSTAR’s headquarters host the world’s largest and most sophisticated liquid nitrogen test facility for cryogenic pumps as well as three test facilities dedicated to turbines. CRYOSTAR engineers subject each pump and turbine to a performance test prior to shipment, offering customers guaranteed performance. CRYOSTAR provides commissioning, start-up and support for onsite performance testing for liquefaction plants and refueling stations.

QUALITY AND ENVIRONMENT

CRYOSTAR is ISO 9001-2008 certified. To structure its environmental approach, CRYOSTAR has used the ISO 14001 standard to set up all the organizational and operational processes necessary for an aspiring Environmentally Responsible company. In parallel, CRYOSTAR has applied this approach to Health and Safety through the OHSAS 18001 standard.

100% of CRYOSTAR’s equipment and solutions comply with most stringent machine and safety regulations such as the Pressure Equipment Directive 97/23/CE (Module H and H1) and ATEX.
Small Scale Liquefaction
LNG Bunkering Station
Pressure Let Down Station
Industry
Satelite LNG Plant
Truck Stop LNG refuelling station
LNG Feeder
LNG Floating Storage and Regasiification Unit
LNG Trailer
LNG Carrier
LNG Bunkering Barge
Ferry
LNG Floating Storage and Regasiification Unit

EQUIPMENT AND SOLUTIONS FOR LNG AND LBG
At CRYOSTAR, we have the requisite operational and industrial experience to have a global understanding of your challenges in monetizing natural gas. Based on your specific environment and objectives, we create flexible solutions based on our wide portfolio of natural gas liquefaction technology, “StarLite LNG™.”

**StarLNG™, StarLNGL™, LIMUM®**
are a trademark of The Linde Group.

**StarLite LNG™**
is a trademark of CRYOSTAR.
Hands-on experience with small to mid-scale plants with StarLNG™

**SMALL-SCALE**

- **120 tpd**
  (~70,000 gpd)
  Bergen, NORWAY

- **21 tpd**
  (~12,000 gpd)
  Altamont, USA

- **175 tpd**
  (~100,000 gpd)
  Kwinana, AUSTRALIA

**MID-SCALE**

- **900 tpd**
  (~530,000 gpd)
  Stavanger, NORWAY
CRYOSTAR’s first liquefaction units: Boil-off gas systems on LNG carriers

Capacity ~7 tonnes per hour (turn down ratio ~30%),
Following an extensive development program CRYOSTAR’s Ecorel process was selected for installation on the world’s largest LNG carriers Q-Max to the Qatar Gas Transport Company.
The capacity of these vessels, 266’000 m³, exceeds by far all that of all other LNG vessels ever built
More than 150,000 hours of combined operation (100 to 120 journeys)
2 x 14 units on Q-Max LNG carriers. In operation since 2008, 187 tpd
2 x 4 units to MOL for PNG LNG project, operational from 2015

A Q-Max LNG carrier with 266’000 m³ of LNG cargo capacity, arrives in the UK to unload its cargo.

IMAGE QatarGas
StarLiteLNG™ - small scale liquefaction system

Based on its experience with the boil off gas re-liquefaction systems onboard LNG carriers, CRYOSTAR developed and now offers, through its StarLiteLNG™ family product, small scale LNG or LBG plants for onshore natural gas or biogas liquefaction applications with capacity from 20 to 200 tonnes per day (17 to 124 k GPD).

CRYOSTAR focuses on a skid-mounted liquefaction unit. For additional packages such as gas treatment, polishing and balance of plant, we offer a solution in collaboration with customers and our network of partners.
**StarLiteLNG™ toolbox**

The idea of StarLiteLNG™ is to standardize and optimize a small scale LNG system from 20 to 200 tonnes per day (17 to 124 k GPD) based on a wide set of process variations. The toolbox is designed to cover about 90% of real-life boundary conditions, with the following major benefits:

**SAFE**
No flammable or toxic refrigerant storage for simpler regulatory compliance and less time to LNG production.

**FINANCEABLE**
CRYOSTAR has produced cryogenic machinery for 40 years and has a strong parent company with investment grade credit rating.

**FLEXIBLE**
Turn down to 30% of design volume as required, for instance to avoid high demand charges from utilities.

**RELIABLE**
Highest in-house content thanks to complete engineering, manufacturing and commissioning of the liquefaction module, including core components. Wide range of services including global maintenance facilities near our customers.

**SIMPLE**
A straightforward process control based on a single turbomachine (componder) in the refrigeration system. Automatic load control in a range of ambient conditions, gas compositions, pressures and temperatures.

**ECONOMICAL**
High efficiency expansion and compression processes minimizes power consumption. Lowest equipment count minimizes installation and maintenance expenses.

**INNOVATIVE**
CRYOSTAR continuously improves its product offering through strong R&D investment and by leveraging the knowledge of its parent company. StarLiteLNG™ products portfolio is the latest extension of the Linde StarLNG™ family of liquefiers.
StarLiteLNG™ liquefier models and Nitrogen process toolbox

Simple, robust and easy-to-operate process with a nitrogen reverse Brayton closed loop, based on CRYOSTAR and Linde’s proven technology and equipment.

<table>
<thead>
<tr>
<th>LIQUEFIERS MODEL</th>
<th>CAPACITY</th>
<th>HEAT EXCHANGER</th>
<th>SPECIFIC POWER CONSUMPTION at 100% capacity</th>
<th>LIQUEFIER FOOT PRINT w/o Air coolers</th>
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<td>K GPD (2)</td>
<td>Number</td>
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<td>XL</td>
<td>200</td>
<td>124</td>
<td>1</td>
<td>cold box</td>
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</tbody>
</table>

(1) Varies with project specifics  (2) Thousands of US gallons per day

Process diagram for XS liquefier

Process diagram for S,M,L,XL liquefier
StarLiteLNG™ liquefier models and Nitrogen process toolbox

**Single stage N₂ process with compander**

**Dual stage N₂ process with compander + JT valve**

![Diagram of liquefier models and nitrogen process toolbox](image-url)

*Graphs showing heat flow and temperature for cold and hot composites.*
StarLiteLNG™ plant overview

- Pre-engineered process solutions and a modularized design approach to accomplish shortest delivery time with minimum on-site construction.
- Applying toolbox approach to ease plant customization while maintaining the benefits of standardization.

CONTENT OF TOOLBOX

Set of generic documents prepared and validated for the base case including:

- BASIS OF DESIGN
- PFD
- PROCESS DESCRIPTION
- PID AT PRELIMINARY STEP
- SAFETY CONCEPT REQUIREMENT
- WINTERIZATION CONCEPT
- PLOT PLAN
- 3D MODEL
- MODULARIZATION DESIGN
- MTO STEEL STRUCTURE
- MTO PIPING
- EQUIPMENT LIST
- VALVE / INSTRUMENTATION LIST
- OPTIMIZED PLANT LAYOUT CONCEPT + COLDBOX
- CONCEPTUAL HAZID
- MASTER PROJECT SCHEDULE
StarLiteLNG™ compander machine

A compander is a combined expander and compressor in a single, integrally-geared machine installed in the refrigerant cycle. CRYOSTAR built the first compander in 1996.

- 3 compression and 1 expansion stages mounted on a common motor driven speed increasing gearbox. Expander power is recovered and reduces drive motor consumption.
- Lube oil and seal gas system (25 to 45 Nm³/h of N₂ consumption)
- Motor with medium voltage requirement

PREVENTATIVE MAINTENANCE
- 2 days per year and 14 days every 35,000 operating hours (4-5 years)

Compander with water cooling system for marine applications

Compander during final test in CRYOSTAR test bench hall
The peak shaving system allows natural gas to be stored and supplied on demand in case of increasing gas consumption, or gas supply outages from the natural gas grid.

These systems usually require very high flows, as well as medium to high pressure. Once the LNG is pressurized, it is sent to the vaporizers before being injected into the grid.

As part of our LNG systems portfolio, CRYOSTAR offers trailer unloading pumps, booster pumps, reciprocating high pressure pumps, as well as complete PLC controls solutions and cryogenic process consultancy to meet customers’ requirements in terms of plant performance and reliability.

**LOADING AND OFFLOADING SOLUTIONS**

**Skidded unit**
- CRYOSTAR centrifugal pump with external or submerged motor
- ATEX skid with piping, valves, instrumentation and safety devices
- ATEX control panel
- Manual or full automatic execution

**Interface panel**
- Control box with start/stop buttons, lights, pressure and level indicators
- Automatic management of trailer offload process which ensures higher safety
- Accessibility to the trailer flexible hose outside of the equipment area
- Possibility to have a wired connection with trailer for higher safety

**Metering skid**
- Coriolis technology based on flow management
- Weights and Measures approval option available
- Measurement of loading and gas return flows
LNG / LCNG refueling stations

CRYOSTAR equipment in Rolande LNG station, Tilburg (The Netherlands)

CRYOSTAR dispenser 2.0

Liquid to Compressed Natural Gas “LCNG” refueling stations

Liquified Natural Gas “LNG” refueling stations
**Turbo expander/compressor for cold production in LNG processes**

Turbo expander with compressor mounted on a common shaft with a large range of cold production, pressure and flows are available from the TC120, ~ 50 kw to the TC600 up to 8 MW.

Usual gases handled: air, nitrogen, or waste gas from air with high oxygen or with CO, CO₂ (Sour) Natural Gas, H₂ & CH₄ mixtures, LNG, NGL, LPG.

CRYOSTAR designs all turbo expander packages to the strict industry and client requirements for various process refrigeration cycles.

Today, CRYOSTAR’s installed base, including industrial gas machines, exceeds more than 1,200 turboexpanders located in more than 60 countries worldwide.
For contact and address of CRYOSTAR locations worldwide, please go to www.cryostar.com/locations