It’s time for
LNG
clean and competitive power

WÄRTSILÄ POWER PLANTS
Power Plants offering

- We are a major supplier of flexible baseload power plants operating on various liquid and gaseous fuels
- We provide unique, dynamic solutions for grid stability, reserve, peaking, load following and intermittent power generation
- Our multi-fuel solutions for the oil & gas industry are used for reliable power generation, pumping and compression

All applications are supported with tailored lifetime operation and maintenance services.
Wärtsilä offers power solutions, products and services for every phase of oil and gas exploration, production, transportation and refining – both onshore and off.

We are involved in bringing more than 5 million barrels per day to the market, which is more than 6% of the total world oil production.

Whatever the conditions, we deliver world-class efficiency, fuel flexibility and environmentally sound solutions.
Offshore Wärtsilä’s Uniform and Integrated Solutions

Widest product portfolio
Leading edge solutions

- Concepts
- Applications
- Project execution
- System integration
- Engineering
- Third party supplies

Offshore Drilling

Offshore Production

Offshore Service Vessels

Automation
Power drives

Power distribution
Engines

Propulsion
Ship design
Onshore Wärtsilä Oil & Gas Process Industry Segments

**UP STREAM**
Exploration & Production (E&P)

**MID STREAM**
Transmission & Processing

**DOWN STREAM**
Selling & Distribution

**FIELD POWER**
- Power generation & waste heat recovery
- Gas flaring solutions

**PUMPING**
- Power generation for electrical driven pumps

**COMPRESSION**
- Power generation for electrical driven compressors

**PROCESS**
- LNG storage
- LNG re-gasification
- Liquefaction
- Separation
- Power generation

**REFINERY**
- Power generation & waste heat recovery

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What is LNG?

- Liquefied Natural Gas (LNG) is Natural Gas that has been cooled below the bubbling point, where it is condensed to a liquid, which occurs at a temperature dependent of the gas composition, typically close to -160°C at atmospheric pressure.
- Consist mainly of methane
- Contains no sulphur or toxic elements
- Odourless

<table>
<thead>
<tr>
<th>Vol-%</th>
<th>Lean</th>
<th>Mean</th>
<th>Rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>96.2</td>
<td>91.7</td>
<td>84.8</td>
</tr>
<tr>
<td>Ethane</td>
<td>3.3</td>
<td>5.7</td>
<td>13.4</td>
</tr>
<tr>
<td>Propane</td>
<td>0.4</td>
<td>2.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Buthane</td>
<td>0.1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Pentane</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>MN</td>
<td>87</td>
<td>76</td>
<td>71</td>
</tr>
</tbody>
</table>
Why LNG?

- Solution to utilize natural gas where pipeline gas is not available
- Liquefaction reduces the volume by approximately 600 times, making it more economical to transport over long distances by specially designed semitrailers and ships

1 m$^3$ of LNG = 600 m$^3$ of natural gas
Density of LNG: 450 kg/m$^3$
### LNG conversion & engine consumption, 1 sample

<table>
<thead>
<tr>
<th>LNG volume</th>
<th>LNG mass</th>
<th>Gas volume</th>
<th>1 ton LNG</th>
<th>13700 kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.25 m³ LNG</td>
<td>1 ton</td>
<td>1370 Nm³ Gas</td>
<td>Electrical energy</td>
<td>6165 kWh</td>
</tr>
<tr>
<td>LHV</td>
<td>49.0 MJ/kg</td>
<td>35.9 MJ/m³</td>
<td>(Engine electrical efficiency 45%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.0 kWh/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHV</td>
<td>54.4 MJ/kg</td>
<td>39.8 MJ/m³</td>
<td>1 m³ LNG</td>
<td>6090 kWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.1 kWh/m³</td>
<td>Electrical energy</td>
<td>2740 kWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Engine electrical efficiency 45%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>50MW Electrical Power</th>
<th>El eff. 45%</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG mass flow</td>
<td>8.2 ton/h</td>
</tr>
<tr>
<td>LNG volume flow</td>
<td>18.4 m³ LNG/h</td>
</tr>
<tr>
<td>Gas volume flow</td>
<td>11 230 m³ LNG/h*</td>
</tr>
<tr>
<td>10 000 m³ LNG</td>
<td>22.6 days</td>
</tr>
</tbody>
</table>

**Density:**
- Gas: 0.73 kg/m³
- Liquid: 444 kg/m³

* At 0°C and 101.325 kPa
How to get LNG? – Conventional LNG supply chain

- Upstream
  - Gas exploration
- Gas processing and Liquefaction
- Large scale LNG shipping
- HUB
  - LNG import and degasification
- Pipeline
- End user (NG)

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How to get LNG? – Mid and Small scale LNG

- Upstream: Gas exploration
- Gas processing and Liquefaction
- Large scale LNG shipping
- HUB: LNG import and degasification
- Pipeline
- End user (NG)

- LNG shipping
- Mid-scale storage and regasification
- End user (NG)

- Truck transport
- Satellite LNG storage plant (pressurized)
- End user (NG)

- Ship bunkering
How to get LNG? – Mid scale LNG

LNG shipping

Mid-scale storage and regasification

End user (NG)

Flat bottom atmospheric tank © Skangass

Pressurized tanks © Chart Industries

Floating storage and regasification unit © Hoegh
How to get LNG? – Small scale LNG

- Mid-scale storage and regasification
- Satellite LNG storage plant
- End user (NG)
- Ship bunkering

© Skangass
Wärtsilä power plants can utilize LNG directly as the fuel is heated before the engine.
**Essential steps in developing a LNG terminal**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility</td>
<td>Setting the goals for the project. Selecting site and checking project feasibility.</td>
</tr>
<tr>
<td>PreFEED</td>
<td>Making the basic technical design, safety assessments and major commercial processes.</td>
</tr>
<tr>
<td>FEED</td>
<td>Design and develop the project. Squire project financing and apply for the key permits.</td>
</tr>
<tr>
<td>EPC</td>
<td>Build and commission the terminal.</td>
</tr>
<tr>
<td>Operation</td>
<td>Terminal life cycle operation (20-30 years)</td>
</tr>
</tbody>
</table>
Essential steps when sizing an LNG terminal

- Power need to be determined, existing, future, grid connection
- Steel vs. Concrete tank
- Supply source of LNG, quality, agreement
- Travel distance, round trip time
- Ship size needed, check availability
- Ship charter, check availability
- Channel depth
- Mooring depth, shore, offshore
- Breakwater
- Infrastructure, existing harbor, residential area
- Safety distances, permits
- Availability of material & Contractors
• Present LNG fleet have been focusing on transocean supplies, i.e ship sizes are spanning from 120 – 250000 m³.
• Small size (1 – 20000 m³) supply vessel availability is limited, worldwide fleet about 20 vessels, in general the small-mid scale LNG supply infrastructure is not existing.
The most important parameter when optimizing the terminal is the LNG supply. The ship size will determine the cargo that will be received. Shipping time and needed weather margins will determine the time between cargos. But also available HUB slots and costs need to be considered.

The sendout requirement will determine the slope of the volume curves and have a determine the sizing of the sendout equipment.
LNG storage capacity (base load operation)

100MW plant
100% utilization
0.14 Million Ton/year (MTPA)
0.31 Million m$^3$/year

300MW plant
100% utilization
0.41 Million Ton/year (MTPA)
0.94 Million m$^3$/year
Process flow diagram

High pressure Sendout and Power plant supply
Low pressure supply to Power plant supply
Propane 2-stage Regasification Systems

- Heat input: About 22 MW pr 100 tons/h
- Heating source: Seawater, Water, Steam, Water/Glycol,

- Power demand:
  100 bar: About 1.4 MW pr 100 ton/h

- System size/weight:
  2*50 tons/h plant: 100 tons 17*5*9 m
Customer Values Regasification Systems

- Leading position in market
- Track record of delivering 9 plants onshore and offshore
- Modularized delivery (Easy installation)
- Easy Operation and Maintenance
- Very quick ramp up/down (0-100% in 1 hour)
- High efficiency compact heat-exchangers
Boil off gas (BOG)

- Heat ingress to the tank or process equipment containing LNG increase the temperature above boiling point of LNG. This is called Boil Off Gas (BOG). In onshore tanks the normal BOG rate is from 0.05% to 0.10% of total tank mass per day.
- During ship unloading the BOG rate is significantly higher, mainly due to large liquid movement and possibly high tank temperature in the ship. The BOG rate during unloading can be up to 10x normal BOG.
- BOG can be heated, compressed and utilized in the Wärtsilä power plant.
Smart Power Generation meets LNG
Smart Power Generation – unique features

Energy efficiency
- Highest simple cycle electrical efficiency
- High efficiency regardless of ambient conditions
- High plant efficiency over a wide load range due to multiple generating sets

Competitive generation cost and high dispatch

Fuel flexibility
- Continuous choice of the most feasible fuel
- Solutions for
  - liquid and gaseous fuels
  - renewables
  - multi-fuel plants
  - fuel conversions

Hedge for the future

Operational flexibility
- Unlimited, super fast, reliable starting and stopping with no impact on maintenance schedule
- Fast reserve, load following, peaking and baseload
- All ancillary services
- Grid support, wind enabling

Multi-tasking plant prepared for future markets
Wärtsilä gas engine reference map

7850 MW, in 44 countries, 275 power plants

Europe
- DF engines: 2160 MW
- GD engines: 300 MW
- SG engines: 115 MW
- SG engines: 1745 MW

Middle East
- DF engines: 220 MW
- GD engines: 95 MW
- GD engines: 50 MW
- SG engines: 75 MW

Asia
- DF engines: 2695 MW
- GD engines: 380 MW
- GD engines: 650 MW
- SG engines: 1665 MW

Africa
- DF engines: 800 MW
- GD engines: 520 MW
- SG engines: 280 MW

North & Central America & Caribbean
- DF engines: 1390 MW
- GD engines: 360 MW
- GD engines: 20 MW
- SG engines: 1010 MW

South America
- DF engines: 585 MW
- GD engines: 110 MW
- GD engines: 125 MW
- SG engines: 350 MW

7850 MW, in 44 countries, 275 power plants
Selected references: USA

Antelope station
- Location: Abernathy, Texas, US
- Operation mode: Peaking
- Installed Capacity: 170 MW
- Technology: 18 x Wärtsilä 20V34SG
- Fuel: Natural Gas
- Commercial operation: 1.1. 2011

Plains End Power Plant I & II
- Location: Plains End, Denver, Colorado
- Operation mode: Peaking
- Installed Capacity: 231 MW
- Technology: 20 x 18V34SG and 14 x 20V34SG
- Fuel: Natural Gas
**Selected references**

**Sangachal**
- Location: Sangachal, Azerbaijan
- Operation mode: **Grid Baseload**
- Installed Capacity: **307.8 MW**
- Technology: 18 x Wärtsilä 18V50DF
- Fuel: Natural Gas and HFO
- Commercial operation: 2006

**Seaboard New Barge**
- Location: Santo Domingo, Dominican Republic
- Operation mode: **Grid Baseload**
- Installed Capacity: **106.3 MW**
- Technology: 6 x Wärtsilä 18V50DF + CHP
- Fuel: Natural Gas and HFO
- Commercial operation: 2011
71MW Power Barge Lihir Gold
Summary of gas and dual fuel power plants today

W34SG CMPP 10-100 MW
W34SG CMPP 100-300 MW
W50SG CMPP 20–500 MW

W34SG GAScube 8 – 30 MW
W34DF / W50DF CMPP
W32GD / W46GD CMPP

CMPP = Compact Modular Power Plant
Comprehensive customer services

Development and Financial Services
- Project development
- Financing support
- Carbon finance expertise

World class Project Management
- Global EPC (Engineering, Procurement, Construction) delivery
- Scope of supply flexibility
- Short delivery time

Global operation and maintenance services
- Local service outlets in more than 70 countries
- Long term operation and/or maintenance agreements
- 24h technical support
- Field service and spare parts