Wärtsilä – the total LNG solution provider

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Wärtsilä realized the importance of gas as a fuel already in 1987 when it started development of its first medium-speed high efficiency gas engine. This was the Wärtsilä 32GD (compression ignited) which was developed in Vaasa, Finland followed by the Wärtsilä 25SG (spark ignited) developed in Trollhättan, Sweden 1991.

Today, almost 30 years of continuous development later, Wärtsilä has one of the most complete gas portfolios of any energy and marine solutions provider.

In 2012, Wärtsilä acquired Hamworthy, a company with a strong reputation in the marine engineering business. This strengthened Wärtsilä's involvement in gas solutions and laid the foundation for the current on-shore and off-shore LNG related portfolio.

Marine Solutions, with focus on marine and off-shore applications has made Wärtsilä the market leader in ship power, propulsion and automation systems. The marine industry is going through a major change due to stricter environmental regulations. This means that many new ships being built will be gas driven and this will in turn require a new LNG (liquefied natural gas) bunkering infrastructure besides the existing diesel and HFO (heavy fuel oil) infrastructure available today. Wärtsilä is the pioneer with gas & dual-fuel engines and complete fuel gas handling systems for all types of vessels, ships and drilling platforms. In addition, Wärtsilä has

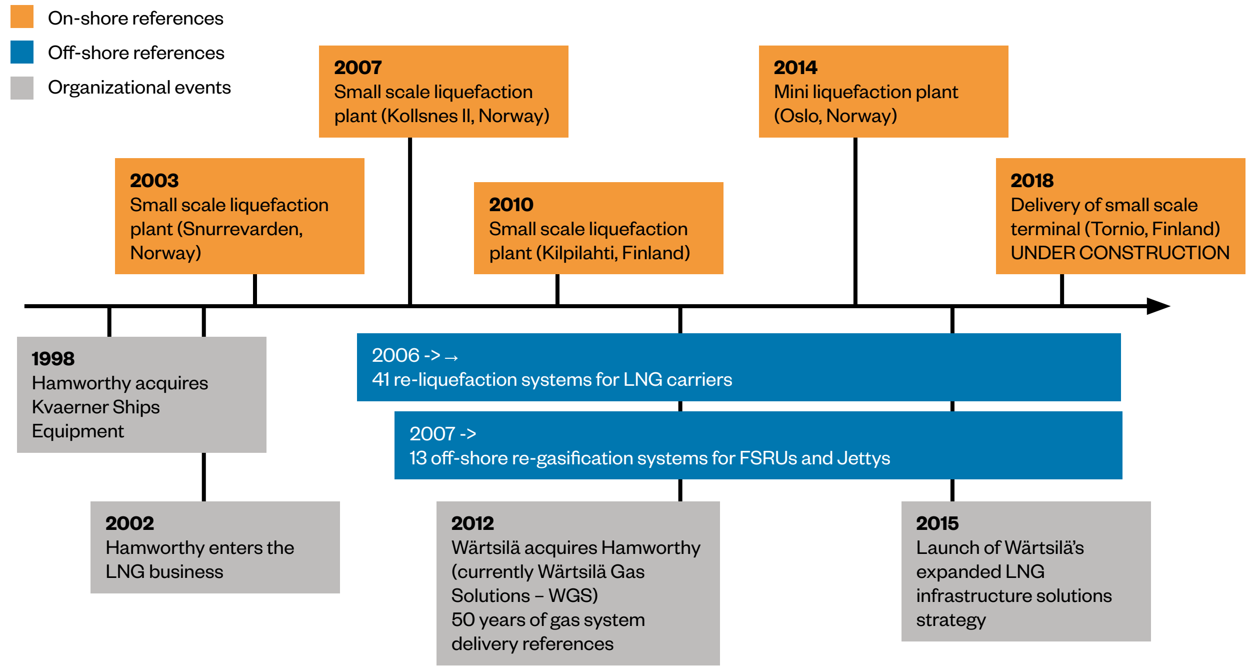
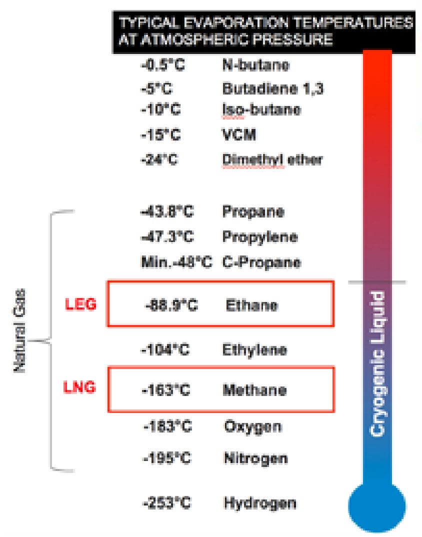


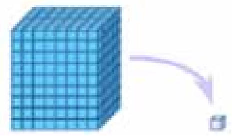
Fig. 1- Major milestones of Wärtsilä LNG history.

What is LNG

Liquefied Natural Gas (LNG) is natural gas cooled down to a liquid which occurs at a temperature dependent of the gas composition, typically close to -162 °C at atmospheric pressure. This way the volume of the gas is only 1/600 of the space it takes as a gas in atmospheric conditions.

Before liquefaction (turning the gas to LNG), the gas is cleaned from water, carbon dioxide, sulphur and other impurities and toxic elements that would cause icing and other problems in its liquid form. Therefore LNG consists mainly of methane and it is odourless.





600m³ GAS -> 1m³ LNG

1m³ = 1000 Liter -> 450kg

Composition Vol %	Natural Gas	Lean LNG	Mean LNG	Rich LNG
Methane CH_4	70–90	96.2	91.7	84.8
Ethane C_2H_6	0–20	3.3	5.7	13.4
Propane C_3H_8	0–20	0.4	2.2	1.3
Butane C_4H_{10}	0–20	0.1	0.3	0.3
Carbon Dioxide CO_2	0–8	0	0	0
Nitrogen N_2	0–5	0	0	0.2
Oxygen O_2	0–0.2	0	0	0
Hydrogen sulphide H_2S	0–5	0	0	0
Rare gases A, He, Ne, Xe	trace	0	0	0
Methane Number	50–90	87	78	71

50 MWe Power Plant	LNG	HFO
Mass flow (ton/h)	8.1	9.8
Volume flow (m^3/h)	18.3	9.9
Fuel storage size for 20 days (m^3)	8800	4700

Properties	LNG	HFO
Density kg/m^3	445	990
LHV MJ/kg	49	41
1000 kg energy content (kWh)	13600	11400
1 m^3 energy content (kWh)	6060	11300

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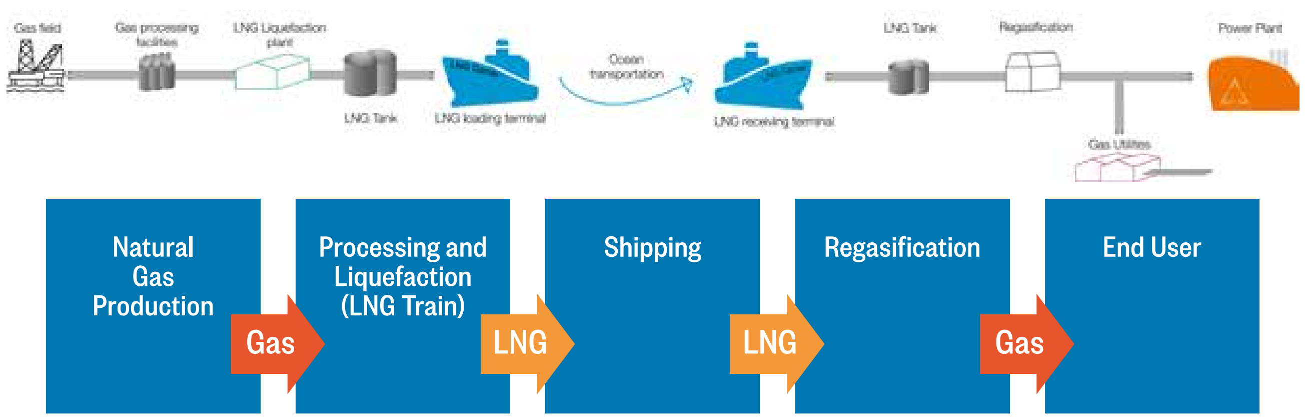
LNG Value Chain



The LNG value chain starts with gas extraction/production followed by pre-treatment/processing and liquefaction. Then the LNG is stored in large insulated tanks ready for transport. It is transported with specially built LNG tankers across oceans. At the receiving end, LNG is pumped to large on-shore tanks or off-shore FS(R)Us. Finally LNG is regasified and pumped into the local gas pipelines or further transported by trucks in the form of LNG.

also been providing complete regasification systems for FSRUs (floating storage and regasification units) and re-liquefaction systems for LNG carriers since 2006.

Energy Solutions, with focus on power plants and other energy related on-shore applications has made Wärtsilä one of the biggest suppliers of gas and liquid fuel power plants in the 5–600 MW range. These plants are used as baseload and/or grid stability plants or lately as "wind chasers" and "sunset balancers", compensating for the intermittency of wind power and the sudden drop of solar power in the evenings when we need power the most. These multi-duty power plants which are providing superior operational flexibility combined with the highest possible simple cycle efficiency are called **Smart Power Generation power plants**. The majority of new plants are equipped either with gas or dual-fuel engines and many existing HFO power plants are being converted to gas. The energy industry is clearly shifting to gas but the challenge is that gas is not yet readily available everywhere in the same way as diesel and HFO are. But with LNG, large amounts of gas can economically be brought to new areas presently not covered by gas pipelines and gas infrastructure.

Wärtsilä has during the last few years developed an extensive LNG product portfolio and know-how. Today we are proud to present one of the most complete portfolios of LNG solutions and services in the market. See Figure 1 for the main milestones in Wärtsilä's LNG history.

The LNG technology

Wärtsilä and former Hamworthy have over the last years made major efforts to develop liquefaction and regasification technology and optimize it for future market requirements. Thanks to the investment, Wärtsilä has today extremely robust and energy efficient solutions available for liquefaction and regasification. The text below explains Wärtsilä's process solutions and unique features of the main processes used in LNG infrastructure solutions, namely liquefaction, storage, boil-off gas (BOG) handling and regasification:

Liquefaction

Wärtsilä has developed two main liquefaction technologies that are suitable for mini and small-scale liquefaction capacities. A **MR (mixed refrigerant)** process for the smaller sizes and the **Reversed Brayton Cycle** process for the larger sizes.

MR (mixed refrigerant): The standard MR or SMR (single mixed refrigerant) process using a turbo compressor and refrigerants consisting of methane, ethane, propane, pentane and nitrogen is normally used for large capacity liquefaction systems. The composition of the mixed refrigerant is chosen for adaptation to the cool down process. A good match between cooling curves will increase the efficiency of the system. The refrigerants work in a closed loop, but during stand-still when the system is heated up, part of the refrigerant charge will be lost. To re-start the system, it needs to be refilled again with the correct mixture.

Wärtsilä has developed a simplified version of the MR process based on a simple screw compressor and a special mix of refrigerants. Thanks to a buffering system it is a fully closed loop system that does not need refilling after a start and stop procedure. The system is delivered as three prefabricated modules. It is based on standard components with a level of standardisation that allows for low investment cost and fast manufacturing of the module. The repetitive design gives consistent high quality in a compact module. With a slightly different 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. For small capacities, below 50 TPD (metric tonne per day), Wärtsilä's MR process is the ideal solution. (Figure 2)

Wärtsilä's MR solution is perfect for biogas and landfill gas liquefaction plants that are usually built in smaller sizes. The first plant built and operating with this

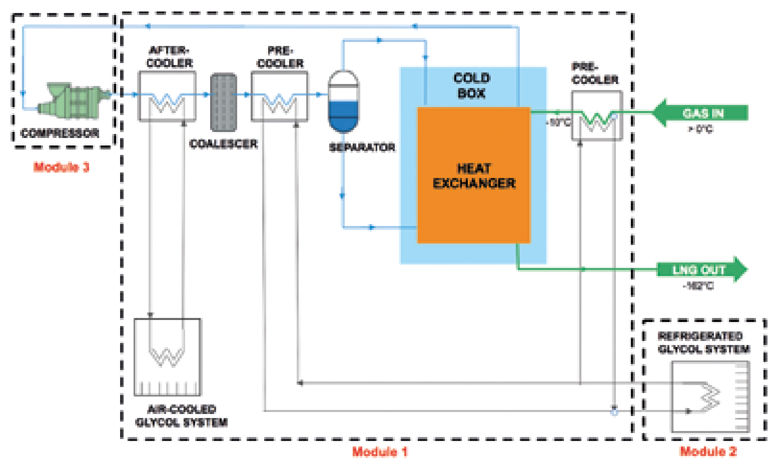


Fig. 2 - Process overview of Wärtsilä MR technology (Cold box = insulated with perlite or polyurethane).

Advantages of Wärtsilä's MR technology for mini liquefaction plants

- Easy and quick start up and shut down of all systems
- Can be started in 30 min, but typically <3h due to heat exchanger cool down limitations
- The lowest specific power consumption in the small size plants.
- All components based on conventional parts and proven technology -> Spares can be delivered quickly
- Short delivery time (<12 months) where the cold box and compressor are the only long lead items
- Reliable main rotating machinery with high efficiency (Oil flooded screw compressor)
- Compact design & easy shipment as all in one module and a separate compressor skid
- Designed for unmanned operation
- Local control of LNG export -> truck driver handles loading
- Simple energy supply, only electrical power needed
- Standard capacities: 10, 17 and 25 tons/day
- Plug and play philosophy, skid based – relocation possible
- Broad range of applications, biogas, pipeline gas, CBM and associated gas

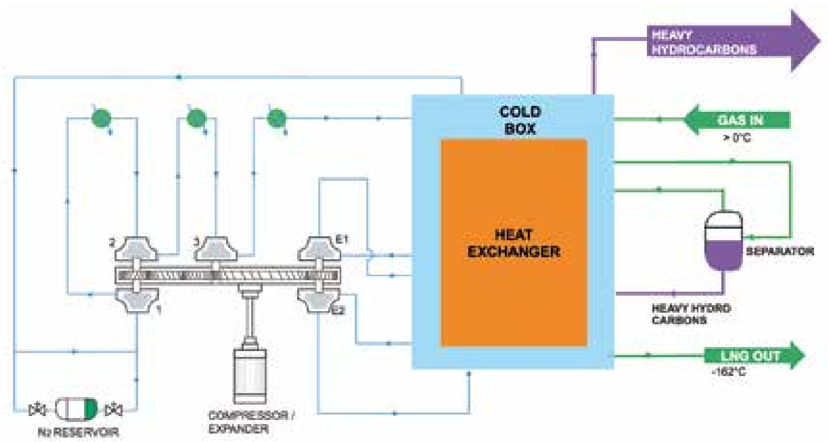


Fig. 3 - Process overview of Wärtsilä Reversed Brayton technology.

Advantages of Wärtsilä's Reversed Brayton Cycle for small scale liquefaction plants

- Robust, reliable and simple to operate technology
- Designed for unmanned operation
- Capacity control is very easy and quick
- Easy start-up and shutdown of all systems
- Local control of LNG export, truck driver handles loading
- Simple energy supply, only electrical power needed
- Refrigerant will be produced directly from air on site – No logistics connected to the refrigerant
- There is no required handling of chemicals
- ZERO FLARE solution -> during normal operations, hydrocarbon losses will be zero.

technology was the biogas liquefaction plant for the City of Oslo, Norway, which is operational since 2014.

Reversed Brayton Cycle: For the larger sizes >50 ton/day Wärtsilä recommends a liquefaction system with double expanders based on the Reversed Brayton Cycle process. The advantages of this system versus other systems is that it is very adaptive to capacity changes and is very easy to operate. Furthermore, the nitrogen used as refrigerant is produced directly from air at site. Wärtsilä has further improved and fine-tuned the Reversed Brayton process for low electricity consumption. Wärtsilä's Reversed Brayton system has been used in more than 40 LNG carriers for their re-liquefaction systems, much thanks to its ease of operation, reliability and robustness. (Figure 3)

LIN (liquid nitrogen): Besides these two main technologies Wärtsilä has also built a small liquefaction plant for Gasum in Finland based on LIN cooling. The advantages of this process is its simple installation with low investment cost, but the disadvantage is high energy consumption.

Storage

Usually the most expensive part of a large LNG terminal is the insulated storage tank(s). Onshore storage can either be arranged using a **flat-bottom tank** with storage capacity of 8000–160,000 m^3, **spherical tanks** of 1000–8000 m^3 or **bullet tanks** for smaller LNG storage volumes. The bullet tanks are normally in the range of 250–1500 m^3 meaning that larger storage capacities (up to 20,000 m^3) are arranged with several tanks in a row.

Flat bottom tanks can be divided into single (integrity) containment, double (integrity) containment or full (integrity) containment tanks. Above-ground full containment tank technology is the preferred solution when it comes to storing large quantities of LNG with maximum safety in a limited site area. But depending on safety requirements and free space available around the tank also the single and double containment tanks can be considered. Flat bottom tanks are produced at site, which prolongs construction time. (Figure 4)

Bullet tanks are of interest when it comes to storing smaller volumes of LNG. They are stainless steel pressure vessels insulated by perlite or/and vacuum. These systems are modular, flexible, available in vertical or horizontal formats, and may be arranged in tank farms of any number of manifold rows of tanks to provide the desired amount of storage. Bullet tanks are pre-fabricated in factories, which potentially reduces site costs. (Figure 5)

Boil-off gas (BOG) handling

One of the challenges handling LNG is the BOG. BOG is produced because LNG is stored at cryogenic conditions (below −162°C at atmospheric pressure) in a much warmer ambient environment. It is the result of several factors:

- Heat leak into the LNG carrier, storage tanks, process equipment and process piping
- Mechanical energy input by process equipment [e.g. low-pressure (LP) in-tank and high-pressure (HP) send-out pumps]
- Displaced vapours from the LNG carrier and LNG storage tanks due to unloading, loading and send-out flowrates
- Atmospheric pressure changes
- Elevation difference between the LNG carrier and the storage tanks

BOG creates pressure in the tank that has to be managed/released in order to maintain the pressure within the allowed tank design pressure. BOG during normal operation and storage is only about 0.05% (of tank mass)/day, while it can be up to 0.15%/day during ship unloading. Then during the ship unloading when excess BOG is generated it is common that the BOG is returned to the LNG carrier through a vapour return line compensating for the liquid volume reduction in the LNG carrier. BOG consists mainly of methane which is not allowed to be purged into the atmosphere due to its greenhouse gas effect, so the simplest way to get rid of BOG is to burn or flare it. This is of course not desirable, wasting expensive gas, therefore this option is only considered when no other options are available. The normal way to handle BOG in terminals with a constant send-out is to use a BOG compressor pumping the BOG out together with the gas send-out to a local offtaker, such as a power plant, or into the gas pipeline. Depending on the gas piping pressure level there is either an LP or an HP BOG compressor. A temporary solution to get rid of the BOG forming at the top of the tank is to recirculate or top spray the tank with cold LNG from the bottom. Another alternative that also requires LNG send-out is to use a BOG re-condenser. In the BOG re-condenser, the BOG is mixed with subcooled LNG for re-condensation of the BOG.

When there is no gas send-out, the LNG terminal is in a so called zero send-out mode. If you have excess BOG during zero send-out mode the only other alternative to flaring is to re-liquefy the BOG and pump it back into the tank.

Wärtsilä has developed modularized packages for the various BOG handling systems with the BOG compressor as the main component.

Wärtsilä's recommendation is to build the terminal in conjunction with gas consumers that can utilize the BOG in their process or power production. This way we can guarantee a consumption any time there is excessive BOG and there is no waste nor any need to use energy for re-liquefying the gas. Combining a Wärtsilä gas power plant with a terminal is a perfect solution as the BOG can be directly converted into electric power which is used in the LNG terminal itself or exported to other electricity consumers.

Send-out system

The send-out system is the main process of a terminal that includes the **regasification/vaporization** unit. The BOG compressor is normally integrated into this system, releasing the excess BOG together with the send-out as described in the earlier chapter.

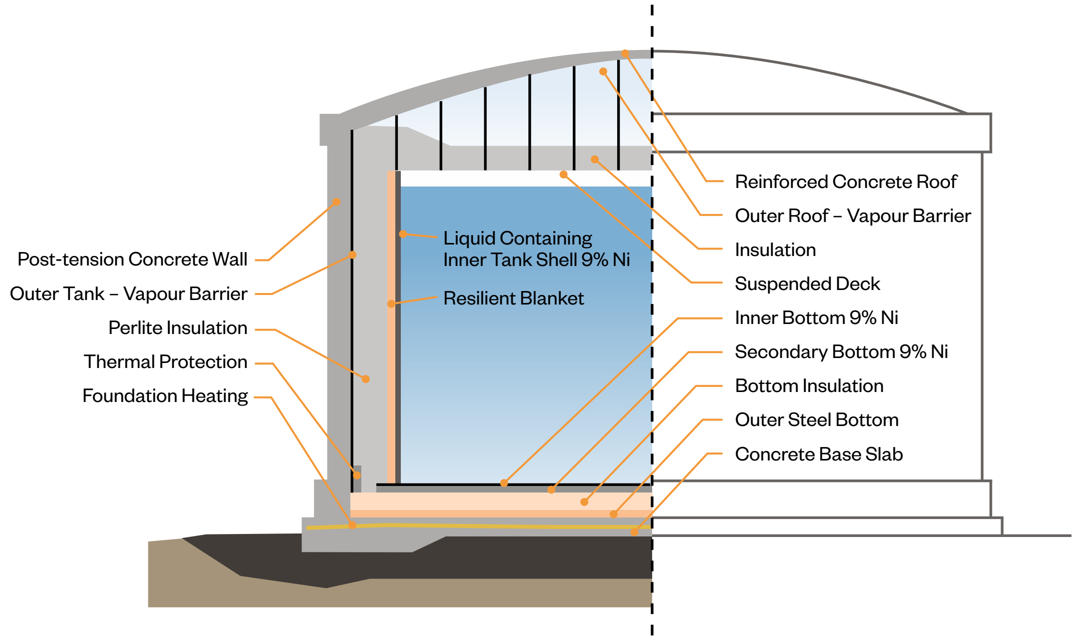


Fig. 4 - Full containment flat bottom concrete tank.

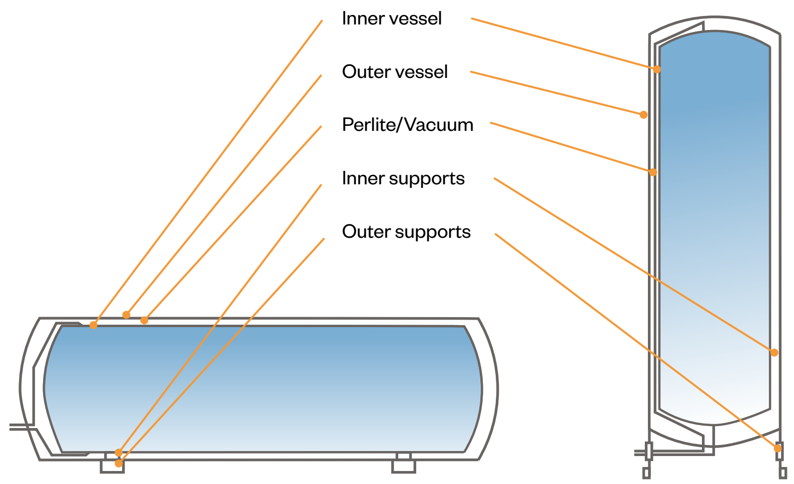


Fig. 5 - Bullet tanks.

Options for handling BOG

- Venting (only allowed in emergency situations)
- Flaring
- Returning the BOG to the LNG carrier during unloading (only an add-on solution during unloading)
- BOG re-condensation and pumping back to LNG tank (requires a constant send-out of LNG)
- Utilizing BOG in a nearby power plant converting it into electric power and heat
- LNG recirculation / top spraying
- Pumping it to the LP gas pipeline (<10bar)
- Pumping it to the HP gas pipeline (10- 50bar)
- Re-liquefaction of BOG into LNG

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Depending on the requirement, there can be an LP send-out system (< 10 bar), or an HP send-out (10-50 bar). The low pressure send-out is a fairly simple system where the tank low pressure LNG pumps are pushing the LNG via the regasification/vaporization module to the pipeline. In case of a high pressure send-out system there will be additional HP pumps that can be supplied as part of the vaporizer/regasification module. Typically gas transmission pipelines require a pressure over 10 bar while more local gas distribution pipelines can have a design pressure of less than 10 bar.

Gas turbines require 15–40 bar of gas pressure, while a Wärtsilä power plant runs well on gas pressures as low as 6 bar.

Regasification/vaporization

In order to convert the LNG back to gaseous form for the final consumers all the energy that was extracted from the gas to make it liquid in the first place has to be returned to it through the vaporizer. The vaporizer is essentially a large heat exchanger that heats the LNG.

Typical types of vaporizers that have been used worldwide for LNG regasification are:

- Open rack vaporizers (ORV) based on seawater heating (Figure 6)
- Submerged combustion vaporizers (SCV) based on fuel heating (Figure 7)
- Ambient air vaporizers (AAV) based on ambient air heating
- Intermediate fluid vaporizers (IFV)

FSRUs (Floating Storage and Regasification Units) and onshore regasification terminals close to shore use only seawater to provide heat for vaporization but this has the risk of seawater freezing and clogging heat exchangers. Instead Wärtsilä uses propane and seawater in cascade loop to warm the LNG. Wärtsilä built the first pilot plant based on this technology already in 2005. Propane is used in the first stage heat exchanger to heat the LNG from -160°C to -10°C. In the second stage, the LNG is then further heated and vaporized by using seawater directly as the heating medium.

Wärtsilä uses printed circuit heat exchangers that allow for a compact design capable of high pressures. The robustness in terms of turndown capability, ramping up and down has also been demonstrated.

In situations where seawater cannot be used, or seawater is too cold, energy has to be provided from a gas burner in a submerged combustion vaporizer (SCV) with a steam/water-glycol heat exchanger. Unfortunately fuel costs when discharging a 145,000 m³ LNG carrier provided with a steam/water–glycol unit only can be quite substantial. To save fuel, Wärtsilä has developed a solution using energy from the seawater in combination with cooling water from the Wärtsilä engines. This is then backed up with energy from the gas burner only when needed. This way fuel costs can be cut considerably.

Wärtsilä's regasification modules, with their optimized energy use in combination with high reliability and simplicity of control, have been a proven solution supplied to 12 or roughly 1/3 of the world's most modern FSRUs.

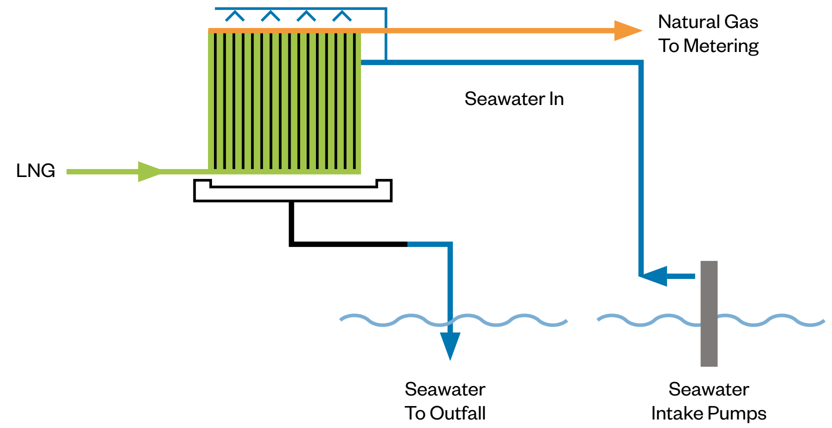

Fig. 6 - Open Rack vaporizer.

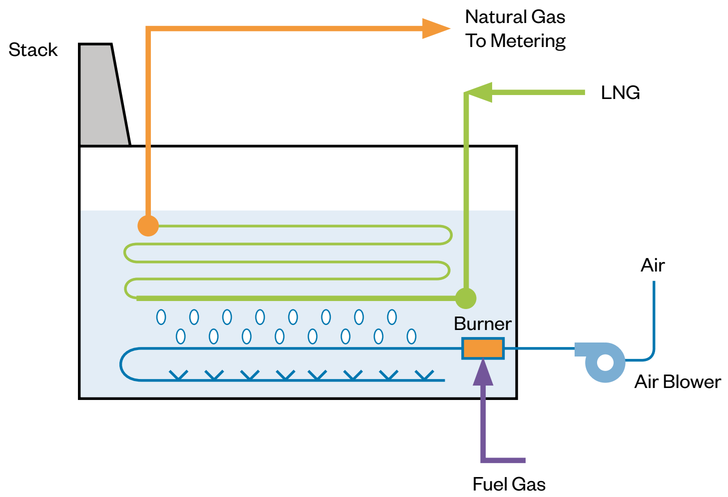

Fig. 7 - Submerged Combustion vaporizer.

Total solutions

We have now described the main sub processes of the liquefaction plants and regasification terminals. But a total system is only as good as its weakest link and Wärtsilä's core competence lays in designing the total system for the liquefaction plant or terminal. To go one step further, Wärtsilä can take full EPC (Engineering, Procurement & Construction) responsibility which includes specifying and purchasing the equipment, taking care of the site preparation, logistics and construction. All of this is managed by our global project management and construction teams that have over 25 years of experience building power plants all over the world. Wärtsilä has ready made concepts both for liquefaction plants and terminals. These concepts are the starting point for the client discussions and used as templates for the final project specific solution. When concepts based on proven process designs and pre-fabricated modules can be re-used, it always leads to lower cost, functional predictability and much higher quality of the total solution. The surprises are minimized by utilizing proven solutions and tested concepts.

Several different concepts are available today:

Fig. 8 - EGE Biogas 4000 TPA biogas-to-LNG plant in Norway, Design and equipment delivery 2014 by Wärtsilä is an example of a Mini LNG liquefaction plant.

Liquefaction plants

Definition: LNG liquefaction plant is a gas processing plant which main purpose is to convert natural gas from gas form to liquid. The main process is liquefaction which is always included. Gas pre-treatment is also an important process in order for the liquefaction process to work properly and to produce LNG according to specifications. Depending on the gas source, pre-treatment methods and their costs vary considerably. The plant always includes one or multiple storage tanks. The storage capacity can be designed for a period of a few days up to several months.

In Wärtsilä's concept portfolio we can find mini and small scale liquefaction plants in the range from 1000 to 300,000 TPA (metric tons per annum) trains. The same proven technology that has successfully been used off-shore in re-liquefaction on board LNG carriers is used here as well.

The liquefaction plant applications can be divided into these categories:

Wärtsilä's product portfolio for liquefaction plants:

L1 Mini liquefaction plants
L2 Small scale liquefaction plants
L3 LNG peak shaving plants
L4 Mid/large scale liquefaction plants
L5 Floating Liquefied Natural Gas (FLNG)

Mini LNG liquefaction plants

a. Virtual pipeline (end-of-pipeline gas liquefaction)
b. Stranded gas liquefaction (well gas, associated gas, coal seam gas etc.)
c. Biogas and landfill gas liquefaction

These are plants that have a capacity of 1000–30,000TPA (metric tonnes per annum) = 3–80 TPD (tonnes per day) and the LNG is primarily intended for local consumption. They can be built anywhere near a gas source as per options a-c. For these applications Wärtsilä mainly uses bullet tanks combined with the MR liquefaction technology due to their small size. (Figure 8)

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Fig. 9 - Kollsnes liquefaction plant in Norway. To the left Kollsnes II, supplied by Wärtsilä, with 84,000 TPA capacity and to the right Kollsnes I with 43,800 TPA capacity. This is an example of a small scale LNG liquefaction plant and export terminal.

For these applications, Wärtsilä is providing the complete process package as a minimum but also the civil & constructions can be included and delivery of the complete plant as an EPC. Furthermore Wärtsilä can offer an Operation & Maintenance (O&M) package tailored for the customer's requirements.

Small scale LNG liquefaction plants and export terminals

These are plants that have a capacity of 20,000–300,000 TPA (= 60–800 TPD). They are either built inland next to a smaller gas field or by the shore at the end of a gas pipeline for easy access by LNG tankers. For these applications, dependent on storage capacity, we use either bullet tanks or flat bottom concrete tanks. The liquefaction technology used is either based on Reversed Brayton cycle or the MR process depending on the specific requirements. (Figure 9)

As in the mini liquefaction plant concept, Wärtsilä can here also provide everything from a full process solution to a complete EPC with a possibility to include a full service and lifecycle support agreement.

LNG peak shaving plants

These are plants that can have a capacity of 10,000–300,000 TPA. They are normally built along gas pipelines and act as temporary storages in locations where the gas consumption varies and a buffer needs to be available for peak demand. In this application Wärtsilä uses mostly flat bottom concrete tanks due to the large sizes normally required. The liquefaction technology used is normally Reversed Brayton Cycle. Similar delivery scopes and services are available as for the previous concepts.

Mid/large scale LNG liquefaction and export terminals

These are plants that have a capacity of >300,000 TPA (>800 TPD). Always located by the sea shore for easy access by large LNG tankers.

These are mega projects normally done in consortiums or as EPCMs. Therefore Wärtsilä is currently not offering these type of plants as EPC but rather as a supplier of selected processes and equipment. In these applications Wärtsilä can provide for example:

- Gas/LNG driven power plant for the terminal (typically 20-100 MW)
- Re-liquefaction units
- Liquefaction process in case it is built of several <300,000 TPA trains

Receiving terminals

Definition: LNG receiving terminal is a liquid gas processing plant which main purpose is to receive, store and further distribute the natural gas in liquid or gas form.

The terminal always includes storage tank(s). The main process if included is regasification and sub process if included is re-liquefaction. As the tank is usually the most expensive part of a terminal, the receiving terminals are usually defined according to the size of the tanks. Wärtsilä's portfolio consists of terminals with various functions combined with a storage capacity in the range from 1000 to 160,000 m³.

Wärtsilä's product portfolio for receiving terminals:

T1 LNG Satellite stations for gas power plants
T2a Satellite&Bunkering stations
T3 Small/Medium scale terminals
T4 Large scale terminals
T5 Floating storage and regasification units (FSRU)

LNG satellite terminals for gas power plants

To this concept belong fuel storage and LNG processing systems in the size 1000–10,000 m³ dedicated for a power plant. They are always single-use built to supply regasified LNG to the power plant (Figure 10). The storage capacity depends on the size of the power plant and the frequency of filling. As an example a 100 MW baseload plant with average time between LNG filling of 15 days would need a storage of at least 10,000 m³. For this concept Wärtsilä provides the complete EPC for both the power plant and the LNG station. The services and maintenance agreement provided can include both power plant and LNG station.

LNG satellite & bunkering terminals

These terminals are smaller local terminals with a size of 1000–30,000 m³ and located by the sea shore or rivers. Often placed in harbours where there is easy access for supply vessels to fill the tanks and for the LNG driven ships to do bunkering. Often these stations are built primarily as bunkering facility for ships but they can include additional services like trans-shipment, truck and container loading to facilitate re-distribution of LNG in liquid form or for the larger sizes, a regasification unit supplying

Fig. 10 - LNG satellite terminal for a 59 MW Wärtsilä dual-fuel power plant in the Dominican Republic. Note the truck unloading LNG to the LNG bullet tanks in the top left corner.

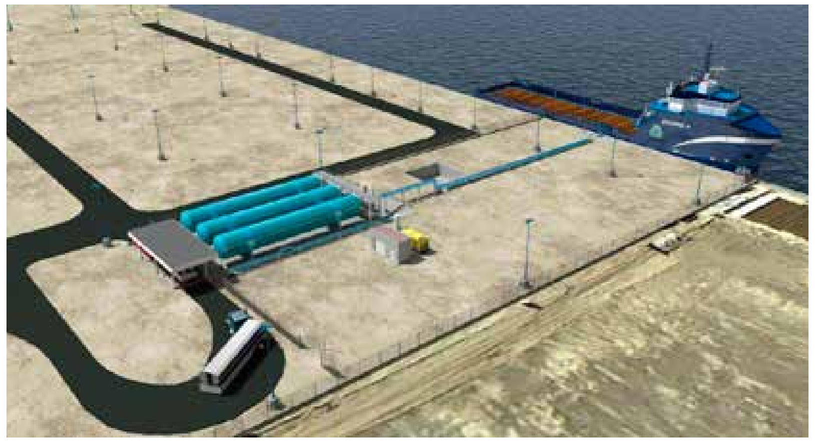

Fig. 11 - Harvey Gulf (Louisiana, US), selected equipment delivery by Wärtsilä in 2013.

Fig. 12 - A 7500 m³ LNG storage & regasification barge designed by Wärtsilä.

a local gas pipeline could be added.

Wärtsilä's preference is to deliver these projects as EPC with full delivery and performance guarantees. The terminal can be supported with full service agreements. (Figure 11)

LNG storage & regasification barges

The smallest FSRUs today are around 120,000 m³. There are no small LNG carriers available that can be converted to FSRUs. Wärtsilä has created a solution for this problem, by designing a barge containing storage tanks (1000–25,000 m³) and regasification systems. These can in certain conditions be an attractive alternative to on-shore satellite and bunkering terminals. The LNG barge can be equipped with the similar processes as the land based solution. The process can also be split between the barge and the land, by locating for example the LNG storage on the barge and parts of the process equipment and support facilities on shore.

Wärtsilä prefers to deliver the barge and necessary infrastructure on-shore as a complete EPC. Wärtsilä can also provide the services and maintenance agreements for the total solution. (Figure 12)

Small/medium scale LNG terminals

These are terminals in the size of 20,000–160,000 m³ located at sea shores, working as hubs for whole regions or larger cities. Due to the major investment and volumes, a group of industries and consumers are needed to make these projects possible. They are always multi use terminals which can include regasification, pipeline distribution, ship bunkering, trans-shipment, truck and container loading to facilitate re-distribution of LNG in liquid form. (Figure 13)

Fig. 13 - Manga LNG terminal in Tornio, Finland. EPC delivery by Wärtsilä.

Large scale LNG terminals

These terminals are built only in countries with large imports of LNG. These are terminals with >150,000 m³ tank capacities and a throughput of >3 MTPA and located at the sea shore for easy access by large tankers. (Figure 14)

In these mega projects Wärtsilä does not assume EPC responsibility but rather supplies selected equipment and design packages. Wärtsilä can for example supply:

- Gas/LNG driven power plant for the terminal (typically 10–50 MW)
- Re-liquefaction process
- Regasification process

FSRU or FSU + jetty regasification

A FSU (floating storage unit) is really an LNG carrier that is stationed at a seashore. If you add a regasification unit it is called an FSRU (floating storage and regasification unit). The sizes are the typical size of LNG carriers or in the range of 120,000–200,000 m³. They have to be located in places with enough draught (>10 m) and easy access and possibility to maneuver large LNG carriers to unload the cargo on to the FSU or FSRU. In case of an FSU, a regasification system needs to be built on the shore or jetty close to the FSU.

The FSU/FSRUs are built in ship yards and Wärtsilä acts as a supplier of equipment and process package. Wärtsilä can deliver the complete power system with engines, propellers and control system for the FSU/FSRU as well as the re-liquefaction and regasification processes. (Figure 15)

Fig. 15 - PGN FSRU Lampung, where Wärtsilä has delivered 3 regasification trains with max capacity of 360 TPH. Photo: Höegh LNG.

Fig. 14 - Dragon LNG Terminal, in Wales, UK. Wärtsilä will deliver the re-liquefaction system, to be installed during 2016–17. Photo: Dragon LNG Limited.

Total solution provider:
LNG terminals and liquefaction plants are complex projects when it comes to design and construction. It is important that the total concept and all aspects of the project is thought through from the beginning. Things to consider:

Location (site & marine) considerations:
- Location and site
- Onshore geophysics
- Seismicity and seismic hazards
- Metocean conditions and effect on construction
- Manoeuvrability
- Mooring analysis
- Bathymetry

Design, construction and operational considerations:
- Size of LNG carriers, replenishment/ supply schedule, tank size
- Required berth availability
- Operating philosophy, BOG management
- Gas delivery flow rate, availability requirement
- Investigations into local construction expertise, equipment and materials

Only by doing proper pre-studies it is possible to optimize the functionality and operational cost of the plant. With the LNG process knowledge in combination with the site preparation and construction services and EPC capabilities in-house Wärtsilä can develop feasible solutions that can be backed up with firm cost estimates. With a Wärtsilä EPC and O&M the customer can get a lump-sum price with guaranteed delivery time and long term performance guarantee.

Project development & financing:
Before you have the final product in place there is typically several years of project development and authority approvals needed. Wärtsilä has over 15 years of experience with project development. Wärtsilä has a team of experienced project developers all over the world with full access to its project execution and technical support organisation. This team has the required knowledge of LNG business environment and available solutions in order to evaluate and make projects happen. Wärtsilä can help our customers arrange financing and with a track record of projects always delivered on time and in budget the banks have one less risk to worry about. Wärtsilä may also invest own equity in selected projects.

Project execution: The core of Wärtsilä has always been our EPC capabilities. Wärtsilä has a unique track record in the EPC business with almost all projects done in time and with lost time injuries rate of less than 1 (<1 accidents/million working hours). LNG projects are always assigned to dedicated project teams that have undergone the necessary training to take on the special requirements of LNG projects. Safety and risk management are of essence in LNG projects. Therefore series of prudent risk analyses are conducted during the project to ensure a safe system. With a lump-sum EPC, Wärtsilä can give guarantees on final price, construction time and plant performance, elements of investment having importance when obtaining financing, and especially for non-recourse debt financing.

Modularised solutions: By high level of modularisation and reusing proven solutions, Wärtsilä can shorten the construction time and guarantee high quality. To fully utilize these benefits, it is important that Wärtsilä can work closely together with the customer. By collaborating from early conceptual phase, Wärtsilä can create a more cost effective solution and quicker project completion than what is achievable through a traditional FEED (Front End Engineering & Design) + ITT (invitation to tendering) process. The client can in some cases save up to 2-5% of the total cost and generate revenue 8-12 months earlier by avoiding the FEED + ITT process. It is important to involve the construction and operation personnel in the design and project planning. Wärtsilä has always had a close co-operation between our designers, constructors and operators as they all belong to the same organisation.

Lifecycle support: Wärtsilä's service agreements cover nearly 19 GW of generating capacity in both marine and land based installations – more than 450 installations. The key persons are Wärtsilä's own experts, with additional well trained labour hired based on needs. Wärtsilä can provide full maintenance agreements of LNG terminals and liquefaction plants. This service covers maintenance planning, parts logistics, manpower coordination and maintenance reporting. In order to perform maintenance efficiently and reliably, we ensure that required manpower and spare parts are available for planned maintenance.

Typical scope of supply for a maintenance agreement is:
- Online remote operations support
- Maintenance management & planning
- Technical evaluation
- Operational data analysis
- Technical support
- Spare parts for planned maintenance
- Manpower for planned maintenance
- Inventory management
- Safety stock & onsite tools
- Capital spare parts

Summary
Combining the LNG process know-how and proprietary liquefaction and regasification technologies with project development, EPC and lifecycle support, Wärtsilä is now in a unique position to help our customers develop, build and operate complete LNG infrastructure solutions and even including the gas power plant. All of this can be backed-up with a price, delivery and performance guarantee. That is what being the total LNG solution provider means! (Figure 16)

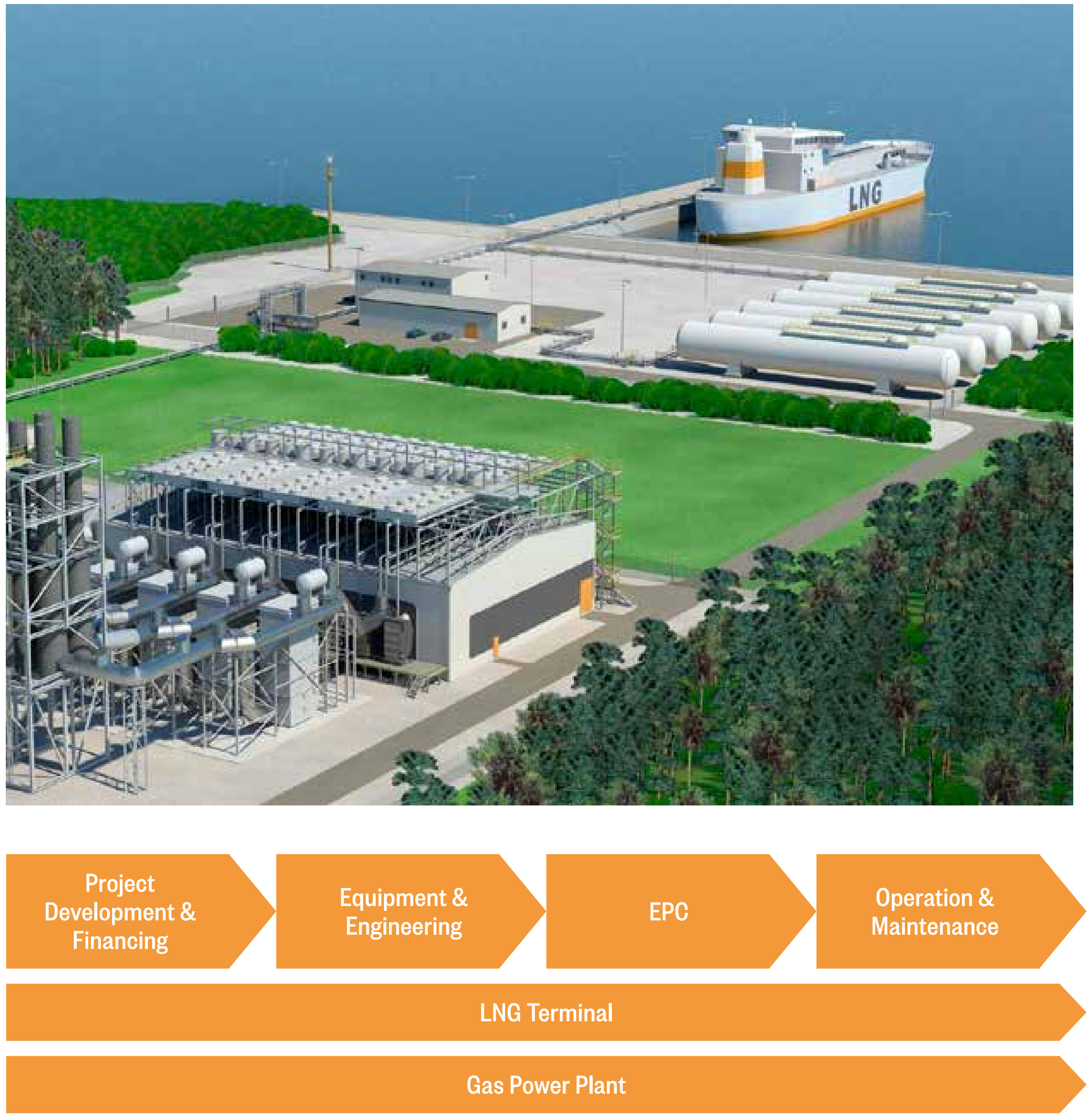

Fig. 16 - Providing complete solutions both for LNG terminals and gas power plants.