2016

POWER PLANTS SOLUTIONS

WÄRTSILÄ

THE POWER SYSTEM OF THE FUTURE. AVAILABLE TODAY.

Electricity consumption will continue to grow rapidly during the coming decades. At the same time, concerns related to global warming and declining fossil fuel resources have created a need to reduce carbon emissions through renewable power. Nowadays, renewable sources, hydropower excluded, cover a good 3% of total production, but their share is rapidly growing.

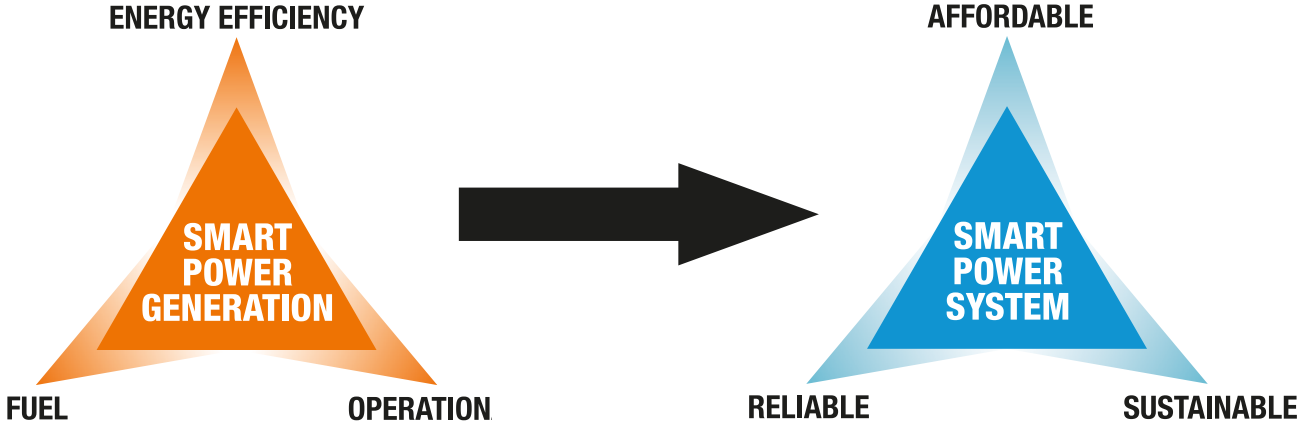
If intermittency problems can be efficiently resolved, wind and solar power offers great potential. Their variability creates new challenges to power systems which cannot be solved by any grid solution. Even small variations in wind speed – which can happen many times per day within time frames of less than 15 minutes – have a dramatic impact on wind power output. In power systems with high shares of installed wind power capacity, this is a challenge which the system is not designed to handle.

The existing power systems need to be complemented by dispatchable, dynamic capacity with the capability of handling frequent fast starts, stops and load ramps. To ensure a sustainable, reliable and affordable power system a dynamic capacity which corresponds to roughly half of the installed intermittent power capacity is required.

Balancing the power system

Wärtsilä smart power generation power plants enable the transition to a sustainable, reliable and affordable power system. The main cornerstones are very high energy efficiency, outstanding operational flexibility, and multi-fuel operation. The applications range from stationary and floating baseload power plants to dynamic grid stability and peak load services, balancing large input fluctuations of wind and solar power, as well as serving a wide variety of industrial self-generation needs.

Reservoir hydropower, where available, and smart grids with demand response, assist in the balancing task. When complementing the power system with Wärtsilä's solutions, all balancing challenges can be solved, maximising the use of intermittent renewables.



Operational flexibility

Being able to operate in multiple modes, from efficient baseload power production to dynamic system balancing in combination with, for example, wind or solar power, Wärtsilä power plants become a key factor in optimising power systems.

They offer ultra fast, zero-emissions, non-spinning grid reserve for any contingency situation or grid black start. They can generate megawatts to the grid in less than a minute from start-up and reach full load in less than five minutes. They are designed to start and stop – at the push of a button – time after time without impact on maintenance.

The multi-unit configuration allows plant availability and reliability of close to 100%, as well as highest possible firm capacity. They also ensure rapid load following and peak load capability with fast frequency regulation and an efficient spinning reserve.

Wärtsilä's plants are also easy to locate next to critical load pockets, i.e. in cities, thanks to plant size, and low emission and noise levels, and thus reduce the grid investment cost notably. The infrastructural requirements are modest, with little or no water consumption, and low pipeline gas pressure needed.

Energy efficiency

Power plants based on multiple generating units are far more reliable and fuel efficient than single – or several – large power stations. They also serve efficiently on part load and in demanding ambient conditions, enabling high dispatch even in hot climates and at high altitudes. We also offer the highest available simple cycle energy efficiency of current technologies, 50% or more. With the Wärtsilä Flexicycle solution the advantages of a flexible simple cycle plant are combined with the superb efficiency of a combined cycle plant.

Fuel flexibility

Wärtsilä's multi-fuel plants enable the continuous choice of the most feasible fuel, including solutions for liquid and gaseous fuels as well as renewables. The possibilities gained from multi-fuel plants and fuel conversion solutions represent a hedge for the future. The role of natural gas in power generation is expected to grow significantly over the coming years. Recent technical breakthroughs and the commercialisation of shale gas have resulted in a substantial extension of the perceived depletion time of gas reserves, and have lowered the price of natural gas. With power plants running on gas, the targets for renewable energy by the European Union and other entities are within reach.

TYPICAL 50 MW SMART POWER GENERATION POWER PLANT

Mechanical components

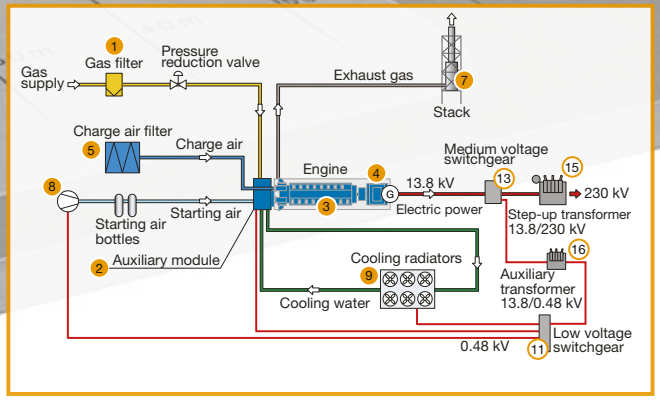
1. Natural gas inlet (Filtration & pressure reduction station)
2. Auxillary module
3. Engine W18V50SG
4. Generator
5. Intake air filter
6. Exhaust gas module
7. Exhaust gas silencer
8. Starting air unit
9. Radiator

Electrical components

10. LV switchgear
11. Generator cables
12. MV switchgear
13. MV outgoing cables
14. Step-up transformer
15. Auxiliary trasformer
16. Black starting unit

Auxiliary equipment

17. Roof ventilator
18. Auxiliary side ventilation air inlet
19. Generator side ventilation air inlet
20. Steel structure building with Paroc elements



WORLDWIDE SUCCESS STORIES

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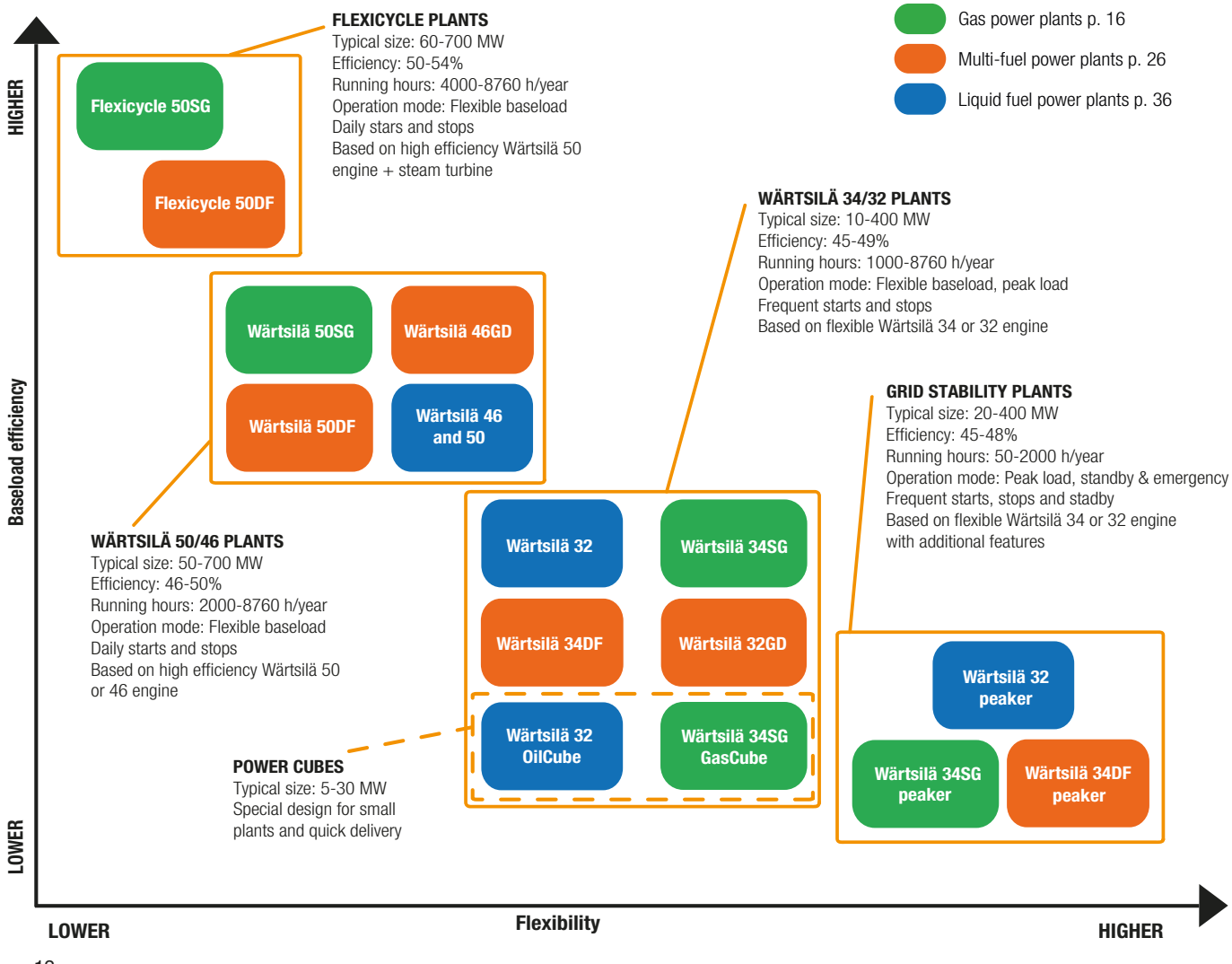
We have delivered about 4800 power plants, with a combined capacity of 60 GW, to 176 countries.

A SOLUTION FOR EVERY NEED



KEY FIGURES*

Plant output (MW)
Typical size of the power plant.

Configuration
Number and type of gensets that correspond to the typical size of the plant.

Minimum load (%)
Lowest plant load that can be maintained for extended periods of time, calculated for a 10-unit plant.

In efficiency mode, load is reduced by turning off units.

In spinning mode, all units are kept online at minimum load.

Efficiency (%)
Plant efficiency based on ISO 3046 conditions and tolerances, excluding auxiliary system losses.

Ramp rate (%/min)
Percentage of the total load that the plant can increase in a minute in order to provide ancillary services.

Regular start time (min)
Start time based on warm standby (preheated or operated in the last 12 hours).

A faster start time translates into the plant being online sooner, thus generating additional power and producing revenue for a longer time.

Fast start time (min)
Start time based on hot standby (preheated to a higher temperature or operated in the last 6 hours).

If the plant is preheated at a slightly higher temperature, starting times can be cut substantially. This field is the equivalent of the previous one in those warm standby conditions.

Ultra fast start time (min)
Start time based on hot standby plus certain start preparations (preheated and quick start prepared, or operated in the last hour).

Certain plants can be fitted with an ultra fast start capability, which dramatically cuts the starting time even further.

Stop time (min)
Time it takes to decrease output from 100% to 0%, disconnect from grid and come to a complete stop.

A shorter unloading time adds flexibility to adapt to any load conditions and only being online when it is profitable, saving fuel and reducing emissions.

* The key figures are used in tables describing the features of various power plant types, starting on page 18.

Wärtsilä gas power plants use natural gas, the cleanest fossil fuel available, in the most economical way, thanks to their high efficiency at any load and unbeatable flexibility to start and stop exactly according to needs.

Besides the combination of efficiency and flexibility, Wärtsilä gas power plants also offer low emissions, and can provide a great amount of power in a reduced site, making it the optimal solution for locations where minimizing the impact is a priority. As such, they can be placed close to consumption nodes, optimizing the power system.

Wärtsilä gas power plants can run on natural gas, LNG and selected biogases.

The specific benefits for gas power plants include:

- Plant electrical efficiency of up to 50% in single cycle and 54% in combined cycle mode
- Only 5 bar gas pressure requirements for operation, which means no gas compressor is needed at the plant.
- Lean-burn technology guarantees very low emissions by itself, complying with most regulations, including IFC (World Bank group). By adding a selective catalytic reactor (SCR), even the most stringent standards worldwide can be met.

Wärtsilä 50SG gas power plant

High efficiency in a small footprint combined with high reliability and flexibility. Powered by the most efficient gas-driven internal combustion engine in the world.
Suitable for: Flexible baseload

Wärtsilä 34SG gas power plant

Agile and flexible, this plant delivers power with high efficiency and reliability, even in the most challenging ambient and operational conditions.
Suitable for: Peak load, flexible baseload

Wärtsilä 34SG grid stability / emergency gas power plant

Designed for low own consumption combined with ultimate flexibility, gives extremely fast response to emergency situations, and able to supply megawatts in a matter of seconds.
Suitable for: Standby & emergency, peak load

Wärtsilä GasCube

Fully pre-engineered solution for quick installation time with all the great features of the Wärtsilä 34 gas power plant.
Suitable for: Small-sized power plants

Wärtsilä 50SG gas power plant

High efficiency in a small footprint combined with high reliability and flexibility makes this solution ideal for flexible baseload applications including daily starts and stops, also providing ancillary services.

- Most efficient single-cycle solution: over 50% efficiency with turbogenerator.
- Combined cycle-like efficiency from a single cycle solution.
- Full power can be achieved with a wide range of gas qualities, a varying methane number or heating value do not affect the operation.
- Robust, reliable genset, proven in the most challenging environments.
- Makes the most out of the cleanest fossil fuel available - natural gas.
- Minimum area requirement for a given output.

Key figures

Plant output	50-700 MW	
Configuration	3-36 x 18V50SG	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	50%	
Ramp rate	>100%/min	
Regular start time	**Sync** <2 min	**Full** <10 min
Fast start time	**Sync** <2 min	**Full** <5 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

Red Gate, Texas, USA

Customer	STEC (IPP)
Type	Wärtsilä 50SG gas power plant
Operating mode	Flexible baseload
Gensets	12 x Wärtsilä 18V50SG
Total output	224 MW
Fuel	Natural gas
Scope	EEQ (Engineered Equipment Delivery)
Delivered	2014

Wärtsilä 34SG gas power plant

Agility and flexibility combined with high efficiency over the whole load range and in any operating profile makes this plant excellent for both flexible baseload and peak load, and supporting the grid with a variety of ancillary services.

- Ultimate combination of efficiency and flexibility. Over 49% efficiency after only 5 minutes from start.
- Best up– and down– ramp rates in the industry.
- Full power can be achieved with a variety of gaseous fuels, from methane to LPG, without affecting the operation.
- Makes the most out of the cleanest fossil fuel available - natural gas.
- Genset is easily transported in one piece to challenging locations.

Key figures

Plant output	10-400 MW	
Configuration	1-36 x 20V34SG	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	49%	
Ramp rate	>100%/min	
Regular start time	**Sync** <2 min	**Full** <10 min
Fast start time	**Sync** <2 min	**Full** <5 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

The Ashuganj power station is equipped with a co-generation element which uses the exhaust heat and increases the power output by 16 MW.

In a deveping economy like Bangladesh you have to have these kinds of modular plants which can ramp production up and down within minutes. Absolutely, this is the future."

— Moinuddin Hasan Rashid, Managing Director of United Enterprises & Co. Ltd.

Ashuganj, Bangladesh	
Customer	United Ashuganj Energy Ltd. (IPP)
Type	Wärtsilä 34SG gas power plant
Operating mode	Flexible baseload
Gensets	20 x Wärtsilä 20V34SG
Total output	195 MW
Fuel	Natural gas
Scope	EEQ (Engineered Equipment Delivery)
Delivered	2015

Wärtsilä 34SG grid stability / emergency gas power plant

Always ready to deliver power to the grid instantly and efficiently in any operating profile makes this plant perfect for peaking and reserve power applications.

- Ultra-fast start capability provides megawatts to the grid in seconds and full plant output in 2 minutes.
- Able to provide non-spinning secondary reserve thanks to a 30-second ultra fast sync time.
- The flexibility of a hydro plant in a gas-fired plant.
- Highest efficiency in pulse load (short-time on-off and part-load) operation.
- Genset is easily transported in one piece to challenging locations.
- Able to provide grid blackstart capability and re-energize a grid even with low gas pressure.
- Extremely low standby consumption, <1 kW per MW of installed power.

Key figures

Plant output	20-400 MW	
Configuration	2-24 x 18V34SG	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	48%	
Ramp rate	>100%/min	
Regular start time	**Sync** <2 min	**Full** <10 min
Fast start time	**Sync** <2 min	**Full** <5 min
Ultra-fast start time	**Sync** 0:30 min/sec	**Full** 1:30 min/sec
Stop time	< 1 min	

This extremely flexible plant was so successful chasing the winds of the Rocky Mountains that its owner decided to order an expansion and double its capacity only five years after its commissioning, turning it into the largest gas engine-based power plant in the United States.

During breakfast and dinner hours demand increases and the plant follows this perfectly. This is the way. This is the future."

— Kent L. Flckett,
Former SVP, PG&E.

Plains End, Colorado, USA	
Customer	Tyr Energy (IPP)
Type	Wärtsilä 34SG grid stability/emergency gas power plant
Operating mode	Peak load/stand-by & emergency
Gensets	20 x Wärtsilä 20V34SG 14 x Wärtsilä 20V34 SG
Total output	231 MW
Fuel	Natural gas
Scope	EEQ (Engineered Equipment Delivery)
Delivered	2001 & 2006

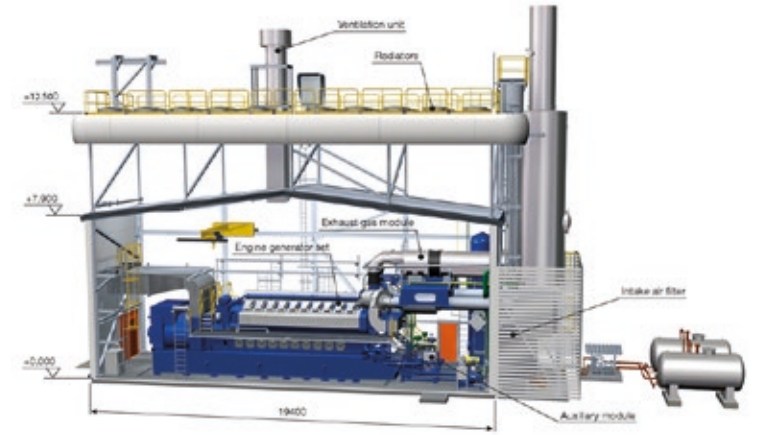
Wärtsilä GasCube

Wärtsilä GasCube has the all great features of Wärtsilä 34SG gas power plant in a compact, ready-to-use pre-engineered package designed for fast delivery time with minimal site work. Consists of a self-contained design with one or several modules, each housing one Wärtsilä 16V34SG or Wärtsilä 20V34SG genset, plus all the auxiliaries needed to make up a working power plant.

- Easy-to-install, pre-built solution for power needs of 7 to 30 MW.
- Ultimate combination of efficiency and flexibility. Over 48% efficiency after only 5 minutes from start.
- Same fuel flexibility and low environmental impact as the Wärtsilä 34SG gas power plant.
- Easy to expand with additional modules if power need grow with time.
- Quickest building and comissioning time.
- Perfect for fast-track EPC deliveries.

Key figures

Plant output	7-30 MW	
Configuration	1-3 x 20V34SG	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	48%	
Ramp rate	>100%/min	
Regular start time	**Sync** <2 min	**Full** <10 min
Fast start time	**Sync** <2 min	**Full** <5 min
Ultra-fast start time	n/a	
Stop time	< 1 min	



Bontang, Indonesia

Customer	PT PLN (Utility)
Type	Wärtsilä GasCube
Operating mode	Flexible baseload
Gensets	2 x Wärtsilä 16V34SG
Total output	14 MW
Fuel	Natural gas
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2009

Multi-fuel power plants make power generation more reliable by being able to adapt to any situation that may occur regarding fuel availability or affordability.

They can even switch fuels while running, for example changing to liquid fuel mode if the gas supply is suddenly interrupted. This capability provides 24/7 security of supply, hedge against fuel price increases and preparation for future fuel infrastructure development.

Wärtsilä's multi-fuel power plants can run in the following operation modes:

- **Gas only** (with liquid pilot fuel)
    - Natural gas, LNG, biogas, associated gas (GD only). Insensitive to gas quality
- **Liquid fuel only**
    - Crude oil, diesel, residual oil (HFO), fuel-water emulsions, liquid biofuel
- **Fuel sharing mode** (in GD plants)
    - Gas and liquid fuel simultaneously
    - Fuel switch without power decrease
    - Automatic and instant trip to liquid fuel mode in alarm situations (applies also for DF plants)

Wärtsilä 50DF multi-fuel power plant

High efficiency in a small footprint combined with high reliability and flexibility. Can operate equally well on gas, HFO and LFO; and switch between them on the run.
Suitable for: Flexible baseload

Wärtsilä 34DF multi-fuel power plant

Agile and flexible, this plant delivers power with high efficiency and reliability. Starting, stopping and changing fuels is not a problem for this plant.
Suitable for: Peak load, flexible baseload

Wärtsilä 34DF grid stability / emergency multi-fuel power plant

Designed for minimised own consumption and extremely fast response to emergency situations, and able to supply megawatts in a matter of seconds. Adding multi-fuel capability to excellent dynamic features, this plant provides maximum supply security.
Suitable for: Standby & emergency, peak load

Wärtsilä 32GD and 46GD multi-fuel power plants

Especially designed to use low-grade fuels, like associated gas, flare gas or crude oil, optimal for fuel supply varying in quantity and quality.
Suitable for: Flexible baseload, reduction of gas flaring

Wärtsilä 50DF multi-fuel power plant

Multi-fuel operation with high efficiency, combined with high reliability and flexibility makes this solution perfect for flexible baseload applications including daily starts and stops, also providing various ancillary services.

- Most efficient single-cycle solution: over 50% efficiency with turbogenerator.
- Can operate on natural gas or any liquid fuel, including HFO, and switch between them while delivering power to the grid.
- Full power can be achieved with a wide range of gas qualities.
- Combination of low emissions in gas mode with an efficient liquid fuel mode that can use low-grade fuel oils.
- Robust, reliable genset, proven in the most challenging environments.

Key figures

Plant output	50-700 MW	
Configuration	3-36 x 18V50DF	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency		
Gas	48%	
Liquid gas	45%	
Ramp rate	>100%/min	
Regular start time	**Sync**	**Full**
Gas	<3 min	<15 min
Liquid gas	<3 min	<15 min
Fast start time	**Sync**	**Full**
Gas	<3 min	<10 min
Liquid gas	<1 min	<10 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

The world's largest combustion engine-based power plant, located in Jordan, is a perfect example of the power and flexibility that the Wärtsilä 50DF can offer, even in extremely challenging ambient conditions.

We trust Wärtsilä to professionally and competently lead the EPC consortium in this successful project."

— Mr Young Jin Bae, CEO, AAEPC

IPP3, Jordan	
Customer	AAEPC (IPP)
Type	Wärtsilä 50DF multi-fuel power plant
Operating mode	Flexible baseload
Gensets	38 x Wärtsilä 18V50DF
Total output	573 MW
Fuel	Natural gas, HFO & LFO
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2014

Wärtsilä 34DF multi-fuel power plant

Multi-fuel operation with full agility and flexibility combined with high efficiency over the whole load range and in any operating profile makes these plants excellent for both flexible baseload and peak load, and supporting the grid with a variety of ancillary services.

- Ultimate combination of efficiency, operational flexibility and fuel flexibility.
- Can operate on natural gas or any liquid fuel, including HFO, and switch between them back and forth while delivering power to the grid.
- Full power can be achieved with a wide range of gas qualities.
- Combination of low emissions in gas mode with an efficient liquid fuel mode that can use low-grade fuel oils.
- Genset is easily transported in one piece to challenging locations.

Key figures

Plant output	10-400 MW	
Configuration	1-36 x 20V34DF	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency		
Gas	48%	
Liquid gas	45%	
Ramp rate	>100%/min	
Regular start time	**Sync**	**Full**
Gas	<3 min	<10 min
Liquid gas	<1 min	<6 min
Fast start time	**Sync**	**Full**
Gas	<2 min	<6 min
Liquid gas	<1 min	<3 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

The 120 MW Musandam power plant is designed to operate in island mode in an isolated grid in Northern Oman. This makes reliability imperative.

We selected an optimal engine configuration for this project, to deliver flexible and sustainable energy to the Musandam Governorate."

— Mohammed Al-Abduwani, Chairman, Musandam Power Company

Musamdam, Oman	
Customer	Musamdam Power Company
Type	Wärtsilä 34DF multi-fuel power plant
Operating mode	Flexible baseload
Gensets	15 x Wärtsilä 20V34DF
Total output	120 MW
Fuel	Natural gas & LFO (back-up)
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2016

Wärtsilä 34DF grid stability / emergency multi-fuel power plant

The most flexible power plant in all aspects, always ready to deliver power to the grid instantly and efficiently, on any fuel. This makes the plant perfect for peaking and reserve power applications in any current or future fuel supply environment.

- Ultra-fast start capability provides megawatts to the grid in seconds and full plant output in 2 minutes.
- Able to provide non-spinning secondary reserve thanks to a 30-second ultra fast sync time.
- Highest efficiency in pulse load (short-time on-off and part-load) operation.
- Able to provide grid blackstart capability and re-energize a grid on diesel or low-pressure gas.
- Extremely low standby consumption, <1 kW per MW of installed power.
- Genset is easily transported in one piece to challenging locations.

Key figures

Plant output	20-400 MW	
Configuration	2-36 x 20V34DF	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency		
Gas	48%	
Liquid gas	45%	
Ramp rate	>100%/min	
Regular start time	**Sync**	**Full**
Gas	<3 min	<10 min
Liquid gas	<1 min	<6 min
Fast start time	**Sync**	**Full**
Gas	<2 min	<6 min
Liquid gas	<1 min	<3 min
Ultra-fast start time	**Sync**	**Full**
	0:30 min/sec	1:30 min/sec
Stop time	< 1 min	

Elering, the Estonian Transmission System Operator, recently added 250 MW of reserve capacity to the national grid by means of a Wärtsilä 34DF Grid stability/emergency multi-fuel power plant. Operating mainly on natural gas but capable of using LFO as a backup, it ensures the national grid is safe and sound at all times.

We had end results that needed to be met and Wärtsilä's engines simply offered an unrivaled solution."

— Ilo Toom,
Project Manager, Elering

Kiisa, Estonia	
Customer	Elering (Utility/TSO)
Type	Wärtsilä 34DF grid stability/emergency multi- fuel power plant
Operating mode	Peak load/stand-by & emergency
Gensets	27 x Wärtsilä 20V34DF
Total output	250 MW
Fuel	Natural gas & LFO
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2013 & 2014

Wärtsilä 32GD multi-fuel power plant

Seamless operation regardless on fuel make this plant great for flexible baseload and industrial self-generation. Especially designed to use low-grade fuels, like associated gas, flare gas or crude oil, it is optimal for fuel supply varying in quantity and quality.

- Ultimate fuel flexibility.
- Can operate on natural gas or any liquid fuel, and switch between them back and forth while delivering power to the grid.
- Unique fuel-sharing mode: adjust the fuel mixture according to the availability of gas and top up with liquid fuel.
- Genset is easily transported in one piece to challenging locations.

Key figures

Plant output	10-400 MW	
Configuration	1-24 x 20V32GD	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	45%	
Ramp rate	>100%/min	
Regular start time	**Sync** <1 min	**Full** <6 min
Fast start time	**Sync** <1 min	**Full** <3 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

Wärtsilä 46GD multi-fuel power plant

- Same fuel flexibility as Wärtsilä 32GD multi-fuel power plant
- A step further in terms of performance: a bigger unit size allows the engine to be even more efficient

GD OPERATION: Original gas-diesel operation mode, where gas is the main source of energy, and pilot fuel oil injection is used to ignite the combustion. Available at any point between 30-100% of rated load, the plant can transfer to and from GD operation within this same range.

FUEL SHARING: Available between 30-100% of rated load. Simultaneous combustion of gaseous and liquid fuel, in a ratio that can be adjusted flexibly. The fuel share set point can be adjusted online. The operator may also change the set point at any time during operation.

FUEL OIL OPERATION: Regular Diesel-principle combustion. Available for the whole load range and for any of the mentioned liquid fuels.

Liquid fuel power plants make power available anywhere, anytime. Proven long-term reliability makes these plants suitable for stationary and floating baseload, and for stand-by applications.

Wärtsilä liquid fuel power plants bring great value to the table, such as

- Tremendous fuel flexibility, with the possibility of running on heavy fuel oil, light fuel oil, crude oil, emulsified fuels or liquid biofuel.
- Great dispatch ability, ability to supply megawatts to grid within seconds, and reach full plant load in minutes.
- Utilising heavy fuel oil (HFO) in the most efficient way possible.

Wärtsilä 46 & Wärtsilä 50 liquid fuel power plant

High efficiency combined with high reliability and flexibility. Able to use any kind of fuel oil, excellent for covering larger and stable power demands. Powered by the most efficient diesel combustion engine in the world.
Suitable for: Baseload, Flexible baseload

Wärtsilä 32 liquid fuel power plant

Agile and flexible, this plant delivers power with high efficiency, even in the most challenging ambient and operational conditions. Based on the Wärtsilä 32 genset with more than 100 million cumulative running hours.
Suitable for: Flexible baseload, peak load

Wärtsilä 32 grid stability/emergency liquid fuel power plant

Based on the Wärtsilä 32 genset, the fastest response in the whole market is the main feature of this plant.
Suitable for: Standby & emergency, peak load

Wärtsilä OilCube

Fully pre-engineered solution for quick installation time with all the great features of the Wärtsilä 32 liquid fuel power plant.
Suitable for: Small-sized power plants

Wärtsilä 46 & 50 liquid fuel power plants

High efficiency and power on any liquid fuel combined with high reliability and flexibility make this solution perfect for flexible baseload applications including daily starts and stops, also providing ancillary services like up– and down– regulation.

- Most efficient simple-cycle liquid fuel solution, up to 47% efficiency.
- Can operate on any liquid fuel, including HFO, LFO, liquid biofuel, crude oil or fuel-water emulsions.
- Robust, reliable genset, proven in the most challenging environments.
- Most compact HFO power plant in terms of footprint.

Key figures

Plant output	50-700 MW	
Configuration	3-36 x 18V46	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	47%	
Ramp rate	>100%/min	
Regular start time	**Sync** <3 min	**Full** <15 min
Fast start time	**Sync** <1 min	**Full** <10 min
Ultra fast start time	n/a	
Stop time	< 1 min	

Betano, East Timor	
Customer	Govt of Timor Leste
Type	Wärtsilä 46 liquid fuel power plant
Operating mode	Flexible baseload
Gensets	8 x Wärtsilä 18V46
Total output	137 MW
Fuel	HFO
Scope	EEQ (Engineering & Equipment)
Delivered	2011

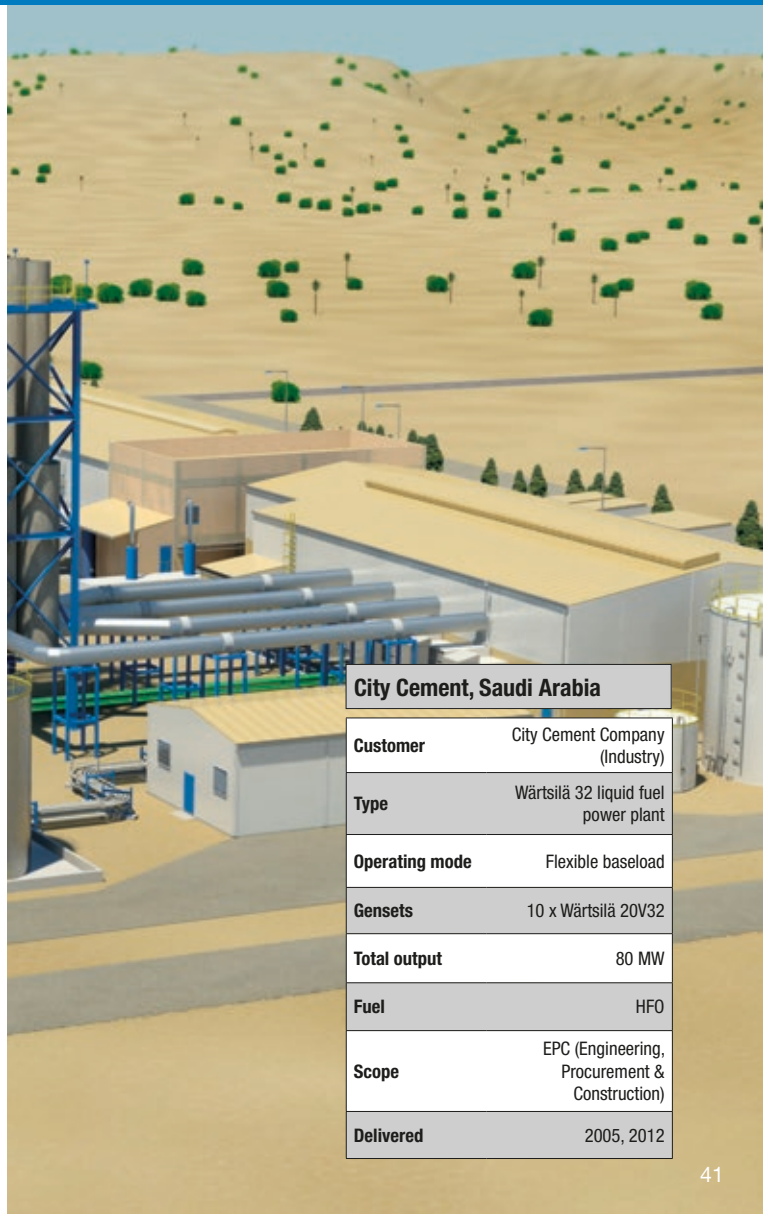
Wärtsilä 32 liquid fuel power plants

Agility and flexibility combined with high efficiency over the whole load range and in any operating profile makes this plant excellent for both flexible baseload and peak load, and also for supporting the grid with a variety of ancillary services.

- Ultimate combination of efficiency, operational flexibility and wide range of liquid fuels capability.
- Two-stage turbocharging applied to the Wärtsilä 20V32TS engine maintains efficiency and power regardless of challenging ambient conditions, like high altitudes or hot temperatures.
- Can operate on any liquid fuel, including HFO, LFO, liquid biofuel or crude oil.
- Genset is easily transported in one piece to challenging locations.

Key figures

Plant output	10-400 MW	
Configuration	1-24 x 20V32TS	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	47%	
Ramp rate	>100%/min	
Regular start time	**Sync** <1 min	**Full** <6 min
Fast start time	**Sync** <1 min	**Full** <3 min
Ultra fast start time	**Sync** 0:30 min/sec	**Full** 1:30 min/sec
Stop time	< 1 min	



City Cement, Saudi Arabia	
Customer	City Cement Company (Industry)
Type	Wärtsilä 32 liquid fuel power plant
Operating mode	Flexible baseload
Gensets	10 x Wärtsilä 20V32
Total output	80 MW
Fuel	HFO
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2005, 2012

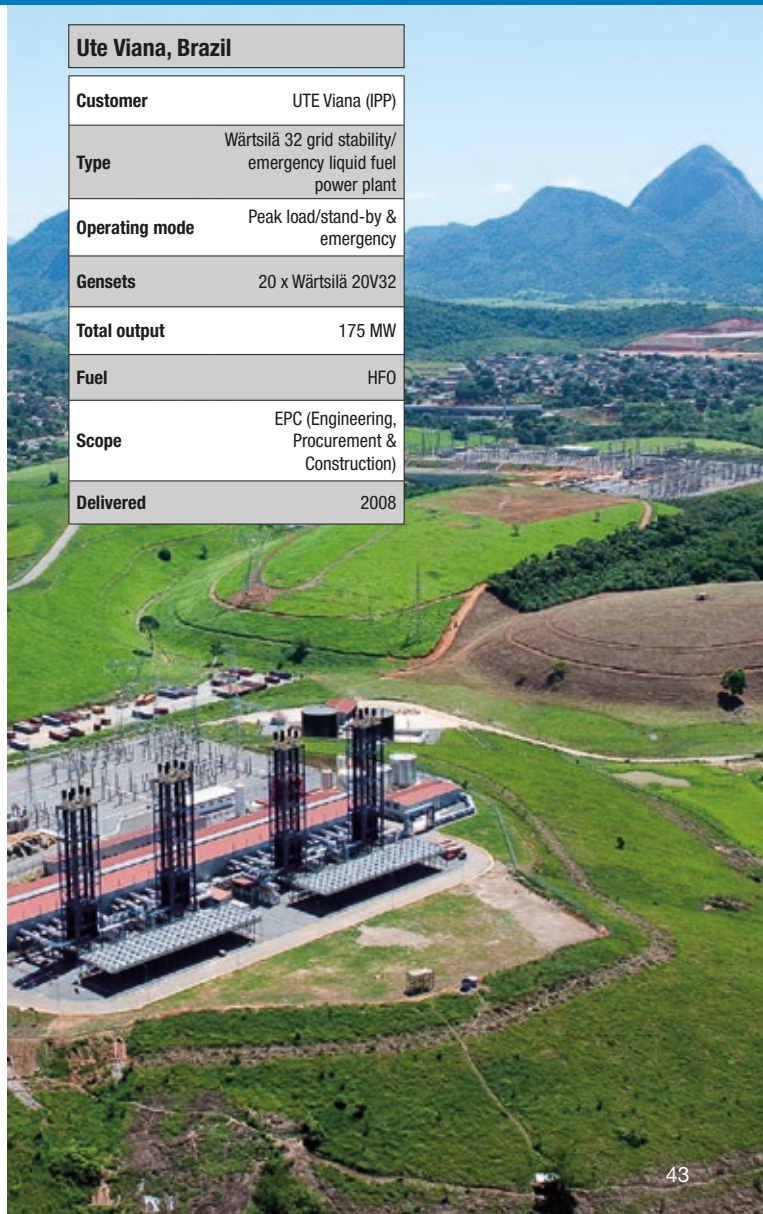
Wärtsilä 32 grid stability / emergency liquid fuel power plant

Always ready to deliver power to the grid instantly and efficiently in any operating profile makes this plant perfect for peaking and reserve power applications.

- Ultra-fast start capability provides megawatts to the grid in seconds and full plant output in less than 3 minutes.
- Able to provide non-spinning secondary reserve thanks to a 20-second ultra fast sync time.
- Able to provide grid blackstart capability and re-energize a grid.
- Extremely low standby consumption, <1 kW per MW of installed power.
- Genset is easily transported in one piece to challenging locations.

Key figures

Plant output	20-400 MW	
Configuration	2-24 x 20V32	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	46%	
Ramp rate	>100%/min	
Regular start time	**Sync** <1 min	**Full** <6 min
Fast start time	**Sync** <1 min	**Full** <3 min
Ultra fast start time	**Sync** 0:20 min/sec	**Full** 1:00 min/sec
Stop time	< 1 min	

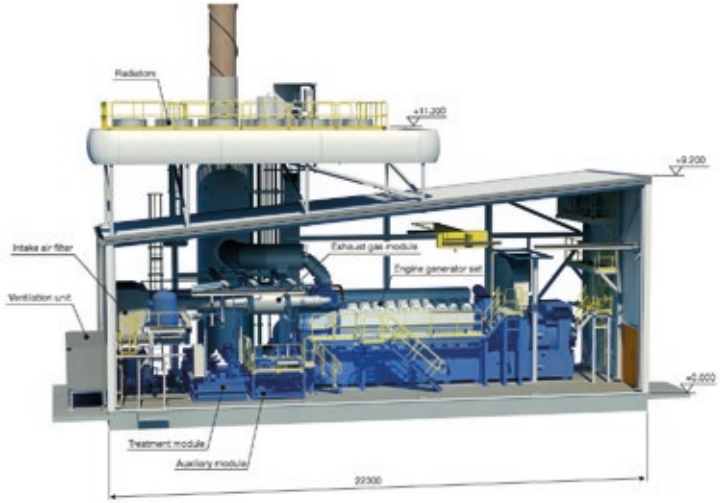


Ute Viana, Brazil	
Customer	UTE Viana (IPP)
Type	Wärtsilä 32 grid stability/ emergency liquid fuel power plant
Operating mode	Peak load/stand-by & emergency
Gensets	20 x Wärtsilä 20V32
Total output	175 MW
Fuel	HFO
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2008

Wärtsilä OilCube

All the great features of a Wärtsilä 32 plant in a compact, ready-to-use pre-engineered package designed for fast delivery time with minimal site work. Consists of a self-contained design with one or several modules, each housing one Wärtsilä 12V32, 16V32, 20V32 or 20V32TS genset, plus all the auxiliaries needed to make up a working power plant.

- Easy-to-install, pre-built solution for power needs of 5 to 30 MW.
- Great fuel flexibility like the Wärtsilä 32 liquid fuel power plant.
- Easy to expand with additional modules if power need grow with time.
- Quickest building and comissioning time.
- Especially designed for environments where infrastructure may be challenging.
- Perfect for fast-track EPC deliveries.



Key figures

Plant output	5-30 MW	
Configuration	1-4 x W32	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency	46%	
Ramp rate	>100%/min	
Regular start time	**Sync** <1 min	**Full** <6 min
Fast start time	**Sync** <1 min	**Full** <3 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

WÄRTSILÄ FLEXICYCLE

Flexicycle is an innovative concept by Wärtsilä, which combines the excellent dynamic capabilities of internal combustion engines with the superb efficiency offered by combined cycle solutions.

By adding a waste heat recovery system to the plant, consisting of a heat recovery steam generator for each engine and a common steam turbine and condenser for the plant, total efficiency can be improved by a very significant 3-4 percent units. The plant can switch between single or combined cycle modes upon request, getting the best of both worlds.

When the steam cycle is equipped with a dry condenser connected to the radiator cooling circuit, the total water consumption of the plant is negligible, making it also suitable for areas where water is a crucial resource. With 2.7 GW delivered to this day, Flexicycle represents the ultimate solution for flexible baseload plants, in either its gas-fired or multi-fuel configuation. One configuration, two switchable operational modes, and the advantages of both single and combined cycle: excellent flexibility and unmatchable efficiency.

Wärtsilä's Dry Flexicycle solution is often the right choice for arid areas. Thanks to the closed-loop cooling system, water consumption is close to zero.

Flexicycle 50SG gas power plant

Adding a flexible steam cycle (Flexicycle) to the highly efficient Wärtsilä 50SG engines makes this solution perfect for flexible baseload or even pure baseload applications. Due to the flexibility of the Wärtsilä 50SG engine, this solution can provide all desirable ancillary services.

- Most efficient flexible baseload solution: up to 54% efficiency without compromising flexibility.
- Suited for a larger amount of running hours per year, it can serve large power needs with a very high efficiency.
- Can start up quickly and inexpensively with extremely high efficiency.
- Can switch between two operation modes:
    - **Dynamic single cycle (SC)** (with all the benefits from a Wärtsilä 50SG gas power plant) with up to 50% efficiency.
    - **Combined cycle (CC),** reaching up to 54% efficiency.

Key figures

Plant output	60-700 MW	
Configuration	3-36 x 20V50SG + steam turbine	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency		
SC	50%	
CC	54%	
Ramp rate	>100%/min	
Regular start time	**Sync**	**Full**
SC	<2 min	<10 min
CC	<40 min	<60 min
Fast start time	**Sync**	**Full**
SC	<2 min	<5 min
CC	<30 min	<45 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

The modular design guarantees constant operation in this Flexicycle power plant in Mexico. If one of the seven engines is under maintenance, the other six are fully operational.

We chose engine technology for reliability and efficiency."

— Guillermo Barragán Toledo, Country Manager, Energía del Caribe, S.A

Huinala, Mexico	
Customer	Energía del Caribe, S.A. (IPP)
Type	Wärtsilä 50SG Flexicycle power plant
Operating mode	Baseload
Gensets	7 x Wärtsilä 50SG
Total output	139 MW
Fuel	Natural gas
Delivered	2016

Flexicycle 50DF multi-fuel power plant

Adding a flexible steam cycle (Flexicycle) to the highly efficient Wärtsilä 50DF engines makes this the ultimate solution for flexible baseload, with complete fuel flexibility.

- Most efficient multi-fuel flexible baseload solution: up to 52% efficiency without compromising flexibility.
- Suited for a larger amount of running hours per year, it can serve large power needs with a very high efficiency.
- Can operate on natural gas or any liquid fuel, including HFO, and switch between them back and forth while delivering power to the grid.
- Can start up quickly and inexpensively with extremely high efficiency.
- Can switch between two operation modes:
  - **Dynamic single cycle (SC)** (with all the benefits from a Wärtsilä 50DF multi-fuel power plant) with up to 48% efficiency.
  - **Combined cycle (CC),** reaching up to 52% efficiency.

Key figures

Plant output	60-700 MW	
Configuration	3-36 x 18V50DF + steam turbine	
Minimum load		
Spinning mode	30%	
Efficiency mode	3%	
Efficiency		
SC	48%	
CC	52%	
Ramp rate	>100%/min	
Regular start time	**Sync**	**Full**
SC	<3 min	<15 min
CC	<40 min	<60 min
Fast start time	**Sync**	**Full**
SC	<3 min	<10 min
CC	<30 min	<45 min
Ultra-fast start time	n/a	
Stop time	< 1 min	

Barrick and EGE Haina teamed up to build twin Flexicycle 50DF multi-fuel power plants in the Dominican Republic, providing efficient and reliable power to a new gold mine and the local community at once.

We can vary the dispatch to match the load without sacrificing efficiency or suffering maintenance impacts."

— Bernerd L. Grill , Commercial Mgr, Barrick

Quisqueya, Dom. Republic	
Customer	Barrick (Industrial) + EGE Haina (Utility)
Type	Flexicycle 50DF multi-fuel power plant
Operating mode	Flexible baseload
Gensets	12 + 12 x Wärtsilä 18V50DF
Total output	430 MW
Fuel	Natural gas & HFO
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2013

Floating power plants

Wärtsilä's floating power plants integrate our expertise in marine technology with the many benefits of flexible, decentralised power generation.

Floating power plants are based on tested components and system solutions. They are constructed cost-effectively and rapidly in a well-controlled industrial setting. When towed into place and connected to the grid, the plants are fully functional, providing a fail-safe option even in the remotest locations and under the most challenging ambient conditions.

Floating power plants can also provide a rapid answer to an increase in power demand in advance of new, land-based plants. Our turnkey solutions include site preparation and operation and maintenance services, according to customer needs. The lead time from contract to start-up of commercial operations is short, guaranteeing a quick return on investment.

Wärtsilä offers floating power plants based on any of the gensets reviewed previously in this catalogue.

Why a floating power plant?

- Provides fast supply of electricity to areas with limited infrastructure
- Is a mobile asset, possible to relocate or trade
- Does not require a large site
- Is not dependent of soil quality
- Provides secure power supply in the event of an earthquake or flood

Estrella del Mar II, Dom. Rep.	
Customer	Seaboard Corporation (IPP)
Type	Flexicycle 50DF multi-fuel floating power plant
Operating mode	Flexible baseload
Gensets	6 x Wärtsilä 18V50DF
Total output	106 MW
Fuel	Natural gas & HFO
Scope	EPC (Engineering, Procurement & Construction)
Delivered	2010

Combined heat and power & trigeneration

Combined heat and power (CHP) and trigeneration plants use fuel in the most efficient way and at the same time help to reduce carbon dioxide emissions. Total plant efficiencies can reach over 90% depending on the application. Wärtsilä's CHP plants can run on various liquid, gaseous and bio fuels, while maintaining low emissions and high efficiency.

Thanks to a hang-on heat recovery system, the plant will maintain the same high electrical efficiency and output, regardless of the heat production and ambient conditions. The products can be steam and hot or cold water.

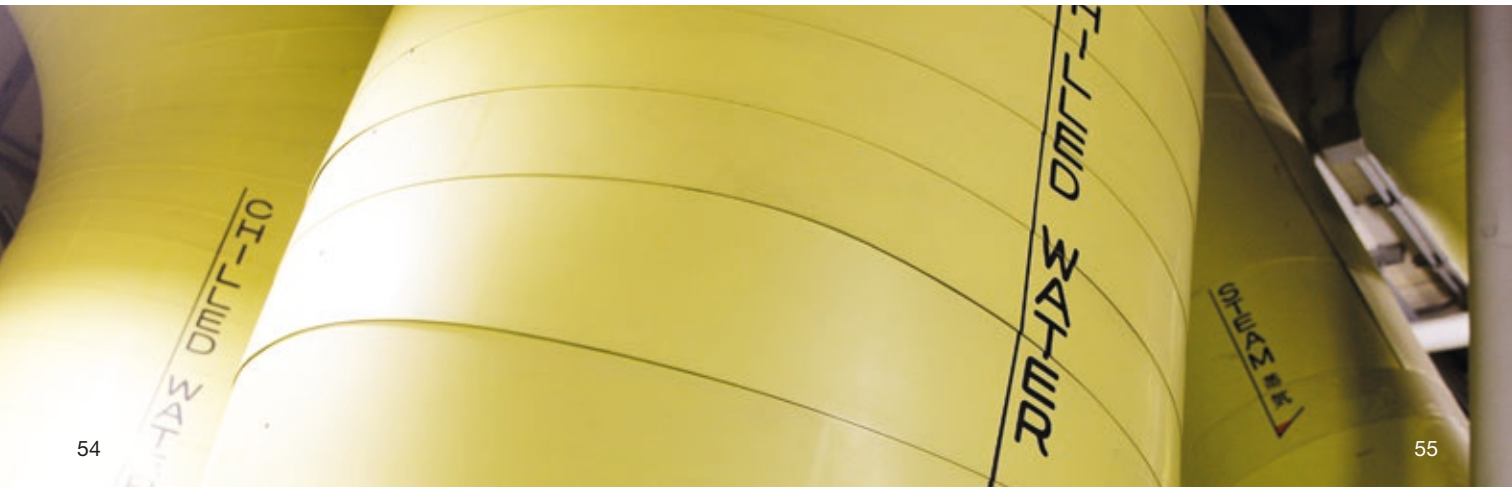
In trigeneration power plants, Wärtsilä can deliver three valuable products for the customer; electricity, heating and cooling - all this in just one power plant. This is possible without sacrificing the high reliability and superb flexibility of an ordinary Wärtsilä power plant.

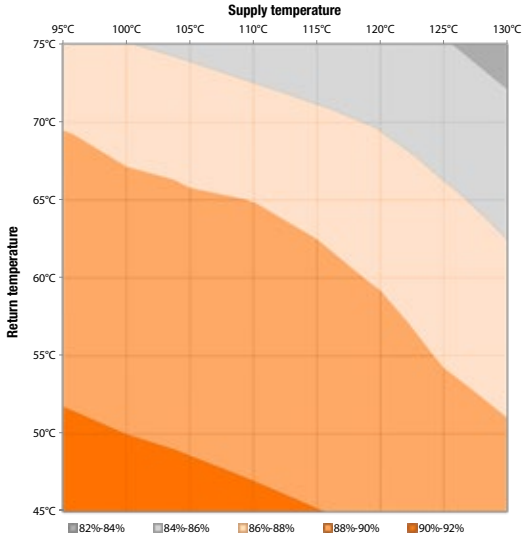
Wärtsilä offers CHP solutions to all customers with substantial heating demands such as utilities and municipalities. Also large facilities such as airports, shopping centers and other building complexes can utilize the Wärtsilä CHP and trigeneration solutions.

Wärtsilä offers CHP & trigeneration power plants based on any of the gensets reviewed previously in this catalogue.

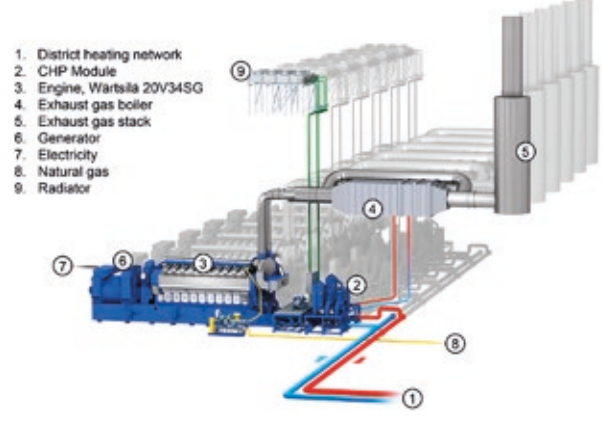
Benefits of Wärtsilä CHP solutions:

- An efficient plant with a high power-to-heat ratio enables more electricity production.
- Multiple units with fast start and ramp rates enable dynamic operation during low heat demand seasons at high efficiency.
- Good dynamic capabilities (multiple units) enable opportunities in ancillary services.
- CHP plants are optimized for maximizing the customer's profitability in any existing DH network.
- High efficiency and flexible operation over a wide load range.
- Dynamically able to respond to electricity price variations and to support intermittent, inflexible generation.
- Flexibility can be further improved with heat storage.
- Proven track record of more than 11 GW of installed Wärtsilä CHP plants.





Total attainable efficiency for a Wärtsilä CHP system depending on hot water supply and return temperatures.



Coupling of the hang-on CHP system, which enables the extremely high total efficiency of the plant without affecting its electrical output.

Cheon Soo, South Korea	
Customer	JB Enertek Co., Ltd (IPP)
Type	Wärtsilä 34SG gas trigeneration power plant
Operating mode	Flexible baseload
Gensets	2 x Wärtsilä 20V34SG & 1 x Wärtsilä 20V34SG
Total output	25 MWe + 21 MWth
Fuel	Natural gas
Scope	EEQ (Engineered Equipment Delivery)
Delivered	2010 & 2015

Besides building power plants, Wärtsilä has the capability to develop and plan the entire LNG/LEG/LPG/LBG fuel supply chain together with our customers and other gas consumers.

Wärtsilä can offer LNG infrastructure and power plant solutions in one EPC package. We also offer EPC for converting existing power plants to operate on natural gas as main fuel. Wärtsilä's dual-fuel technology helps to reduce LNG supply risk.

We help our customers to develop concepts along the fuel supply chain and supporting them with our broad experience in Project Development & Financing and Front End Work.

We are also utilizing Wärtsilä Marine Solutions' experience, knowhow and network when developing the LNG/LEG/LPG/LBG fuel supply chain. Thanks to this we can also plan and develop the shipping side of the fuel logistics.

For terminals and liquefaction projects we are able to provide the same full range of project and lifecycle support services, as we provide in the power plant deliveries. Scope of supply is flexible and the delivery method can be anything from engineering & equipment deliveries to full EPC turnkey contracts with guaranteed performance and delivery time.

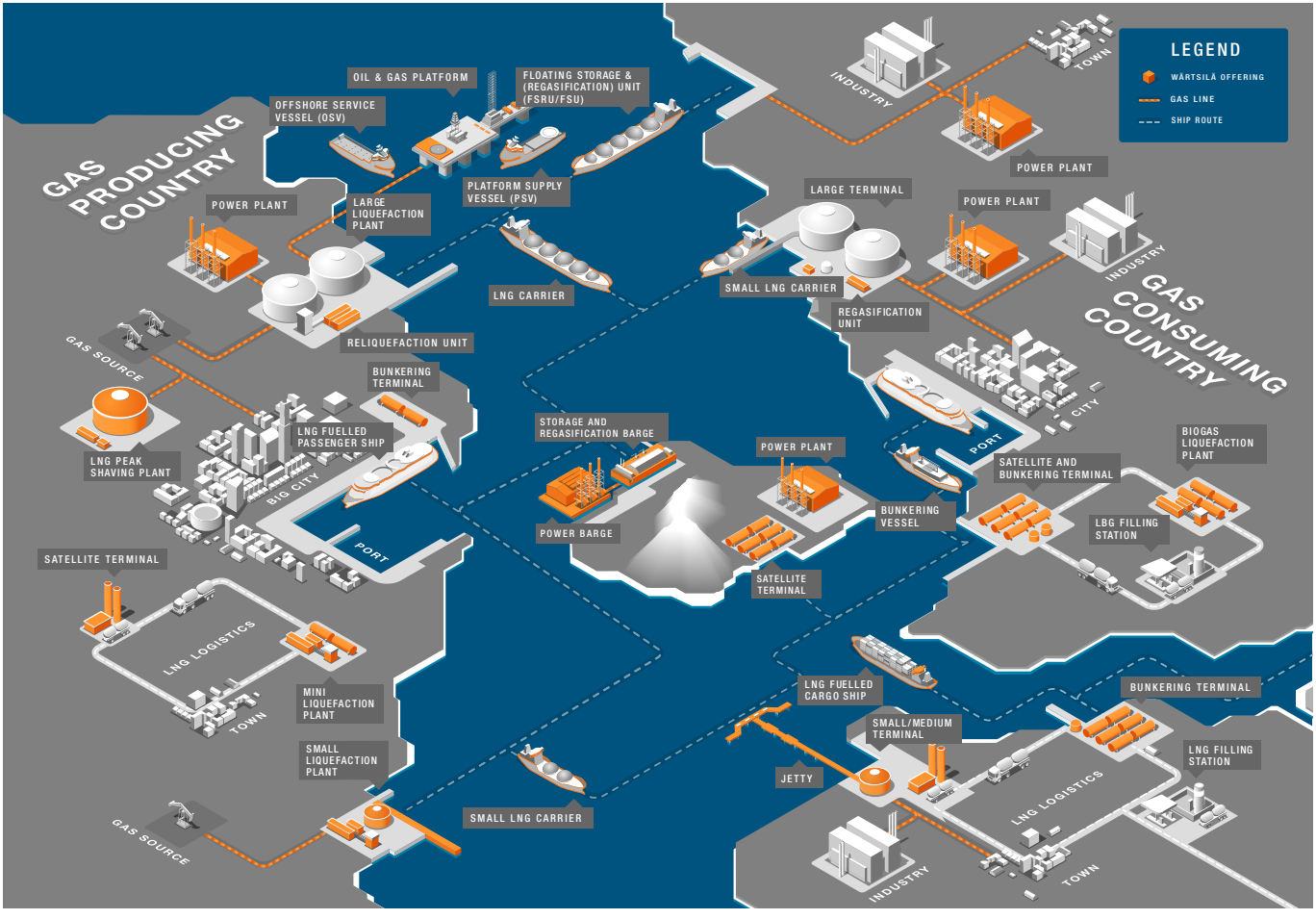
Regarding the lifecycle support we are capable to provide services to operate run & maintain the facilities during their entire lifetime.

Combining our project and lifecycle management capabilities with the gas processing knowledge and proven marine experience makes Wärtsilä the most valued business partner you can have when it comes to LNG solutions.

For more information please see separate LNG Solutions catalogue and wartsila.com.

Wärtsilä LNG value chain

With the introduction of small-scale LNG infrastructure, the LNG landscape changes radically. Small LNG carriers take natural gas to new places, enabled by small and medium-sized import terminals, satellite terminals and regasification units. Gas-fired power plants complement the picture. Wärtsilä's LNG technology builds to a great extent on the acquisition of the global engineering company Hamworthy in 2012. Combined with our existing offering for the marine and energy markets, Wärtsilä's LNG portfolio now includes solutions for almost every step along the LNG value chain.



MODULARITY

A module is a self-contained component of a system, which has a well-defined interface to the other components. Something is modular if it includes or uses modules, which can be interchanged as units without disassembly of the module. As energy demand grows, the high modularity of Wärtsilä's products makes it easy to expand a power plant to meet increasing future demand.

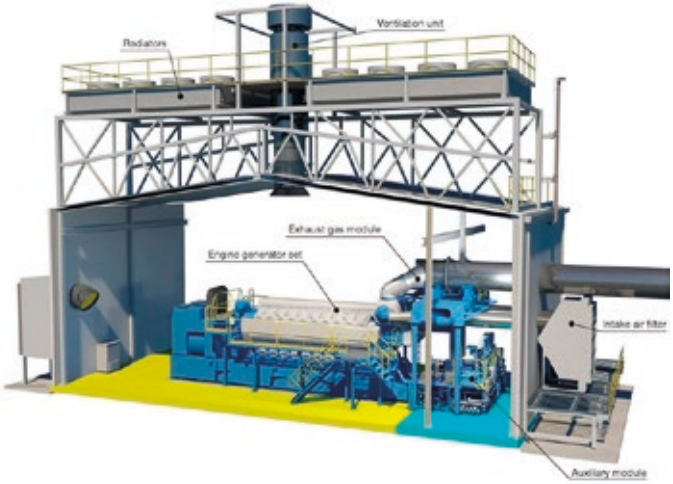
The common interfaces and flexibility of Wärtsilä's modular design, fulfilling a range of specifications and recommendations, addresses both the demand of today's customer and potential future needs. By using predefined modular solutions, Wärtsilä can ensure that set performance targets are reached.

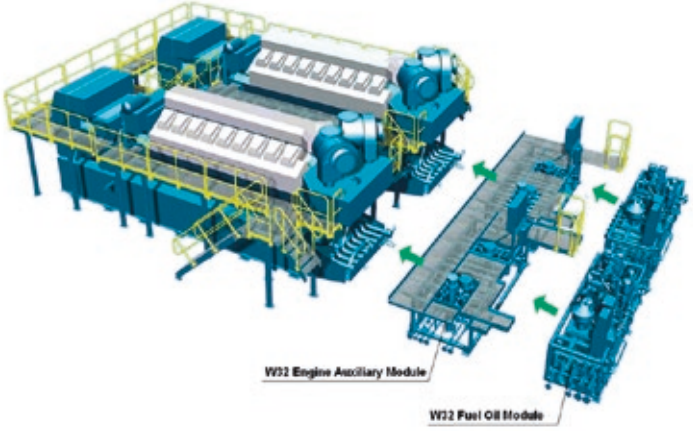
Rapid installation time is one of the main benefits. Prefabrication also ensures consistent high quality. Other benefits include the compact and predefined design for transportation, and the use of well-proven components from well-known suppliers. The use of portfolio modules leads to higher documentation quality during the tender phase.

When compared to carrying out such work on site, the controlled manufacturing, cleaning, and painting processes associated with modularisation, have a positive environmental impact. For our customers, modularised design means higher return of their power plant investment.

Some of the benefits of modularisation are:

- A **pre-designed solution** that can be customised to suit specific needs
- **Fast and easy installation** on site
- **Proven design**
- **Reliable and thorough** quality control
- **Optimised plant** layout
- **Standardised connection** interfaces
- **Optimised transport** dimensions
- **Serviceability**





ELECTRICAL & AUTOMATION

The Wärtsilä Power Plant Electrical and Automation concept provides a complete plant management solution with standardised modules, generators, switchgears and transformers, which can be tuned to the customers or utility requirements. Wärtsilä Power Plant Automation is based on the following building blocks. All these systems have been developed with complete integration, and have clear and easy user interfaces providing a uniform interface and logic for the operators.

- **WOIS** (Wärtsilä Operators Interface System) is the operator's workstation, for process displays, control actions, trends, alarm and event lists.
- **WISE** (Wärtsilä Information System Environment) is the workstation for reports, logbook, electronic documentation and 3rd party interfaces.
- **UNIC** is the engine embedded control system, handling all the control, monitoring and protection functions of the engine, together with the PLC.
- **PLC** based process control system handles all the control, monitoring and control functions of the genset and plant equipment.
- **Remote connection** provides a secure internet or satellite link, to give remote access to the information in the WOIS and WISE systems.

- Condition Based Maintenance (**CBM**) reporting system, is a subscriber-based condition evaluation and reporting system created by Wärtsilä experts.
- An optional **Archiving Station** enables a lifelong storage of the plant's operational data.

AUTOMATED OPERATION MODES

Operational flexibility is applied in the same package supporting either baseload, intermediate, peak load or stand-by power generation. Thanks to the intelligent controllers, the Wärtsilä solution provides:

- True MW control with embedded frequency support and power factor control for easy plant power management and import/ export control
- Isochronous load sharing of both active and reactive power for island mode operation support
- Droop mode as a backup and traditional operation mode.

All these operating modes are inbuilt and transfer between the modes is automatic and smooth.

EMISSIONS REDUCTION AND MONITORING

Wärtsilä Energy Solutions maintains a high level of expertise in emission cleaning methods for power plant effluents and stack emissions, in order to offer a variety of proven reduction technologies for different market needs.

Emissions reduction for gas power plants

Sulphur dioxide (SO_2) and particulate matter (PM) emissions are insignificant for power plants running on natural gas. Nitrogen oxide (NO_x) emissions are also low.

Dry methods (primary)
Wärtsilä gas engines use a lean-burn combustion process. In this process, natural gas and air are premixed in a low air/fuel ratio (lambda 2-2.5) before being fed into the cylinders. The lean-burn process efficiently reduces NO_x emissions due to a lower combustion temperature. Another advantage with the lean-burn process is the increased output and efficiency of the engine. Wärtsilä gas engines have sufficiently low NO_x emissions to comply with most national/local regulations using lean-burn primary method only.

Selective Catalytic Reduction (SCR)
In areas with more stringent control of NO_x emissions the engines can be equipped with SCR units. In the SCR, NO_x is reduced by a catalyst, combined with a reagent that is either an aqueous solution of urea or ammonia.

Oxidation catalysts
Gas (SG) engines and multi-fuel (DF) engines can be equipped with oxidation catalysts for the abatement of carbon monoxide (CO) and/or hydrocarbon (HC) emissions, if required by national regulations.

Wärtsilä IOXI
The Wärtsilä IOXI (Integrated Oxidation Catalyst) is a compact, cost efficient solution for moderate CO and formaldehyde (CH_2O) reduction from gas engines. Gas engines equipped with IOXI ensure compliance with most stack emission limits.

Humboldt, Eureka, California (10 x Wärtsilä 18V50DF, 162 MW)
The multi-fuel DF engines can operate on light fuel oil as back-up.
The plant is equipped with combined SCRs and oxidation catalysts and meets the strict Californian emission requirements both in gas and liquid fuel mode.

Combined SCR and oxidation catalyst
In some areas efficient multi-component emissions reduction is required. The combined catalyst system comprises SCR for NO_x emissions and oxidation catalyst for CO and/or HC emissions.

Emissions reduction for liquid fuel power plants

NO_x, SO_2 and particulate matter are the main emissions of interest regarding stationary liquid fuel engines. SO_2 and PM emissions are mainly related to the quality of the liquid fuel. Wärtsilä liquid fuel engines have low carbon monoxide (CO) and hydrocarbon (HC) emissions thanks to their high thermal efficiency.

Wärtsilä's liquid fuel power plants are designed to meet the stack emission limits set by the World Bank/IFC Guidelines for liquid fuel power plants up to 300 MWth (~140 MWe) in non-degraded airsheds by using dry primary methods. Secondary flue gas treatment methods are available for more strict regulations, or when only low grade liquid fuels are commercially available.

Dry methods (primary)
The primary method (Low NO_x combustion process) used in Wärtsilä liquid fuel engines is designed for the best overall emissions performance, while maintaining the good thermal efficiency of the engine. The main elements of the low NO_x combustion process are:

- Late fuel injection start
- High compression ratio
- Optimised combustion chamber and fuel injection rate profile
- Early inlet valve closing (Miller concept) together with high boost pressure.

These are the key elements for suppressing the combustion peak temperatures, resulting in reduced NO_x formation.

Selective Catalytic Reduction (SCR)
Wärtsilä's liquid fuel power plants can be equipped with SCR units to reduce NO_x emissions if required.

NO_x emissions are typically reduced by up to 80-90% by using a reagent that is either an aqueous solution of urea or ammonia. The composition and structure of the catalyst element are selected based on fuel properties. At high reduction rates, the size of the SCR reactor increases and more complicated premixing and reagent injection systems are needed. In addition the control system becomes very critical due to operation within a narrow window.

Flue Gas De-sulphurisation (FGD)
Several FGD types are available for the power plant market. The most feasible methods in stationary engine plants have generally been proven to be wet sodium hydroxide (NaOH) FGD in smaller plants, and wet calcium carbonate ($CaCO_3$) FGD in larger plants. Wet FGD systems are typically capable of removing up to 90% of the SO_2 emissions. All wet FGD solutions require large quantities of water and reagents.

The FGD end products, either liquid or solid depending on the chosen FGD technique, need to be disposed of in an environmentally acceptable way. The composition of the end product depends on the fuel oil used, lubrication oil, process water and reagents. The disposal and utilisation options available for the end product should be examined in the environmental assessment of the project.

Electrostatic Precipitator (ESP)
A dry ESP unit can be used to reduce PM emissions. The ESP technique provides a stable, low pressure-loss option to reduce PM emissions. ESP's dry end product, fly ash, needs to be disposed of in an environmentally acceptable way. The composition of the end product depends on the fuel and lubrication oil used. The disposal and utilisation options available for the end product should be examined in the environmental assessment of the project.

Continuous Emeissions Monitoring (CEMS)
In cases where continuous data on emission levels is required, indicative or parametric emissions monitoring systems will provide robust, good quality and cost efficient emissions monitoring. In these systems, emissions are calculated based on process data, such as engine parameters, fuel composition and ambient data. In some installations, continuous emissions monitoring systems (CEMS) based on analysers are required.

There are many different CEMS on the market and the choice of system needs to take into careful consideration the installation's specific features, such as measured components, fuel and stack configuration. The integration of emissions data handling and reporting into the plant system is a crucial part of a successful emissions monitoring system.

Reducing contaminated water
The oily water collection and treatment system is an essential part of the engine power plant. The system is designed to collect water from areas that are potentially contaminated with oil and other impurities for treatment. Before discharge from the plant, contaminated water can be either treated on-site by the Wärtsilä oily water treatment (OWT) unit or transported for proper treatment. In areas that are subject to stringent effluent limits, biological treatment might also be required. Wärtsilä Senitec Biosys is a biological treatment system for grey water, treated oily water and/or similar effluents from power plants.

WÄRTSILÄ DEVELOPMENT & FINANCIAL SERVICES

A global team of power plant project developers and finance professionals in Wärtsilä Development & Financial Services (WDFS) offers expert services to Wärtsilä's customers worldwide.

Financial Services

WDFS supports clients with advice and assistance in deal structuring and financing. Through its strong relationships with both local and international financing institutions, including export credit agencies (ECA), commercial banks and development banks, WDFS is well positioned to structure financing to suit each customer's requirements. A manufacturing presence in several countries provides a competitive advantage for accessing ECA guarantees and funding, especially through Finnvera (Finland) and SACE (Italy). WDFS also offers financial advisory services including financial modelling and feasibility studies.

Project Development

WDFS develops independent power producer (IPP) projects based on Wärtsilä ICE technology and know-how with a focus on environmentally responsible power projects with sound financing structures. With a proven track record since 1991, WDFS has successfully developed and closed over 30 highly feasible IPP projects (approx. 3500 MW) around the world. WDFS structures and negotiates project financing for IPP projects on a limited recourse or non-recourse basis. WDFS has over the years proven its ability to mobilize capital from multilateral and bilateral institutions, local and international commercial banks, and equity investors.

PROJECT MANAGEMENT SERVICES

Wärtsilä's Project Management organisation plans, leads, manages and executes projects for customers. We support our customers with cost estimates, scheduling and project planning.

The Project Management process at Wärtsilä Energy Solutions is based on the Project Management Institute's (PMI) standards, the PMBOK® Guide, ISO 21500, ISO 10005 and Wärtsilä best practise and experience.

Each project will be assigned a dedicated Project Management Team led by a Project Manager. The Project Manager is fully responsible for achieving the agreed objectives and requirements, and is empowered to represent Wärtsilä as EPC Contractor. Wärtsilä Project Management Teams have executed thousands of projects over the last three decades with acknowledged track record. More than 500 projects have been executed including infrastructures, civil works and building structures on EPC basis. The challenging project locations have varied from Siberian tundra to African rain forest, or from the Caribbean shores to Himalayan mountains. Our aim is not only to deliver the project on time, but work sustainably as well as enhance safety and offer the best possible working conditions both during construction and for the facility operators.

Capabilities

- Inter-disciplinary team of more than 200 Project Managers and Project Engineers with 100+ PMI certified professionals
- Project control and Planning team
- Certified HSE Management System OHSAS 18001 & ISO 14001. Lost Time Injury Frequency Rate ≈ 1.0 (EPC construction sites)
- Quality Management System ISO9001
- Efficient sourcing process and well managed supplier base
- Experienced construction management team of 400+ engineers

- Established network of partners, engineering, manpower etc.
- Sustainable construction strategy utilizing qualified subcontractors with positive local socioeconomic impact

Information Systems

- Project Portfolio Management (Clarity)
- Schedule Management (built on MS Project)
- Document Control Management (DCM365) to manage collaboration, submittals and interfaces between project stakeholders
- Digital Document Repository (IDM) for document management
- Project Quality Management Plan (PQMP) Configurator
- HSSE Incident Investigation and Reporting tool (WeCare)
- Management of Construction Site Information (Site 365)
- Commissioning Management (SQAD) to generate and configure projects' Quality Assurance / Control Documentation
- Project Logistics and Material Management (LOGWIS)

Wärtsilä offers the following options of scope of supply & contract types:

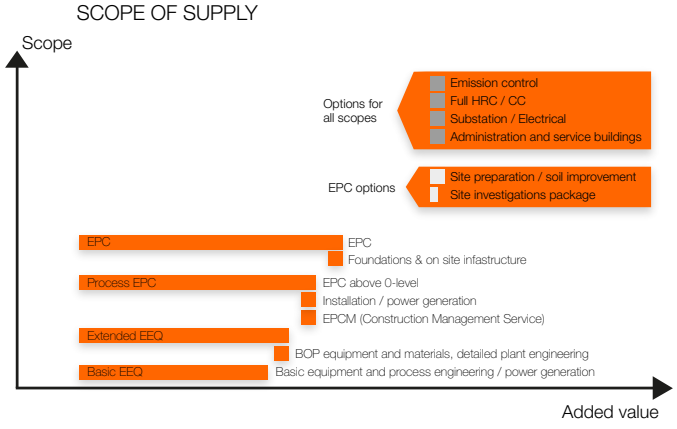
Basic EEQ *(Basic Engineered Equipment Delivery)* is the most basic service where only the main equipment and related auxiliaries are engineered and supplied. The service includes configuration and engineering for supplied equipment and materials, transport, and technical advisory for installation and commissioning.

Extended EEQ *(Extended Engineered Equipment Delivery)* is a complete supply solution for defined scope including detailed engineering for total solutions, all materials and equipment plus technical advisory services for installation and commissioning. The customer needs to hire a contractor to perform installation and civil works on site.

EPCM *(Engineering, Procurement, Construction & Management)* is a service contract adding Construction Management services to the scope. It includes construction and site management, project and construction scheduling, sub-contracting, site supervision and documentation services for site works and subcontracts. It includes assistance to customers in local work, monitoring and reporting on the performance of subcontractors. This service contract is made in connection with extended EEQ contracts.

EPC *(Engineering, Procurement & Construction)* is a solution where the customer has only one point of contact, thereby minimising their risks. The contract covers project management, site management and supervision, engineering, materials and equipment, civil works, foundation and site infrastructure works, transport and installation, and commissioning, as well as schedule and performance guarantees for the entire solution.

Process EPC includes the same features as EPC, but installation is only done above floor level. Subsoil and foundation works, underground materials supply and site works are performed or subcontracted by the customer.



Project management value proposition

Speed

- ✓ Pre-fabricated product minimizing site work
- ✓ Global network of proven partners and suppliers
- ✓ Fast Track concept
- ✓ Earlier access to market

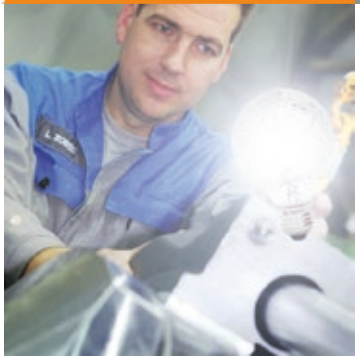
Predictability

- ✓ 25 years of EPC construction experience in 90 countries
- ✓ Quality assured, Professional Project Management
- ✓ Experienced personnel and partners
- ✓ Access to all Wärtsilä experts and resources
- ✓ Risk mitigation

Customer

Collaboration

- ✓ Early involvement enables proactive and collaborative project approach
- ✓ Listening to Customer needs
- ✓ Open communication
- ✓ Customer Relation On-Line process CROL®



Scope flexibility

- ✓ Clear and managed contractual interfaces
- ✓ Reduced project complexity
- ✓ Optimal scope of supply through several scope packages

POWER PLANT LIFECYCLE

Optimising your operations and preventing the unexpected is our shared passion – we serve you whenever, wherever.

Wärtsilä serves and supports customers in improving and optimising their operational efficiency throughout the whole lifecycle of the installation. Our Services organisation currently features more than 11,000 dedicated professionals in almost 70 countries.

Our Services solutions cover everything from comprehensive customised long-term service agreements to product support with parts, field service and technical support, performance optimisation including upgrades and conversions, environmental solutions, training, and online support.

With more than 13 GW of power plants under long term service agreement, Wärtsilä is recognised by customers as their preferred service supplier in ensuring the availability and cost-efficient operation of their installations. They benefit from having their entire power system fully serviced by one global supplier.

On the basis of our experience in operating and maintaining more than 500 marine and land-based installations located in almost 70 different countries, and through the know-how and support of Wärtsilä's worldwide organisation, a Wärtsilä service agreement has become established as a proven and reliable instrument for both parties.

Wärtsilä adds value to your business at every stage in the lifecycle of your installations. With us as your service partner, you receive many measurable and guaranteed benefits, such as availability and performance, productivity gains and cost benefits. Above all, you have peace of mind in the knowledge that your installation is being serviced by the most experienced partner you could have.

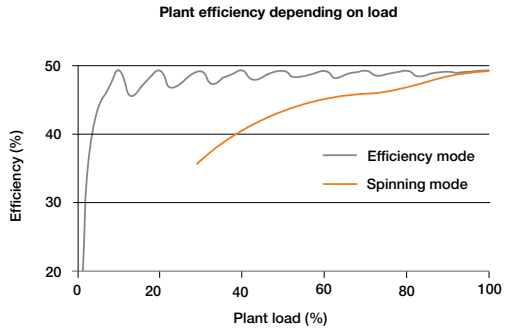
Operation of a multi-unit power plant

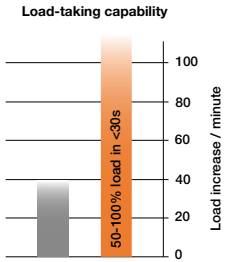
There are often significant seasonal, weekly and daily variations in power demand. In a multi-unit power plant the units can be started and stopped as per demand. It is possible to optimise the usage of each single unit by choosing to either provide spinning reserve or to run it flat-out to obtain maximum efficiency.

A multi-unit power plant can be run in various ways dependent on the situation at hand. Basically, there are two main operating principles:

In **spinning mode**, the gensets are synchronized and running, but at a reduced load. This way the plant is fully ready to take large, immediate load increases just in seconds.

In **efficiency mode**, the minimum amount of gensets are running at full load to meet the current load demand, thereby allowing them to operate at their best thermal efficiency. Still, the remaining gensets, which are in stand-by mode, can come online and reach full load in a matter of a few minutes to meet any unforeseen load increases.





Plant features in the two different operation modes

Internal combustion engine maintenance

Maintenance of gas, dual-fuel and liquid fuel engines is easy. Keeping strategic spare parts for exchange purposes on site considerably reduces the downtime required for maintenance. All maintenance can be effectively performed on site. One engine at a time can be maintained, without affecting the operation of the other units of the plant.

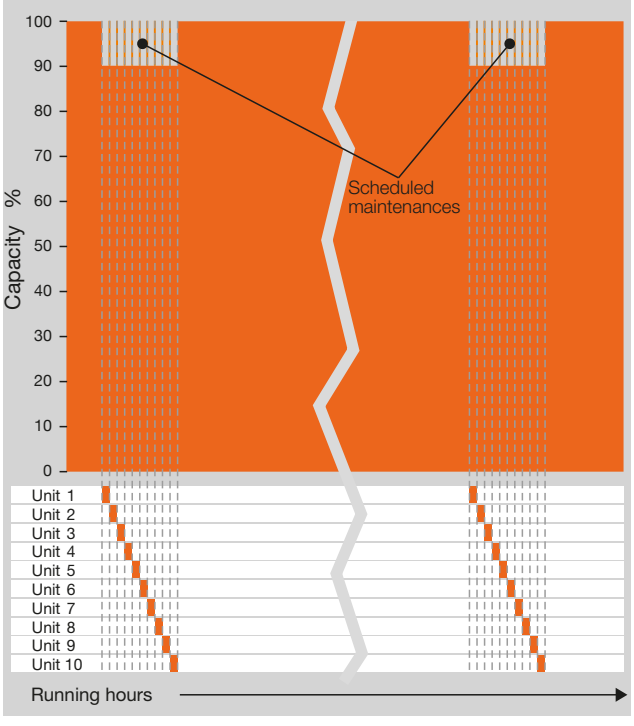
The multi-unit setup means that the annual average unit running hours, depending on the actual load profile, can be considerably lower than the annual plant running hours. In a multi-unit plant the units can be dispatched, so that the running hours are unequally spread on each unit. This allows for scheduling the maintenance one unit at a time, thereby maximising the available power generation capacity at any given time. Ideally, the maintenance is scheduled for periods of lower power demand.

For Wärtsilä's internal combustion engines (ICEs) there is no equivalent operating hours (EOH) calculation. This means that the maintenance schedule is not affected by the number of starts and stops.

Maintenance scheduling

Thanks to condition-based, flexible maintenance, engine servicing can be performed when it best suits the customer´s operations. The figure below illustrates the scheduling principle of maintaining one engine at a time in a Wärsilä power plant.

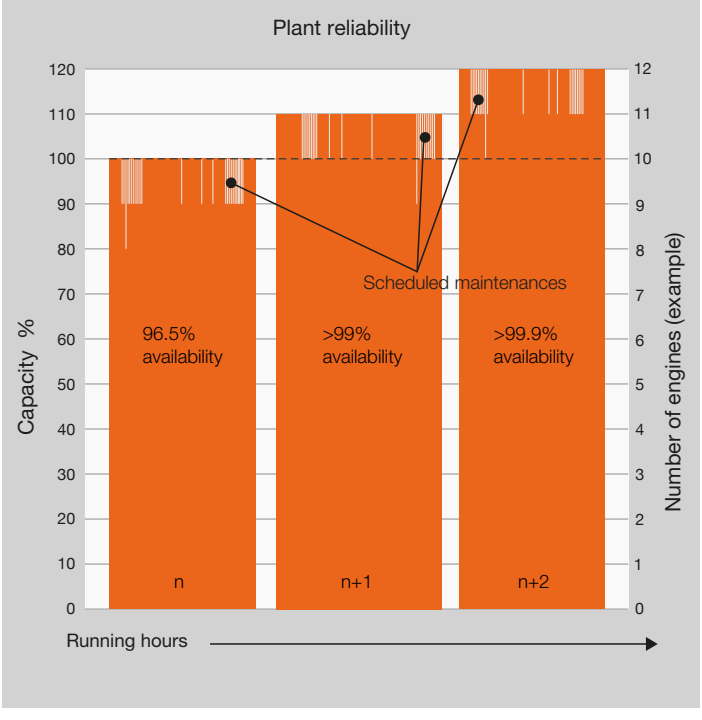
- Maximum firm capacity due to sequential maintenance of one unit at a time
- High reliability and unsensitiveness to unscheduled maintenance outages thanks to multiple units



Reliability & availability

Thanks to the multi-unit configuration, the highest availability and reliability targets can be achieved.

The below figure illustrates the typical operational availability of a Wärtsilä power plant. If the plant capacity matches the actual maximum load (corresponding to the power generated by *n* units), the availability of the plant capacity is above 96.5%. By adding a stand-by unit, the availability can be increased to >99%, and a second stand-by unit further raises the availability to >99.9%.



Approved fuels

Wärtsilä power plants are able to run on a wide selection of fuels, ranging from natural gas to fuel-water emulsions. Detailed specifications for the approved fuels are available upon request.

Gaseous fuels & LNG

Natural gas
Natural gas consists mainly of methane plus small quantities of heavier hydrocarbons, carbon dioxide and nitrogen. Commercial gas is processed to meet specifications for heating value, Wobbe index and cleanliness.

Liquefied natural gas (LNG)
LNG is natural gas that has been converted to liquid form for easier transport and storage. LNG takes up about 1/600th of the volume of natural gas in gaseous state.

Coal bed natural gas
Coal bed natural gas is found in underground coal layers. It contains methane, water and carbon dioxide in varying proportions. Coal bed gas contains more heavier hydrocarbons than conventional natural gas, but no natural gas condensate.

Shale gas
Shale gas is natural gas trapped in fine-grained sedimentary rock, particularly quartz and calcite. Together with coal bed gas and methane hydrates, shale gas is an unconventional source of natural gas.

Biogas
Biogas is the result of treating organic matter in digesters or through other decomposing processes. The resulting gas consists mainly of methane and carbon dioxide.

Associated gas
Associated gas is separated from crude oil in field degassing equipment. The methane content is lower than in natural gas, but the concentration of heavier hydrocarbons is higher, normally yielding a higher energy density. GD engines are very suitable for burning associated gas, also when operating in fuel sharing mode.

Liquefied petroleum gas (LPG)
Liquefied petroleum gases, also referred to as simply propane or butane, are flammable mixtures of hydrocarbon gases. LPG, vaporised at atmospheric pressure, has a higher calorific value (94 MJ/m^3 equivalent to 26.1 kWh/m^3) than natural gas (methane) (38 MJ/m^3 equivalent to 10.6 kWh/m^3).

Gas					Liquid				
	Natural gas (/LNG)	Biogas	LPG (>97% propane)	Associated gas	Crude	LFO/diesel	Liquid biofuel	HFO	Fuel-water emulsion
Density (kg/m3)	0.7-0.8	~ 0.8	1.3-1.4	1.3-2.5	835-1002	810-900	~ 910 - 930	920-1010	1005 @30% water
Viscosity (cSt)	N/A	N/A	N/A	N/A	2-70@50°C	~ 2 -11@40°C	~ 26@50°C	100 - 700@50°C	350-450@50°C
Wärtsilä 34SG	●	●	●						
Wärtsilä 50SG	●	●							
Wärtsilä 34DF	●	●				●	●	●	
Wärtsilä 50DF	●	●				●	●	●	
Wärtsilä 32GD	●	●		●	●	●	●	●	●
Wärtsilä 46GD	●	●		●	●	●	●	●	●
Wärtsilä 32/32TS					●	●	●	●	●
Wärtsilä 46					●	●	●	●	●
Wärtsilä 50					●	●	●	●	●

Liquid fuels

Light fuel oil
Light fuel oils or diesel oils are high value distillates that have traditionally been used to fuel diesel engine power plants, both for stand-by operation and baseload applications. Light fuel oil is typically used in backup power plants and installations in islands or arctic conditions where cheaper alternatives are not available.

Heavy fuel oil
Heavy fuel oils are blended products based on the residues from refinery distillation and cracking processes. They are black viscous liquids which require heating for storage and combustion. Heavy fuel oils are used for diesel engines in power plant and marine applications.

Crude oil
Crude oil is a highly complex mixture of hydrocarbons and other components. The flash point of crude oil is low, typically below the ambient temperature. Crude oil can also be used as fuel in power plants with diesel engines, for example in oilfield power production. Another application is for pumping stations located along a crude oil pipeline, where fuel from the pipeline can be used for the prime movers.

Liquid biofuels
Liquid biofuels are derived from biological material and can be produced from a variety of carbon sources. Common liquid biofuels approved for use in Wärtsilä engines include oils from various oilseeds, such as palm oil, palm stearin, rape seed oil, sunflower oil and jatropha oil. Liquid biofuels can also be of non vegetable origin, i.e. oils or fats from fish, poultry and animals. Refined biofuel qualities, such as transesterified biodiesel or hydrogenated renewable diesel, can also be used.

Fuel-water emulsions
An oil-in-water type emulsion is one way of utilising the residue coming from a refinery as fuel in a diesel power plant. By making an emulsion with water the viscosity is dramatically reduced, enabling it to be pumped at ambient temperature in warm countries. Using it in the diesel engine requires only a fraction of the heating needed for heavy fuel oil.

Gas					Liquid				
	Natural gas (/LNG)	Biogas	LPG (>97% propane)	Associated gas	Crude	LFO/diesel	Liquid biofuel	HFO	Fuel-water emulsion
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Wärtsilä 50SG	●	●							
Wärtsilä 34DF	●	●				●	●	●	
Wärtsilä 50DF	●	●				●	●	●	
Wärtsilä 32GD	●	●		●	●	●	●	●	●
Wärtsilä 46GD	●	●		●	●	●	●	●	●
Wärtsilä 32/32TS					●	●	●	●	●
Wärtsilä 46					●	●	●	●	●
Wärtsilä 50					●	●	●	●	●

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Power plant gensets

The core of a power plant solution is the genset. Wärtsilä gensets consist of a four-stroke medium-speed engine, connected to a generator via a flywheel and coupling, mounted on a common baseframe. The genset is aligned, fine-tuned and pre-tested in the factory, fully ready for installation with minimal work at site.

Small and medium sized gensets (based on Wärtsilä 32/32TS/32GD/34DF/34SG) are normally transported as complete gensets. If required by the logistics of the project, the gensets can also be delivered split into two blocks: engines mounted on the baseframe and generators shipped separately.

Larger gensets (based on Wärtsilä 46/46GD/50DF/50SG engines) are normally delivered in two blocks: engine and generator mounted on its own base frames, ready to be bolted together at site. This allows a considerably reduced transportation weight.

Fuel	Engine (speed, 50/60 Hz)	Cylinder configuration	Power, electrical (kW, 50Hz)	Power, electrical (kW, 60Hz)	Genset dry weight (tonne), ±5%	Reduced transport weight (tonne), ±5%
Gas	Wärtsilä 50SG (500/514 rpm)	18V50SG	18440	18880	365	210
		9L34SG	4380	4190	77	-
	Wärtsilä 34SG (750/720 rpm)	16V34SG	7840	7510	120	73
		20V34SG	9810	9400	130	85
Multi-fuel	Wärtsilä 50DF (500/514 rpm)	18V50DF	16740	17220	369	215
		9L34DF	4380	4190	79	-
	Wärtsilä 34DF (750/720 rpm)	16V34DF	7840	7510	120	50
		20V34DF	9810	9400	134	65
	Wärtsilä 46GD (500/514 rpm)	12V46GD	11430	11430	272	209
		18V46GD	17150	17150	370	298
	Wärtsilä 32GD (750/720 rpm)	6L32GD	2670	2600	58	-
		9L32GD	4030	3920	79	-
		12V32GD	5380	5240	93	-
		16V32GD	7200	7030	120	-
		20V32GD	9000	8790	131	-
Liquid fuel	Wärtsilä 50 (500/514 rpm)	18V50	18440	18880	369	297
	Wärtsilä 46 (500/514 rpm)	12V46	11430	11430	269	207
		18V46	17190	17220	368	296
	Wärtsilä 32 (750/720 rpm)	6L32	2900	2780	53	33
		9L32	4390	4190	78	-
		12V32	5840	5590	92	-
		16V32	7840	7510	117	-
		18V32	8810	8460	128	-
		20V32	9810	9420	130	-
	Wärtsilä 32TS (750/720 rpm)	20V32TS	10200	9790	151	-

Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. By emphasising technological innovation and total efficiency, Wärtsilä maximizes the environmental and economic performance of the vessels and power plants of its customers.

In 2015, Wärtsilä's net sales totalled EUR 5.0 billion with approximately 18,900 employees. The company has operations in more than 200 locations in nearly 70 countries around the world. Wärtsilä is listed on the Nasdaq Helsinki.

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