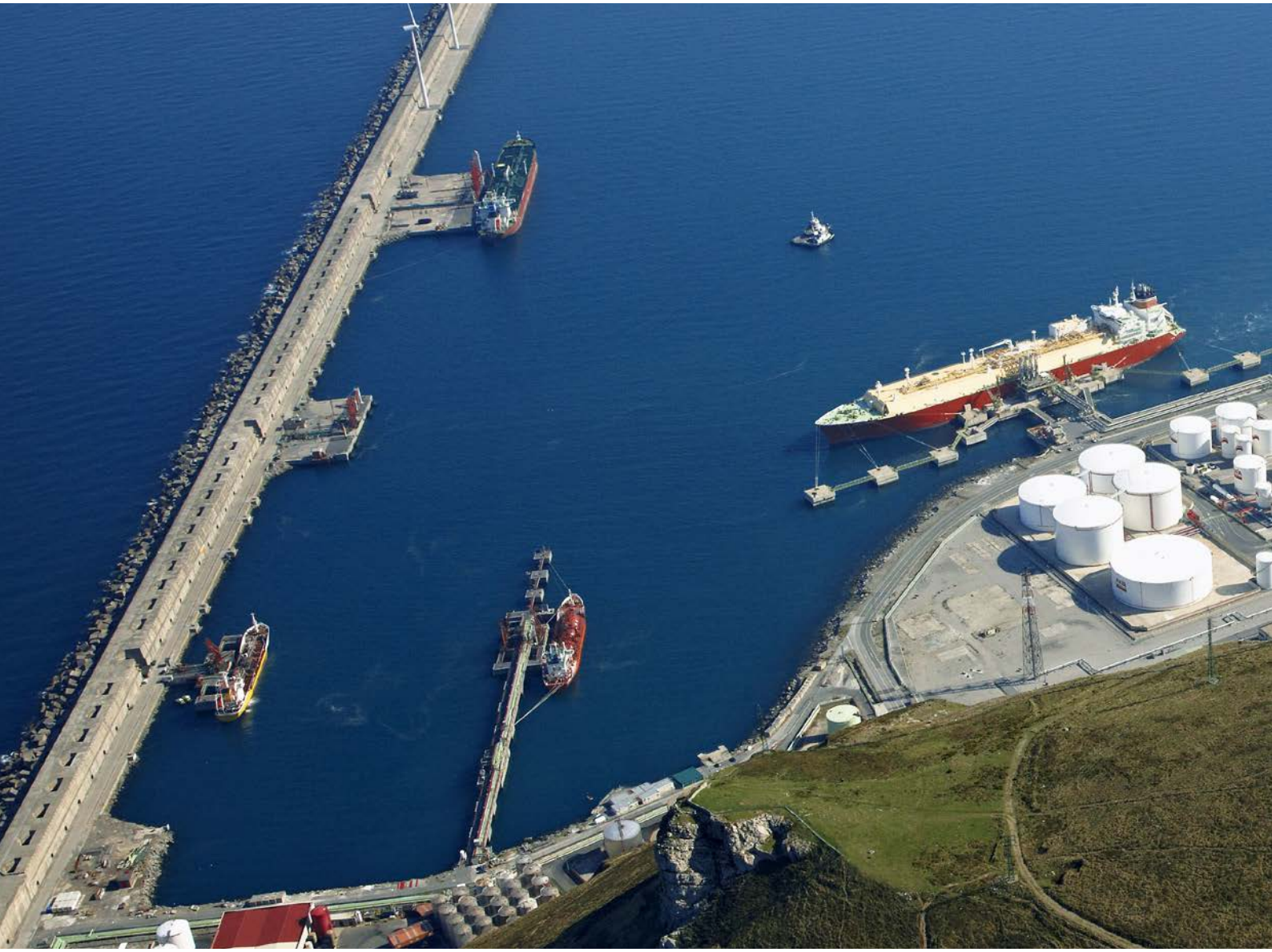
WÄRTSILÄ

Small- and medium-scale LNG terminals

POWER UP ON CLEAN AND AFFORDABLE GAS

A BANKABLE PROJECT WITH A COMPLETE VALUE CHAIN

SOLUTIONS ADAPTED TO THE REQUIREMENTS OF SMALL-SCALE LNG



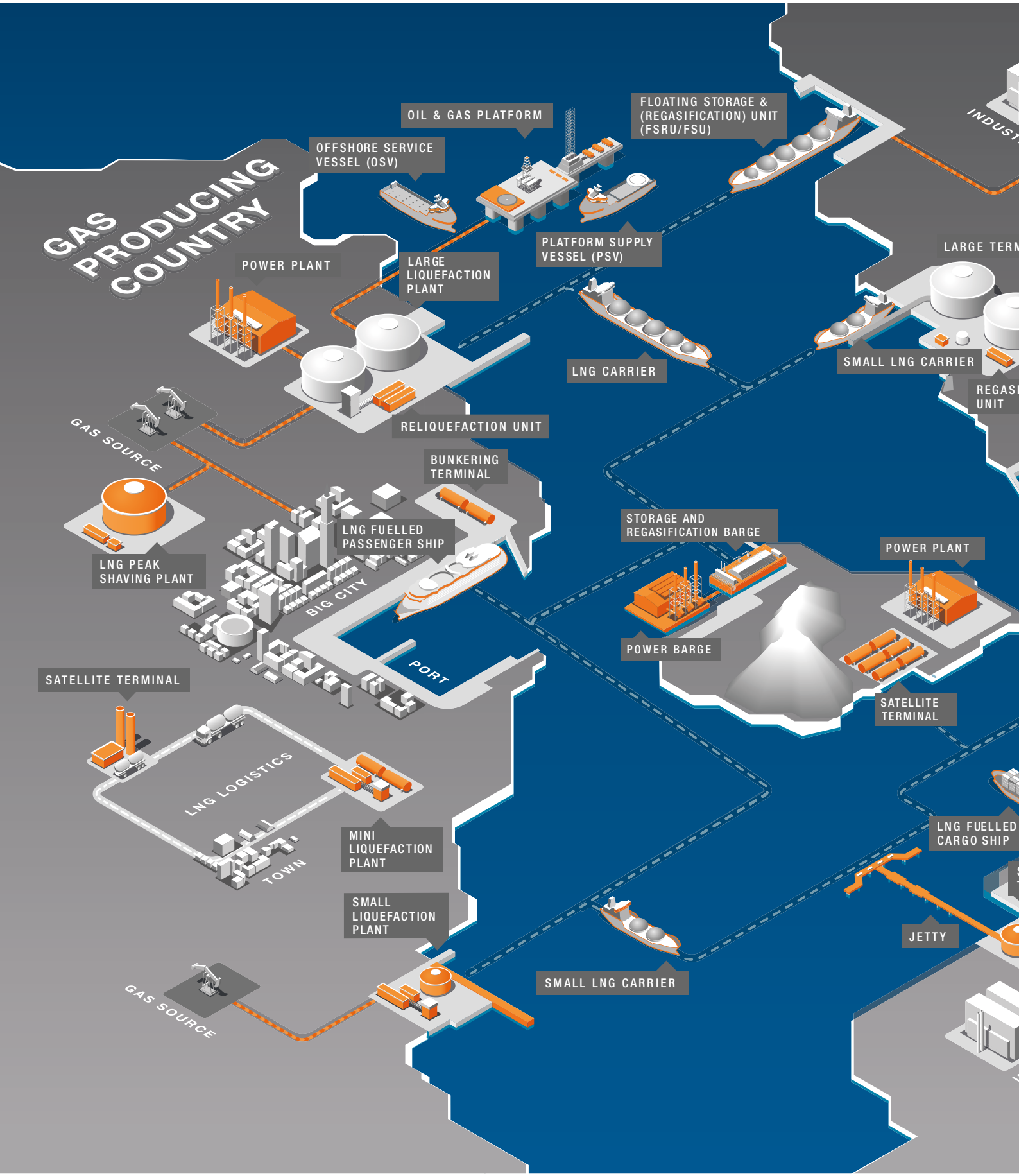
The global trend

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 heavy fuel oil, marine diesel oil and diesel, contributes positively to the environment, with emissions of NO_X, SO_X, and particulates being almost entirely eliminated and CO_2 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 liquefied natural gas (LNG) consumption is driven by:

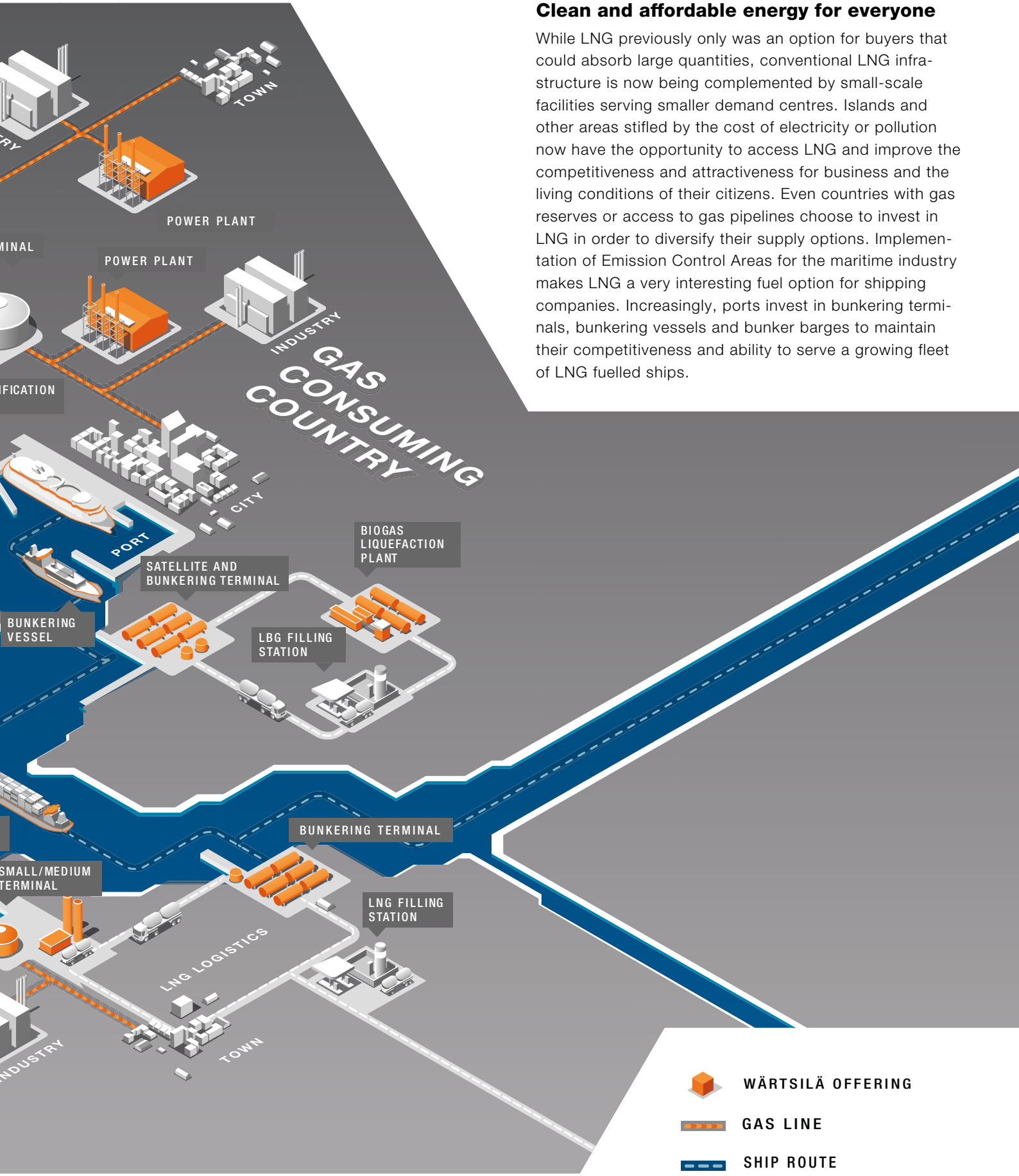
- **Environmental requirements on emission reduction**
  - LNG for feedstock. Natural gas is used as feedstock for about half of the commercial hydrogen production in the world and it is currently the cheapest source of hydrogen. The heavier feedstocks, like coal and oil, are more complex to process; therefore, the capital costs are higher compared to natural gas.
  - Rapid growth of renewables in the power generation mix increases the demand for gas fuelled power plants to balance the load.
  - 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 greenhouse gas (GHG) emissions.
  - Fuel for heavy road transport. There are currently about 170,000 trucks and buses running on LNG in Asia, 3500 in North America, and 1500 in Europe.
- **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.

Wärtsilä makes the difference



Clean and affordable energy for everyone

While LNG previously only was an option for buyers that could absorb large quantities, conventional LNG infrastructure is now being complemented by small-scale facilities serving smaller demand centres. Islands and other areas stifled by the cost of electricity or pollution now have the opportunity to access LNG and improve the competitiveness and attractiveness for business and the living conditions of their citizens. Even countries with gas reserves or access to gas pipelines choose to invest in LNG in order to diversify their supply options. Implementation of Emission Control Areas for the maritime industry makes LNG a very interesting fuel option for shipping companies. Increasingly, ports invest in bunkering terminals, bunkering vessels and bunker barges to maintain their competitiveness and ability to serve a growing fleet of LNG fuelled ships.



Small- and medium-scale LNG terminals

While the LNG market continues to grow, ensuring access and availability is a key prerequisite. The need for LNG terminals is particularly relevant in places where the gas infrastructure is under-developed but the potential demand for gas-fired power generation and natural gas for other industrial uses is substantial. Alternatively, LNG terminals can complement the existing gas reserves or pipelines in order to improve fuel supply security.

Wärtsilä's terminal portfolio

The storage tank is usually the most expensive part of a terminal unless marine facilities are part of the scope, and the terminals are often 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 of 100-160,000 m^3. Depending on project location and requirements, we specify the most suitable type of regasification system. As Wärtsilä has supplied regasification system modules for more than one third of the floating storage and regasification units (FSRU) in active operation, this is an area where we have extensive expertise. Additionally, Wärtsilä Tank Control Systems are used in many of the world's leading LNG facilities. We are able to deliver a complete terminal under an EPC contract.

- Specifically adapted for the requirements of small-scale LNG through elimination of complexity and increase of flexibility
- Single use (e.g. providing fuel for a power plant) or multi-use (e.g. gas send-out, ship bunkering, truck loading)
- Available for both hub and spoke operations
- Onshore and near shore (barge) concepts
- Stringent safety regulations during both construction and operation.

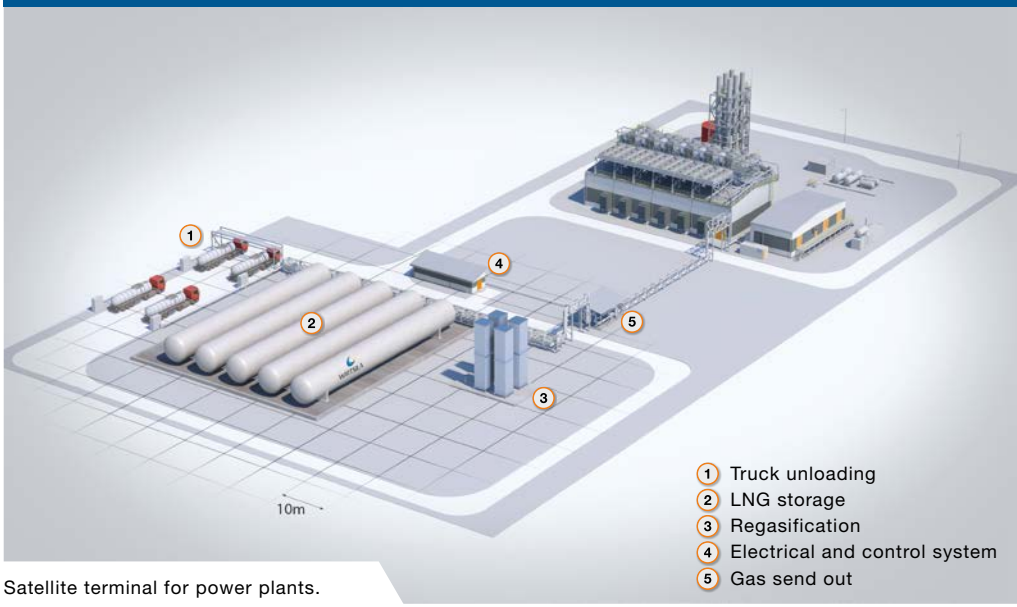
Wärtsilä's range of small- and medium-scale LNG terminals.


Manga
Lng

Satellite terminals for power plants

These are single-use satellite terminals dedicated to supply a gas or dual-fuel power plant and include fuel storage and LNG processing systems in the size range of 100-20,000 m^3. The storage is mainly built as bullet tanks and the capacity depends on the size and operational profile of the power plant and the frequency of filling. For example, a 50 MW base-load plant with an average of 12 days between fillings would need a storage of about 5000 m^3.

For this concept Wärtsilä provides a complete engineering, procurement and construction (EPC) delivery for both the power plant and the LNG satellite terminal. The operations and maintenance agreement provided can also include both facilities.

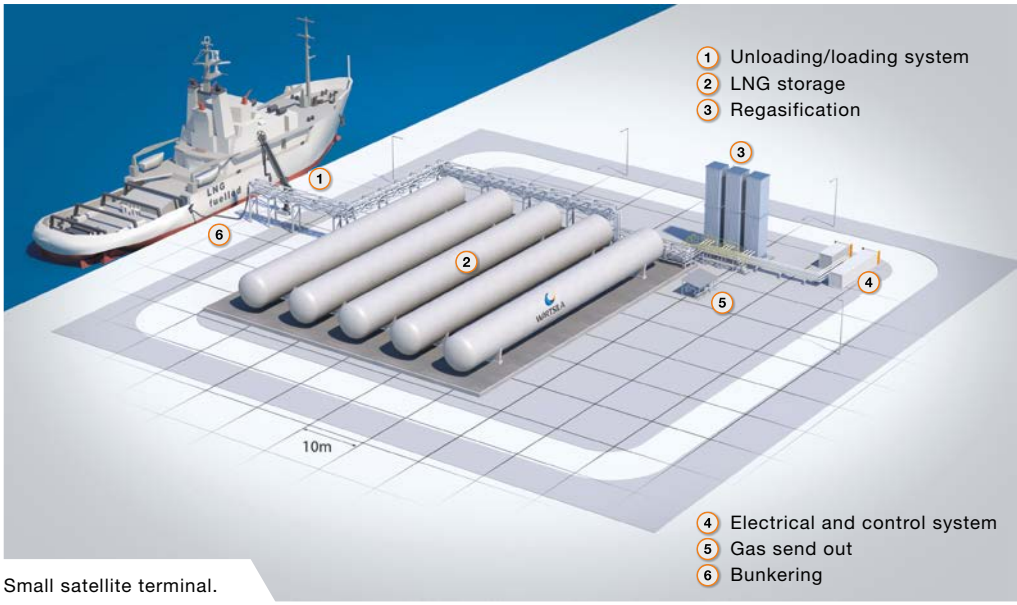


Satellite terminal for power plants.

Small satellite terminals

These terminals are smaller local terminals with a size of 100-20,000 m^3, and located by the sea shore or rivers. They are often placed in harbours where there is easy access for supply vessels to fill the tanks. The storage is mainly built as bullet tanks. These terminals are often built primarily as bunkering facilities for ships, but they can also include additional services such as truck and container loading to facilitate distribution of LNG in liquid form. In larger sizes, a regasification unit supplying a local gas pipeline can also 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.



Small satellite terminal.

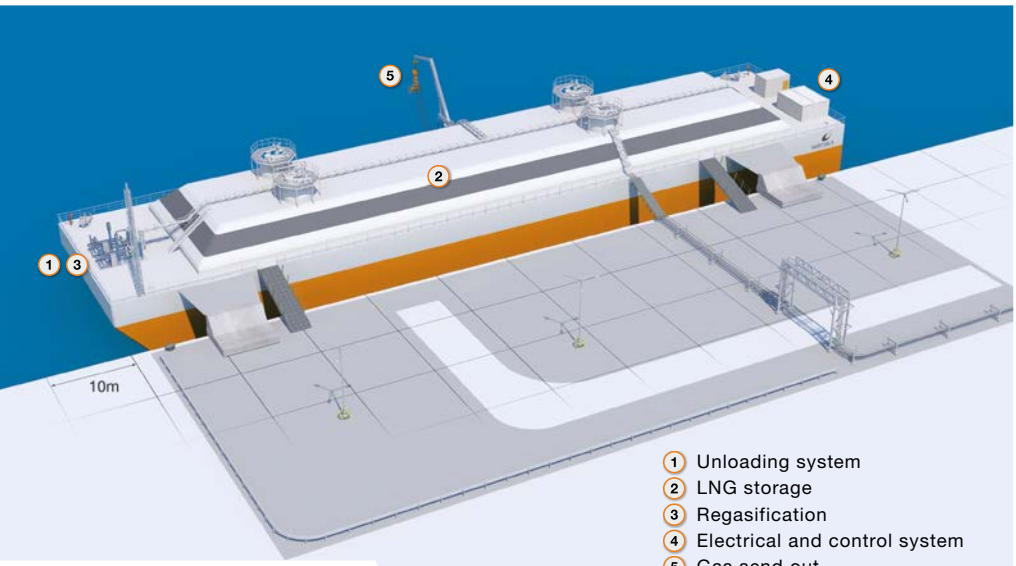
Storage and regasification barges

The smallest FSRUs today are around 120,000 m^3. 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 (1000-30,000 m^3) and regasification systems. These can be an attractive alternative to onshore small satellite terminals. The barge can be equipped with the similar processes as the land-based solution. The process can also be split between the barge and land. This can be done, for example, by locating the LNG storage on the barge and process equipment and support facilities onshore.

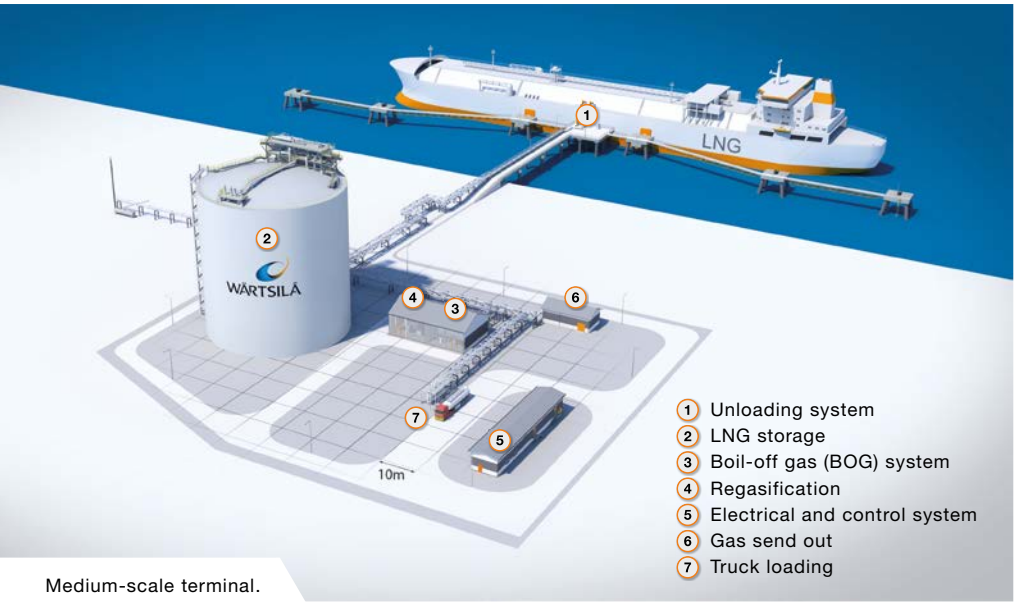
Wärtsilä prefers to deliver the barge and necessary infrastructure onshore as a complete EPC. Wärtsilä can also provide services and maintenance agreements for the total solution.

- Ideal for providing fast and flexible access to gas in new areas
- For land unsuitable for onshore LNG tanks or difficult to permit

Marine infrastructure



Storage and regasification barge.



Medium-scale terminal.

For small-scale LNG projects a sensible approach to marine infrastructure is crucial since these projects are not able to absorb CAPEX-heavy infrastructure costs. It is especially important to pay attention to site selection and not to overscale the installation, as this will significantly add to the costs and damage project economics. Also, the concept of the project needs to be adapted to limitations set by LNG suppliers.

To mitigate the risks involved, a number of studies are required, such as:

- Conceptual study
- Requirements check from relevant authorities
- Manoeuvring study
- Mooring study
- Metocean study
- Bathymetric study
- Navigational studies
- Off-shore soil investigations.

In order of priority, the below options are suitable for berthing small LNG carriers:

- Berthing at pier or quay
- Berthing at jetty
- Off-shore berthing (or mooring).

- Where there is a lack of skilled labour and local construction material
- A mobile asset, possible to relocate or trade – ideal for temporary demand and uncertain market conditions.

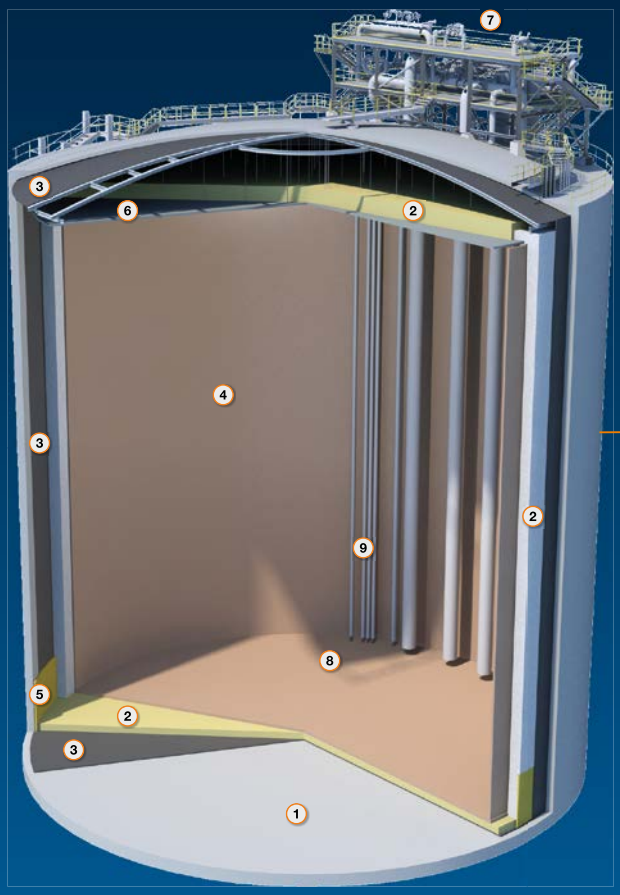
Medium-scale terminals

These are LNG terminals in the size of 20,000-160,000 m^3 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 multi-use terminals with flat bottom tanks and can include regasification, pipeline distribution, ship bunkering, re-loading, truck and container loading to facilitate re-distribution of LNG in liquid form.

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.

LNG
storage tanks

Onshore storage for small-scale LNG can either be arranged using a flat bottom tank with storage capacity of ≈15,000-160,000 m^3, spherical tanks of ≈1000-8000 m^3 or, for small LNG storage volumes, bullet tanks. Bullet tanks are available up to 1200 m^3, meaning that larger storage capacities (up to 20,000 m^3) are arranged with multiple bullet tanks.



Flat bottom tanks

Flat bottom tanks can be divided into single containment, double containment or full 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, the single and double containment tanks can also be considered. Flat bottom tanks are produced on site, which prolongs construction time.

Single containment tank

A single containment tank is composed of an inner, self-supporting cylindrical container made of cryogenic steel (9% nickel steel). Insulation surrounds the inner tank to control heat leak into the tank. An outer tank made of carbon steel holds the insulation. The outer tank is non-cryogenic (carbon steel). Only the inner tank provides containment for the LNG. However, single containment tanks are always surrounded by an external safety bund.

Double containment tank

The double containment tank is similar to a single containment tank, but instead of a containment bund, the tank is surrounded by a close-in, reinforced open top concrete outer container. If the inner tank fails, the secondary container is capable of containing all of the cryogenic liquid. The outer concrete wall increases the cost of the tank, but less space is required because there is no need for a containment bund.

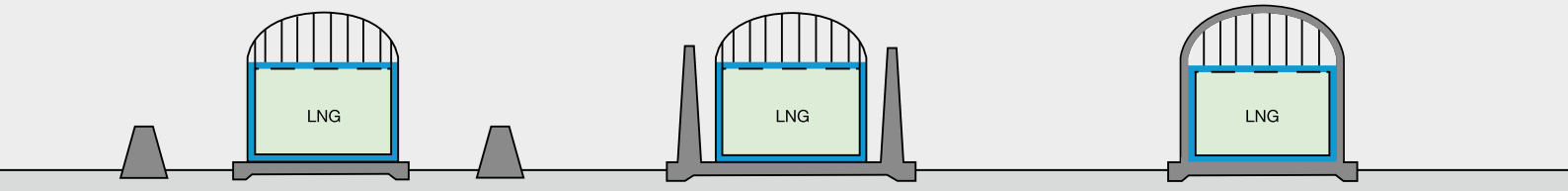
Full containment tank

Full containment is essentially a double containment tank in which the secondary container completely encases the primary container and is designed to be liquid and vapour tight in case of rupture. It therefore offers the highest inherent safety of the tank alternatives whereby limiting the required safety area. The majority of LNG flat bottom storage tanks built in the last 10 years worldwide have been designed as full containment tanks.

Single containment tank
- Primary container contains liquid and vapour
- Outer shell retains insulation
- Bund around the tanks retains liquid (not vapour) if primary container fails.

Double containment tank
- Primary container contains liquid and vapour
- Outer shell retains insulation
- Secondary container is an open top tank that retains liquid (not vapour) if primary container fails.

Full containment tank
- Primary container contains liquid
- Secondary container retains insulation and is also liquid and vapour tight
- Smallest foot print since no bund around the tanks is required.



Full containment tank.

1. Concrete
2. Insulation
3. Steel lining
4. Inner tank
5. Thermal protection system
6. Suspended roof
7. Main operating platform
8. Pump columns
9. Instrumentation casing pipes

Spherical tanks

Spherical tanks are rarely used for LNG, but can in some cases be the best option. The spherical shape creates a strong structure because of the even distribution of stresses on the sphere's surfaces. Their main advantage is that they have a smaller surface area per unit volume than any other shape of tank, meaning less heat ingress and thus less boil-off gas (BOG).

Bullet tanks

Bullet tanks are of interest when it comes to storing smaller volumes of LNG. They are vacuum and perlite or vacuum and multilayer insulated stainless steel pressure vessels, operating above 0.5 barg. These tanks 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 prefabricated in factories, which reduces site costs. Pressurised tanks are designed and operated so that no boil-off gas compressor is needed.

Vertical tanks

- Small footprint compared to horizontal tank
- Heavy foundations
- Sizes up to approximately 300 m^3 per tank.

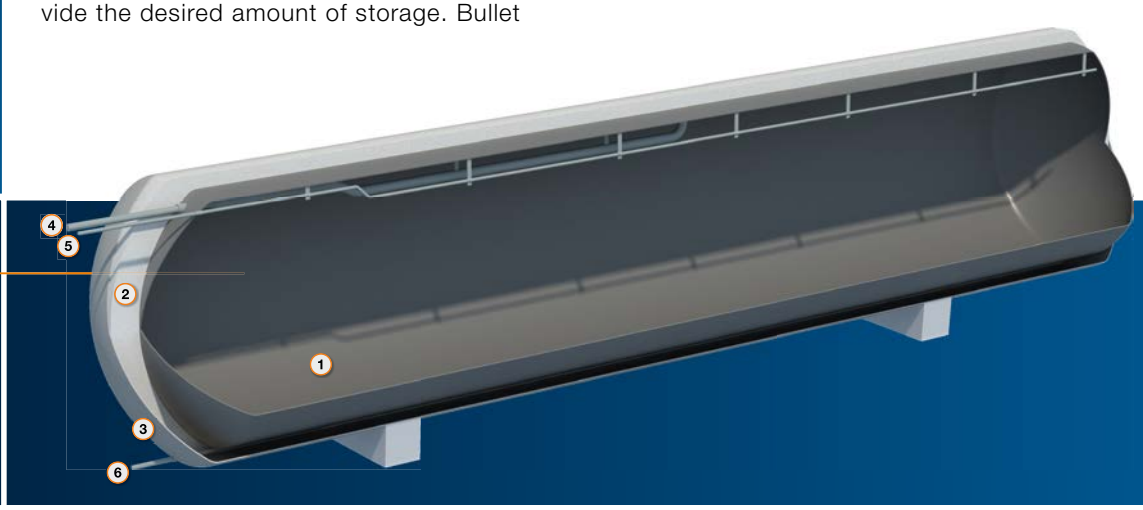
Horizontal tanks

- Large footprint compared to vertical tank
- Sizes up to approximately 1200 m^3 per tank.

The safety requirements are an important input for selecting the type of bullet tank system. Bullet tanks have an inner shell made of cryogenic steel and an outer shell of cryogenic or non-cryogenic steel. The tanks can have a bund around the whole tank farm area or only under the process area.

Bullet tank.

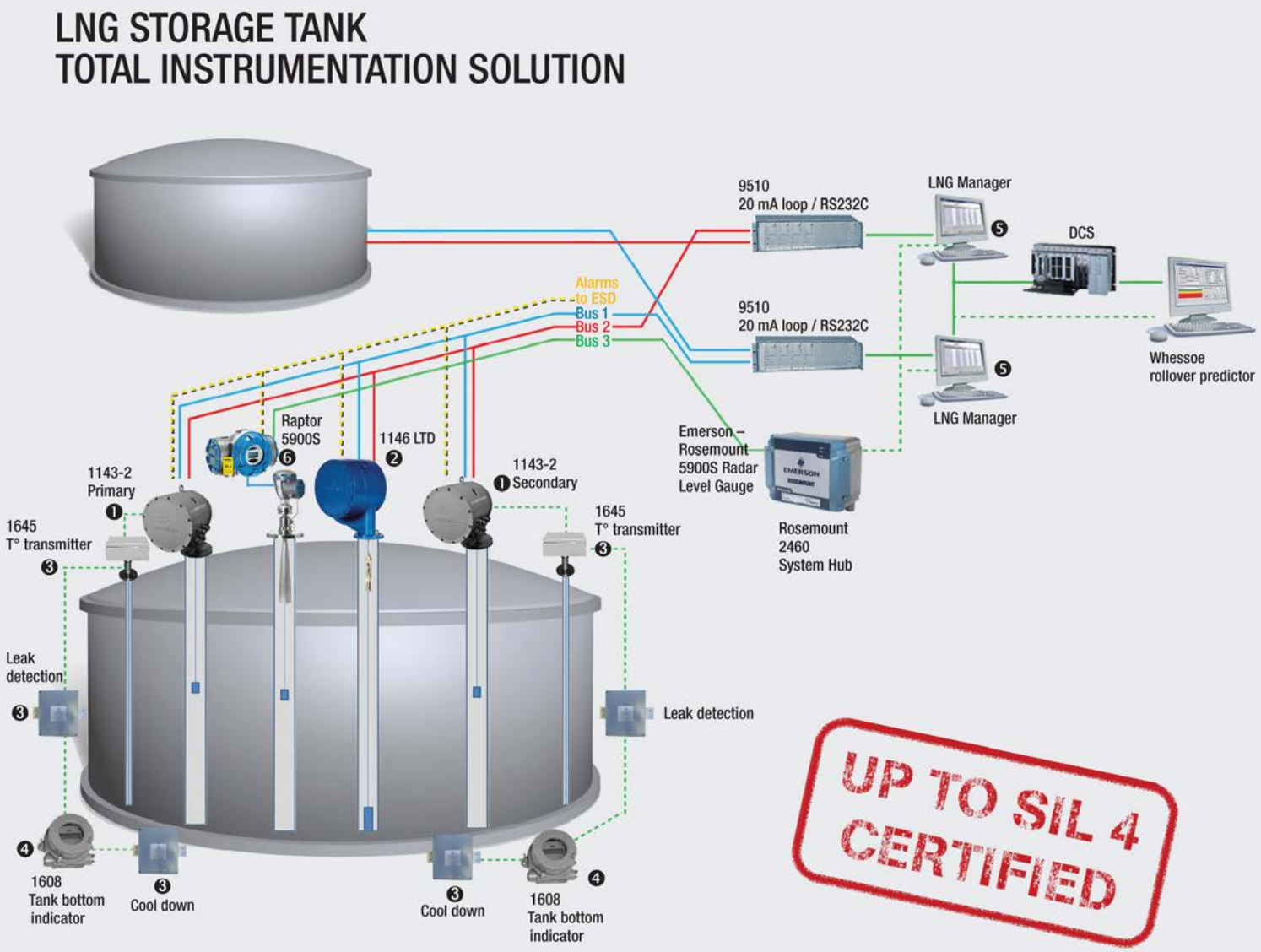
1. Inner vessel (cryogenic steel)
2. Insulation (vacuum and perlite)
3. Outer vessel (cryogenic steel or non-cryogenic steel)
4. Inner vessel over pressure line
5. LNG spray line
6. LNG inlet/outlet line



LNG storage alternatives offered by Wärtsilä

	Bullet tank (double shell steel tanks)	Flat bottom tank (single, double or full containment)
Tank type		
Capacity	Single tank 100–1200 m^3 Multiple tanks 100–20,000 m^3	15,000–160,000 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 one month	0.05% per day
Operating pressure	0.5–8 barg	Athmospheric
Rollover monitoring needed	No	Yes
Manufacturing method	Pre-fabricated in factory	On site
Installation time on site	Days to weeks	24-36 months

Tank control systems



In order to apply efficient business management, while adhering to stringent safety regulations, operations personnel must have access to correct information. Throughout the production cycle, from storage to distribution, the availability of precise data is essential, and it needs to be relayed to the control room in real time.

Whether your operation is large or small, Wärtsilä Tank Control Systems (previously Whessoe) are custom designed to suit your requirements. They can operate independently, or be interconnected within a plant-wide system. Our vast experience, research, instrumentation technology, and service support will add value to your business.

Total LNG tank gauging system

Our total LNG storage tank instrumentation solution comprises the following, fully integrated system components:

- SIL-3 certified servo level gauges
- High/high level alarm gauges
- Product temperature probes
- Fully automatic LTD gauges
- Leak detection and cooling temperature transmitter system
- PC based SCADA package
- Roll-over predictive alarm software.

The entire system communicates via a redundant communication link.

Boil-off gas handling

One of the main challenges of LNG storage is handling the boil-off gas. BOG is produced because LNG is stored at cryogenic conditions in a much warmer ambient environment. It forms in the top of the LNG tank and creates pressure that has to be managed or released in order to maintain the pressure within the limits of the tank design.

For **flat bottom tanks**, during normal operation and storage BOG is only about 0.05-0.1% of tank mass per day, while it can be eight to ten times higher during ship unloading. When excess BOG is generated during ship unloading it is common to return the BOG to the LNG carrier through a vapour return line, compensating for the reduction of the liquid volume in the vessel. However, in small-scale LNG terminals it is sometimes possible to eliminate the vapour return line if the LNG carrier is equipped with vaporization systems for equalizing the pressure. In **bullet tanks** used for smaller volumes of LNG the boil-off gas is 0.05-0.15 % per day, but the tank is capable of handling the increased pressure for up to 1 month. Bullet tanks are designed and operated so that no BOG compressor is needed.

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)
- Utilising BOG as fuel in a nearby power plant converting into electric power and heat
- LNG recirculation / top spraying
- Pumping it to the low pressure (LP) gas pipeline (<10 bar)
- Pumping it to the high pressure (HP) gas pipeline (10-50 bar)
- Reliquefaction of BOG into LNG.

The suitability of these options must be evaluated based on the project specific needs. Wärtsilä's recommendation is to build the terminal in conjunction with gas consumers that can utilise the BOG in their processes or power production. This way we can guarantee BOG consumption at any time. In addition, no gas is wasted and energy use for reliquefying the gas is avoided. Combining a Wärtsilä gas power plant with a terminal is a perfect solution as the BOG can be directly converted into electric power. The electricity can be used in the LNG terminal itself or exported to other consumers.

Why Wärtsilä?

We make it possible to switch over to LNG, a cleaner and more affordable fuel, in locations that previously were deemed too small for an LNG terminal. Wärtsilä helps you to develop the project rapidly and with lower risk. With us as a partner, you will have a well-functioning asset for years to come.

Projects are customized for 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.
- Proven LNG infrastructure solutions supported by a world-class LNG Solutions Design team.
- Complete 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 terminals 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.

Support throughout the entire lifecycle

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.

Experience and successes

Tornio, Finland.

TORNIO MANGA TERMINAL

Customer	Manga LNG Oy
Type	Medium-scale terminal
Tank net volume	50,000 m^3
Send out	Max 40 tonnes per hour at 6.0 barg
Delivery method	EPC turnkey
Delivery	2018

Scope of supply

- Civil works and infrastructure
- Full containment storage tank
- Regasification & gas metering
- BOG system
- Electrical and control system
- Unloading system
- Bunkering and truck loading.

Waterston, Wales, UK.

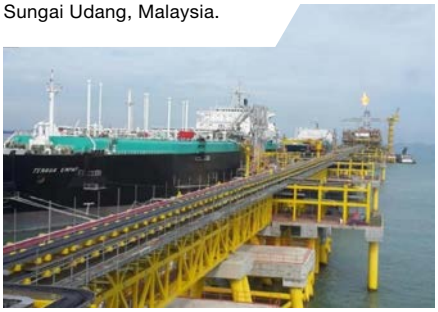
DRAGON LNG

Customer	Dragon LNG (JV between Petronas and BG Group)
Type	Boil-off gas reliquefaction unit for large-scale terminal
Capacity	340 TPD/120,000 tonnes per annum (TPA)
Details	Emphasizing flexibility. Liquefaction capacity can go down to 62 TPD
Delivery method	Engineering & procurement
Delivery	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.

Sungai Udang, Malaysia.



MELAKA LNG IMPORT TERMINAL

Customer	Ranhill Worley for Petronas
Type	Jetty regasification unit for large-scale terminal
Capacity	10,608 TPD / 3.9 million tonnes per annum (MTPA)
Outlet gas pressure	70 bar
Size of module	32 x 20 x 13 m, 945 t dry weight
Delivery method	EPC
Delivery	2011

Scope of supply

- Sea water/propane 3 x 5304 TPD / 2 MTPA trains (3 x 50%)
- BOG recondenser capacity 576 TPD / 21,240 TPA per train.

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.

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06.2016 / Bock's Office