

PRODUCT GUIDE

LNG plants – mini and small scale liquefaction technology



THE WORLD
POWERS UP
ON LNG

SMALL SCALE
LIQUEFACTION
ENABLES A RETAIL
LNG MARKET

WÄRTSILÄ TECHNOLOGY
OVERCOMES SMALL SCALE
PROJECT CHALLENGES

The global trend

Natural gas is today one of the world's most needed feedstocks as well as an important energy source. Global consumption continues to increase significantly. The replacement of liquid fossil fuels, such as HFO, MDO and diesel, contributes positively to the environment, with emissions of NO_x, SO_x, and particulates being almost entirely eliminated and CO₂ emissions being notably reduced. By liquefying natural gas the volume is reduced by a factor of around 600. This enables efficient transport to end-users overseas, as well as on land where pipelines are not a suitable sustainable solution.

The growth of LNG consumption is driven by:

- **Environmental requirement on emissions reductions**

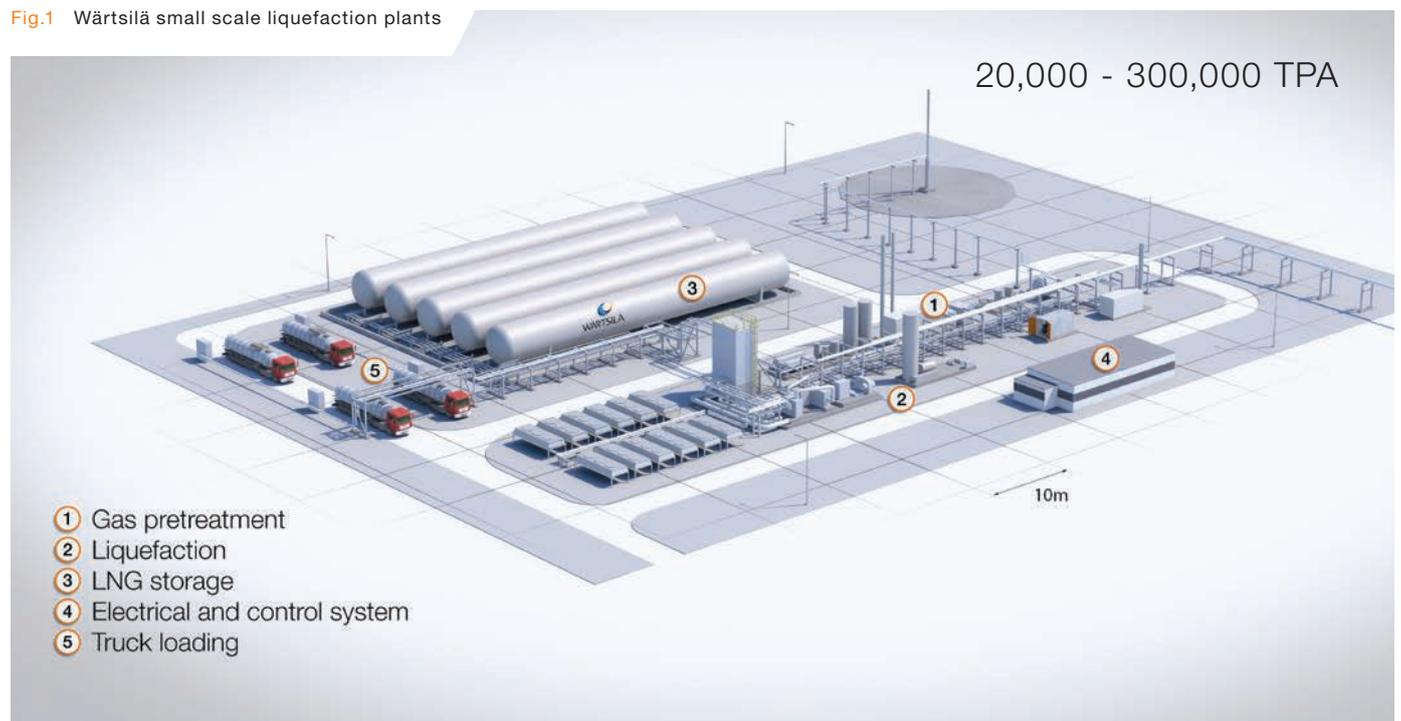
- Fuel for marine vessels. As at the end of 2015, there were an estimated 90 vessels fuelled by LNG. It is cost competitive and contributes to a reduction in maritime GHG emissions.
- Fuel for heavy road transport. There are currently about 170,000 trucks and buses running on LNG in Asia, 3,500 in North America, and 1,500 in Europe.
- Rapid growth of renewables in the power generation mix increases the demand for gas fuelled power plants to balance the load.
- Liquefied Biogas (LBG) is a locally produced, almost CO₂ neutral biofuel.

- **Availability of subsidies in the EU and China for LNG infrastructure projects**

- **Energy demand**

- A need for lower energy costs in power generation and energy intensive industries.
- Energy security considerations.
- A need for decentralized power generation in some areas.

Fig.1 Wärtsilä small scale liquefaction plants



Mini and small scale liquefaction

Mini and small scale liquefaction plants are an increasingly attractive complement to large scale LNG infrastructure. Technological advances have made monetization of small and stranded gas reserves possible in new locations. This opens the door for business owners and energy companies to take advantage of the growing LNG market.

Wärtsilä technology has been specially developed to overcome typical small scale LNG project challenges by using principles such as modularisation, standardisation, simplicity, flexibility, and lean operational and maintenance strategies. This enables very competitive capital and operational costs for LNG plants with capacities of up to 300,000 TPA.

BIOGAS LIQUEFACTION

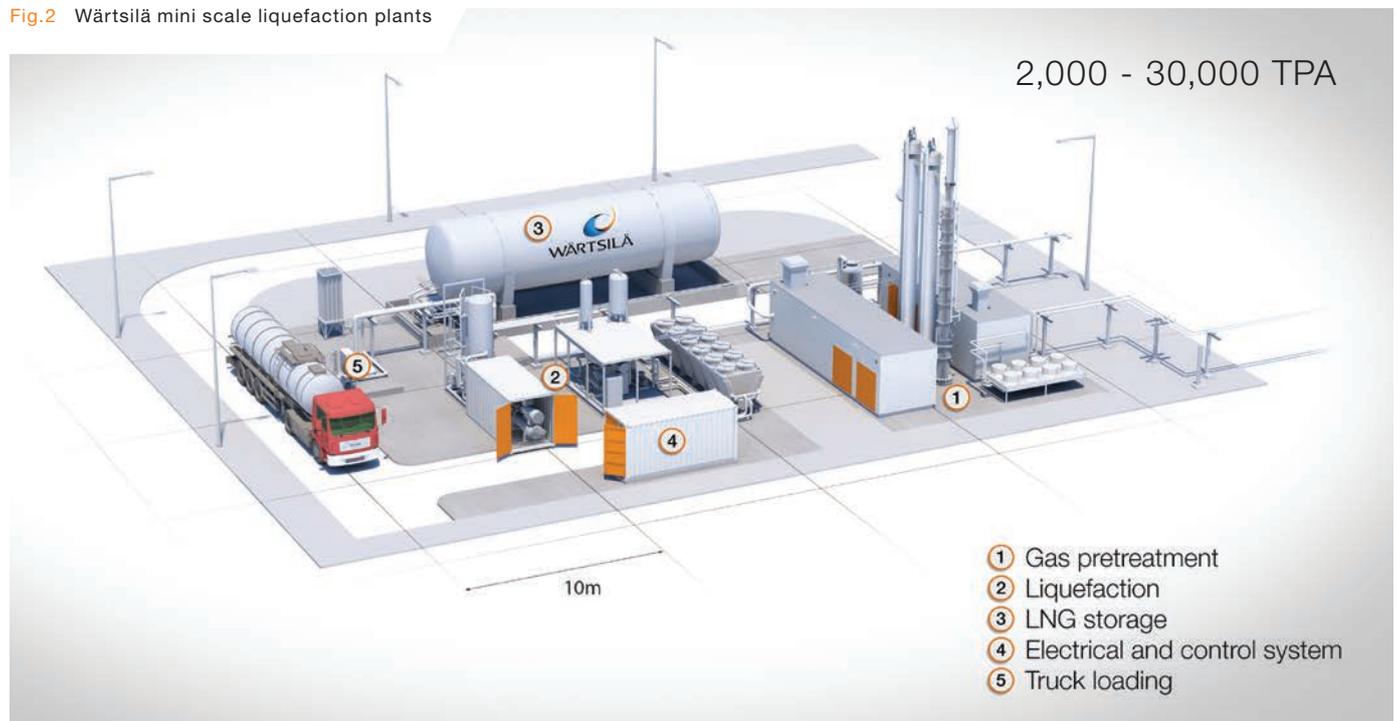
Biogas is a renewable source of energy, and thus liquid biogas (LBG) can be characterised as a renewable fuel. However, the quantity of biogas at any single site is far lower than that from natural gas reservoirs. Wärtsilä has developed an integrated solution for the cleaning and liquefaction of biogas. It has been specifically developed to overcome the technological and economic challenges of mini scale liquefaction.

BENEFITS

- LBG always contains 99% of CH₄ — a premium product with a very high Methane Number.
- LBG and conventional LNG can be utilised in the same way using the same infrastructure.
- The production and use of LBG contributes positively to the environment.

Wärtsilä has years of valuable experience in developing liquefaction technology for small scale applications. We understand the importance of operational simplicity, flexibility, efficiency, equipment robustness, and a compact footprint when dealing with small scale LNG projects. The bottom line is to have a project that is profitable for the owner. These capabilities are well demonstrated in our references.

Fig.2 Wärtsilä mini scale liquefaction plants



The Wärtsilä solution with two different processes

Wärtsilä liquefaction technologies are based on two processes; the MR (mixed refrigerant) process and the Reversed Brayton process. Both are designed with a closed loop refrigerant cycle, thereby eliminating make-up or chemical/logistics handling for the refrigerant. The main elements of the plant are as listed below, while different modules can be incorporated to improve the efficiency of the plant according to the specific project requirements.

MAIN SYSTEMS

- Feed gas/source
- Gas pre-treatment
- Liquefaction
- LNG storage
- LNG export

OPTIONAL SYSTEMS

- Power generation
- Instrument air system
- Hot oil system
- Separation of heavy hydrocarbons
- Boil-off gas handling

THE MR (MIXED REFRIGERANT) CYCLE

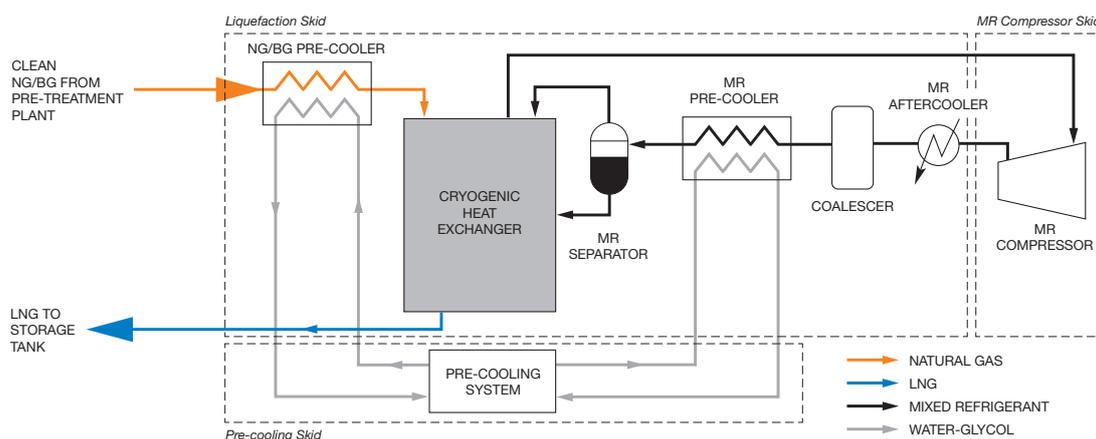
Wärtsilä's MR process is based on a simple screw compressor and a proprietary mix of refrigerants. Thanks to a buffering system, it is a fully closed loop solution that does not need refilling after a start and stop procedure. It is based on standard components to offer a low investment cost and rapid manufacturing of the module.

With the right refrigerant mixture, an intelligent automation system and standardized components,

Wärtsilä has been able to combine the high efficiency of the MR process, with the simplicity needed in smaller plants. Wärtsilä's MR solution is perfect for biogas and natural gas liquefaction plants below 50 TPD (metric tons per day).

For this liquefaction process, we offer standard capacities of 10, 17 and 25 TPD.

Fig.3 Diagram of Mixed Refrigerant process

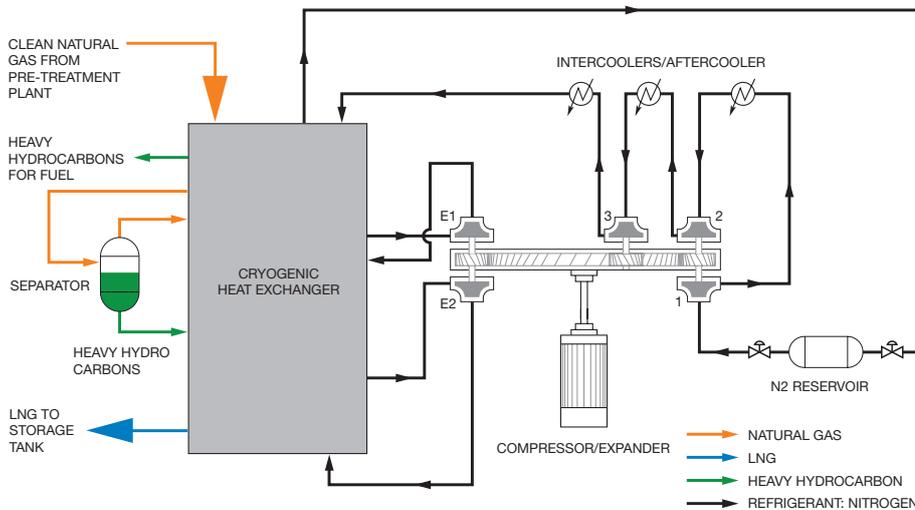


TECHNOLOGY	MIXED REFRIGERANT
Production capacity	2,000 to 30,000 TPA
Refrigerant system	Proprietary mix of hydrocarbons in a closed loop
Energy consumption	As low as 0.70 kWh/kg depending on project specific conditions
Technology features	Off-the-shelf components that enable a less expensive solution, quick delivery and simplified maintenance
Installation	Plug-and-play design with standard capacities 10, 17 and 25 TPD delivered within 12 months

THE REVERSE BRAYTON CYCLE

In this process, nitrogen is the sole refrigeration medium and is produced on site directly from the air. The nitrogen is compressed and expanded in order to obtain the required cryogenic temperature. Wärtsilä's patented dual Brayton cycle further improves and fine-tunes the Reverse Brayton process for low electricity consumption. These liquefaction plants are easy to operate, reliable, fully automated, and represent a low lifecycle cost solution for small scale liquefaction.

Fig.4 Diagram of Reverse Brayton process



TECHNOLOGY	REVERSE BRAYTON
Production capacity	20,000 to 300,000 TPA
Refrigerant system	Nitrogen produced from air on-site
Energy consumption	As low as 0.35 kWh/kg depending on project specific conditions
Technology features	Robust technology that allows for quick and simple start-up/shutdown & ramp up/ramp down compared to competing technologies
Installation	Reduced installation time and small footprint through a modularized design

Benefits of Wärtsilä's LNG liquefaction technologies

- Robust and reliable technology that is simple to operate.
- Designed for unmanned operation.
- Easy start-up and shut down of all systems.
- Quick and easy capacity control.
- Compact and modularized design ensures easy shipment and cheaper installation.
- The lowest specific power consumption in small size plants.
- All components based on conventional parts and proven technology -> Spares can be delivered quickly.
- Reliable main rotating machinery with high efficiency.
- Local control of LNG export -> truck driver handles the loading.
- ZERO FLARE solution -> during normal operations, hydrocarbon losses will be zero.
- The refrigerant is kept in a closed loop and produced directly from the air on site for the Reversed Brayton process = No logistics/handling needed for the refrigerant.
- Fast project delivery time (FOB 12 months for the MR Process and 16 months for the Reversed Brayton Process).
- Broad range of applications, biogas, pipeline, CBM and associated gas.

Storage & distribution

Bullet tanks are the most common storage option for mini and small scale liquefaction plants. They are vacuum and perlite or vacuum and multi-layer insulated.



Photo courtesy of Tropigas, Dominican Republic

For liquefaction plants that require more than 15,000 m³ of storage, flat bottom tanks become an option. The final choice depends on cost, delivery schedule and distribution requirements.

Typical considerations that need to be taken into account include the distance to the LNG consumers, their rate of consumption, the replenishment schedule, and whether or not the LNG plant will operate during weekends and holidays. This information provides an indication of the number of minimum buffer

days for storing the LNG. The export systems setup is configured based on what transport infrastructure best serves the intended customers. LNG carriers are often the best option for facilities located by the sea when there are fairly large quantities of LNG to be transported. Tanker trucks are commonly used for distribution of LNG from in-land liquefaction plants. Some liquefaction plants also offer the possibility of bunkering ships or filling LNG-fuelled trucks.

BULLET TANK SPECIFICATIONS

Capacity	Single tank 100 – 1200 m ³ Multiple tanks 100 – 20,000 m ³
Boil-Off Gas (holding mode)	0.05 – 0.15 % per day, but the tank is capable of handling the increased pressure for up to 1 month
Operating pressure	0.5 – 4.0 barg
Manufacturing method	Pre-fabricated in factory
Installation time on site	Days to weeks

WHY WÄRTSILÄ?

Wärtsilä's 50 years of gas handling experience has resulted in first rate technologies and an outstanding track record in liquefaction and regasification systems.

Projects are tailored to customer needs based on a set of pre-defined scopes and proven designs to provide a high quality asset at a competitive price. The scope and quality of our services sets Wärtsilä apart from its competitors, and our range of capabilities is unique. We offer:

- Advice and assistance in deal structuring and financing, including financial modelling and feasibility studies, if requested.
- Proven LNG infrastructure solutions supported by a world-class LNG Solutions Design team.
- Complete Engineering, Procurement & Construction (EPC) deliveries with guaranteed pricing, delivery schedules and performance, as well as process solution deliveries.
- The use of professional project management methodology and best practices.
- Operations & Maintenance agreements for guaranteed performance and predictable maintenance costs.
- EPC packages combining both liquefaction and power plants that create potentially considerable synergistic benefits.

Wärtsilä is proud to serve each customer with the same high level of quality and excellence to ensure that all expectations and priorities are fully understood and met.

Experience and recent successes

During the past 15 years, Wärtsilä has delivered 40 LNG (re)liquefaction systems and there are 10 more under construction. We have 50 years of references for gas handling systems.

Karmøy, Norway



SNURRVARDEN

Customer: Gasnor
 Type: Small scale liquefaction plant
 Tank net volume: 2 x 250m³
 Capacity: 60 TPD / 22,000 TPA
 Gas source: Pipeline gas. Inlet pressure 120-150 bar
 Details: LNG transported to customers by road tanker
 Delivery method: EPCIC
 Delivered: 2003

Scope of supply:
 Complete plant, including:

- Gas pre-treatment
- Reversed Brayton liquefaction process
- Cooling system (ambient air)
- Storage tanks
- Electrical and control systems
- Truck loading system
- Gas engine (excl. substructures)

Bergen, Norway



KOLLSNES II

Customer: Gasnor
 Type: Small scale liquefaction plant
 Tank net volume: 4,000m³
 Capacity: 230 TPD / 84,000 TPA
 Gas source: Pipeline gas. Inlet pressure typically 70 bar
 Details: Extension to Kollsnes I. Includes two truck loading stations and existing loading jetty for small LNG carrier.
 Delivery method: EPCIC
 Delivered: 2007

Scope of supply:
 Complete plant, including:

- Gas pre-treatment
- Double Reversed Brayton liquefaction process
- Cooling system (Seawater)
- Storage tank
- Electrical and control systems
- Civil works

Porvoo, Finland



GASUM KILPILAHTI

Customer: Gasum
 Type: Mini liquefaction plant
 Tank net volume: 3 x 700m³
 Capacity: 55 TPD / 20,000 TPA
 Gas source: Pipeline gas
 Details: Utilization of excess nitrogen from adjacent air separation plant. No rotating machinery.
 Delivery method: EPCIC
 Delivered: 2010

Scope of supply:

- Pre-treatment
- LIN liquefaction process
- Storage tanks (excl. substructures)

Oslo, Norway



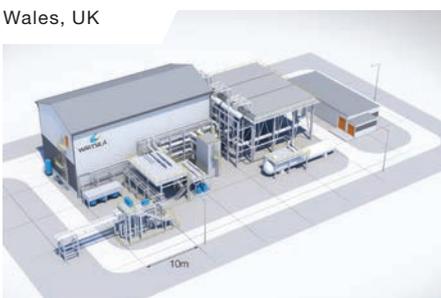
EGE BIOGAS

Customer: Cambi AS
 Type: Mini liquefaction plant
 Tank net volume: 180m³
 Capacity: 11 TPD / 4,000 TPA
 Gas source: Biogas from 50,000 TPA of food waste
 Details: Fuel production for 135 buses in the city of Oslo
 Delivery method: EPC
 Delivered: 2013

Scope of supply:
 Complete plant, including:

- Gas pre-treatment
- MR liquefaction process
- Cooling system (ambient air)
- Storage tank
- Electrical and control systems
- Service agreement (excl. civil works and installation)

Wales, UK



DRAGON LNG

Customer: Dragon LNG
 Type: Boil-off gas reliquefaction unit for large scale terminal
 Capacity: 340 TPD / 120,000 TPA
 Details: Emphasizing flexibility. Liquefaction capacity can go down to 62 TPD
 Delivery method: Engineering and procurement
 Delivered: 2017

Scope of supply:

- Reversed Brayton liquefaction process
- Cooling system (Ambient air)
- LNG buffer tank
- LNG transfer pump
- Instrument air compressor/dryer,
- Instruments, valves, control system
- Supervision/commissioning of site installation

Wärtsilä's service network reaches almost all corners of the world. This extensive coverage ensures that plant operators receive fast and effective response to their maintenance needs.

Wärtsilä can also support plant owners with O&M agreements that offer the following benefits:

- **Ensured productivity** throughout the lifecycle of the asset
- **High availability** with minimized unplanned downtime
- **Predictability** of maintenance costs over the medium to long term
- **Attention to safety** and environmental aspects

SUPPORT THROUGHOUT THE ENTIRE LIFECYCLE



Wärtsilä is a global leader in advanced technologies and complete lifecycle solutions for the marine and energy markets. By emphasising sustainable innovation and total efficiency, Wärtsilä maximises the environmental and economic performance of the vessels, power plants and LNG infrastructure of its customers. In 2015, Wärtsilä's net sales totalled EUR 5 billion with approximately 18,800 employees. The company has operations in over 200 locations in more than 70 countries around the world. Wärtsilä is listed on Nasdaq Helsinki.

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