WÄRTSILÄ

# ENERGY SOLUTIONS

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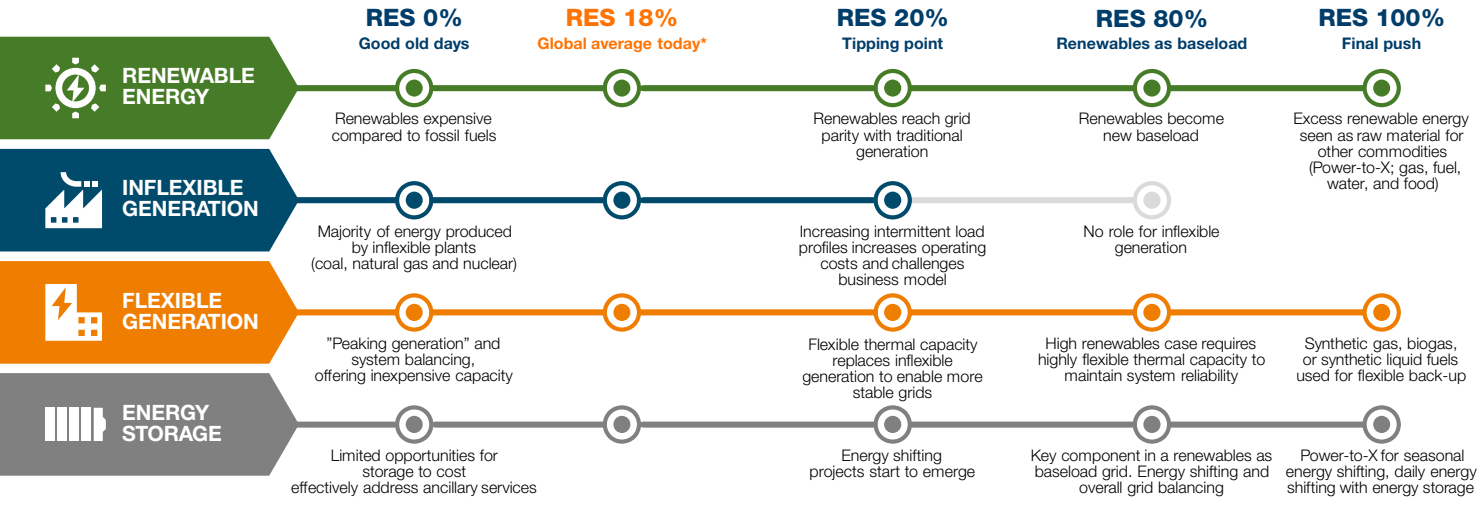
# Towards a 100% renewable energy future

The energy landscape is in transition towards more flexible and sustainable energy systems. Global progress towards achieving a 100% renewable energy future is being made at an incredibly rapid pace. Power providers, utilities and governments are changing their perspectives towards inflexible generation and existing inflexible thermal capacity, like coal and nuclear power plants, is being replaced with renewables. This phased transformation requires considerable changes in infrastructure, innovation and investments in technology.

Today, 18% of all energy production globally comes from renewable energy sources. As renewables are becoming more competitive even without subsidies, flexible solutions, like engine power plants, have begun to replace inflexible power generation to enable more stable grids.

Ever increasing share of renewables will require highly flexible thermal capacity to maintain system reliability. Energy storage will also become a key component in the baseload grid to maintain overall grid balance. The knowledge and technology for creating the optimal path to a 100% renewable energy future according to your unique needs already exists.




RES = global production capacity of renewable energy sources (wind and solar)

* BNEF New Energy Outlook, 2019

## Energy system optimisation

The journey towards a 100% renewable energy future is different for every continent, every country and every city – each has their own individual path. Wärtsilä understands, designs, builds and serves optimal flexible power systems – while helping secure a clean environment for future generations.

### Understand

We understand the evolving energy market and recognise **value-based opportunities** for our customers in the utility and industrial market

### Design & Build

As a leading **EPC** and **lifecycle service** partner, we support our customers with engine power plants, gas-to-power solutions, hybridised solar PV, energy storage and optimisation.

### Serve

We provide a comprehensive understanding of energy systems, including **fully integrated assets** and advanced software complementing value adding **lifecycle services** for our customers.

## Wärtsilä solutions for a 100% renewable energy future

In the future, wind and solar power will become the backbone of the power system, while engine power plants and energy storage will be increasingly used for system balancing and back-up. Flexible power generation solutions provide the required operational flexibility and enable a transition towards a future powered by 100% renewable energy sources.

Understanding the role of different technologies, and putting our customer's assets together through software, full EPC offerings and global service capabilities allow us to, together with our customer, create an optimal path towards a 100% renewable energy future.

## Tucson Electric Power, Arizona, USA

**Large investor-owned utilities are investing in smart power generation together with energy storage**

Wärtsilä was selected to provide a **future-proof and flexible** natural gas power plant with up to 200 MW of capacity

Greensmith Energy provided 10 MW/2.5 MWh **energy storage system** to Tucson Electric Power in 2016

- Improved overall **efficiency** of the plant reduced **emissions** of nitrogen oxides by approximately 66% → about 350 tons annually
- Engines require **minimal amount** of **water** for cooling
- Ability to respond quickly and reliably to the variable production of **renewable resources**

## AGL Energy Limited, Australia

**The first utility-scale reciprocating engine power plant in Australia's national electricity market**

Wärtsilä delivered a 211 MW future-proof and flexible power plant to AGL

AGL is planning to **replace Liddell coal plant** with renewables and additional 750 MW of flexible gas capacity

- Flexibility of our power plants is a **key enabler** for utilities in an electricity market with high share of renewable energy
- Flexibility is rewarded in the National Electricity Market, which drives **investment in flexible gas as well as in energy storage**
- The new power plant will improve the **reliability and security** of supply in South Australia

## Operational flexibility

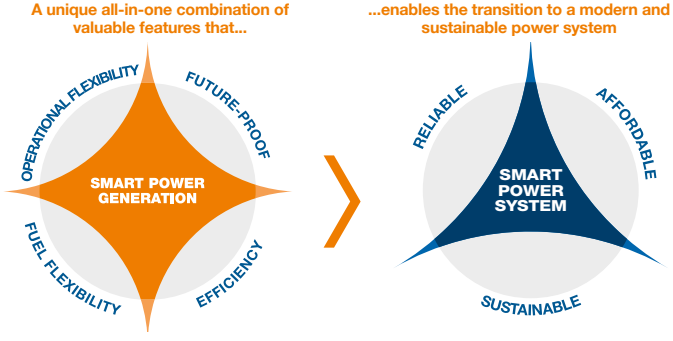
Being able to operate in multiple modes, from efficient baseload power production to dynamic system balancing in combination with, for example, wind or solar power, Wärtsilä engine power plants become a key factor in optimising power systems.

They offer fast, low-emission, non-spinning grid reserve for any contingency situation or grid black start. They can generate megawatts to the grid in less than 30 seconds from start-up and reach full load in less than two minutes. They are designed to start and stop – at the push of a button – time after time without any impact on maintenance.

The multi-unit configuration allows plant availability and reliability of close to 100%, as well as the 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 engine power plants are also easy to locate next to critical load pockets, i.e. in cities, thanks to plant size as well as low emission and noice 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.

**Smart Power Generation technology enables transition to a sustainable power system**




Smart power generation enables existing power system to operate at maximum efficiency as well as large scale renewables integration by effectively absorbing current and future system load variations – leading to dramatic savings.

## Energy efficiency

Power plants based on multiple engine generating set 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 power plants enable the continuous choice of the most feasible fuel, including solutions for liquid and gaseous fuels as well as synthetic and traditional biofuels. The possibilities gained from multi-fuel plants and fuel conversion solutions represent a hedge for the future. The fuel flexibility of the engine improves energy security and increases resilience against unpredictable interruptions to the fuel supply. Should a reliable supply of gas become available following e.g. installation of the Wärtsilä 31DF, the engine can be easily converted to pure-gas operation because of its modular design.

Our customer can start operating with liquid fuels they have access to, like diesel, and then transfer to gas when that becomes available, or even leap directly to renewable fuels—the Power-to-X.

Power-to-X technology is going to play a key part in the future of energy generation – from power-to-gas solutions, where electricity is used to split water into hydrogen and oxygen through electrolysis, to solutions where hydrogen from an electrolyser is combined with carbon dioxide and the two gases are converted into synthetic renewable methane, as well as other potential power-to-fuel solutions that can be developed to create synthetic fuel.

Up until now, renewable energy generation has been driven by weather, but renewable energy can also come from a range of other processes where any kind of excess is created, and – perhaps most crucially – from those that generate excess carbon in the form of emissions.

'Power-to-X' is an umbrella term for a number of different emerging technology solutions for electricity conversion, energy storage, and energy reconversion, all of which use surplus power in one form or another.

## Future-proof

The rapid growth of affordable and clean renewable power sources like wind and solar has brought in uncertainty for utilities on betting on the right technology to reach the decarbonisation targets. The features of an internal combustion engine allow flexible power generation that is needed to optimise the power system. With our technology, you can run your plant on baseload or balancing without compromising efficiency.

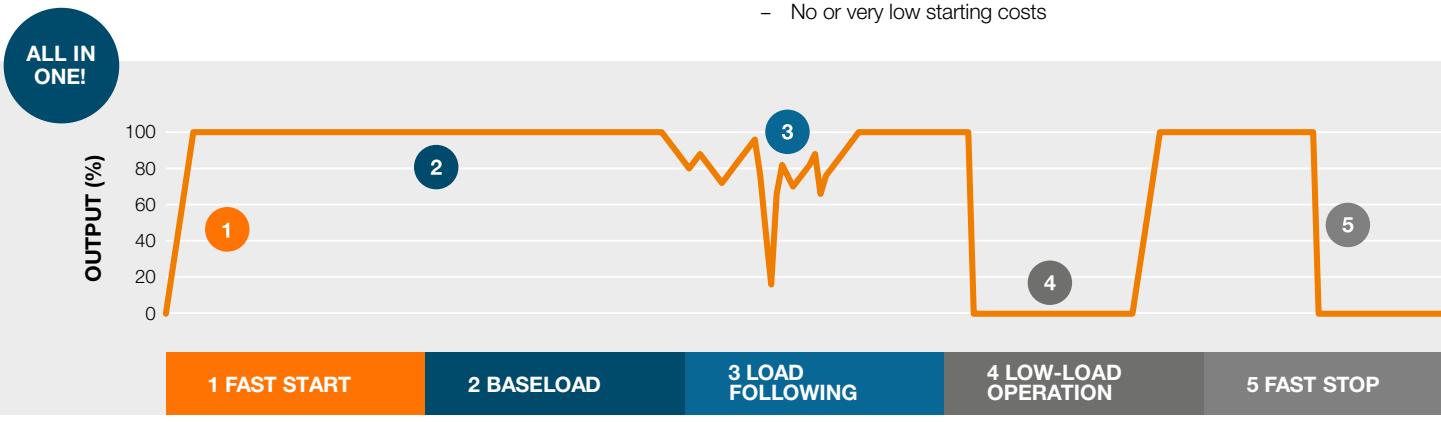
System level flexibility benefits:

- the absorption of maximum amount of renewables
- lowers emissions
- increases reliability
- becomes more affordable
- improves energy security

The modular design enables easy fuel conversions between pure gas, multi-fuel and pure liquid fuel variants, and can also be adapted to run on renewable fuels. It is ideally suited for customers looking to gradually transition to gas-powered operations, especially in geographic locations where pipeline gas or LNG deliveries are not yet available or sufficiently secured. You can truly improve your energy security and plant adaptability with our fuel-flexible engines. That's what we call future-proof.

## Future power system balancer

- Operates in pulses, every day
- Thousands of fast starts and stops yearly
- Medium capacity factors (10...40%)
- Modular design allows transformation to future needs
- Typical characteristics
  - Fast starting & stopping (less than 5 minutes)
  - No or very low starting costs
  - Lowest possible heat rate
  - Multiple units for better flexibility in operation
  - Optimises the power system as a whole.
  - Versatile tool for grid stability
  - Facilitates large scale renewables integration




| 1 FAST START | 2 BASELOAD | 3 LOAD FOLLOWING | 4 LOW-LOAD OPERATION | 5 FAST STOP |
|---|---|---|---|---|
| **VALUE**<br>• Grid stability support<br>• Ancillary Service market | **VALUE**<br>• Competitive lifecycle generation cost<br>• Any output, same generation cost | **VALUE**<br>• Wind and solar balancing<br>• Ancillary Service market | **VALUE**<br>• "Low load" = No load<br>• Not running when no revenue | **VALUE**<br>• Not running when no revenue<br>• PV enabler |
| **FEATURES**<br>• Power to grid in 30 sec<br>• 2-5 min to full power<br>• Start-up efficiency | **FEATURES**<br>• Highest simple cycle efficiency<br>• Multi unit → high firm capacity<br>• Flexicycle™ | **FEATURES**<br>• Part load efficiency unaffected<br>• No equivalent operating hours (EOH) for cycling | **FEATURES**<br>• 1 min shutdown<br>• No minimum down time<br>• Zero fuel cost<br>• Zero emissions | **FEATURES**<br>• 1 min shutdown<br>• No minimum up time<br>• No EOH calculation |

## Future-proof power plant solutions

To meet the ever-tightening emission requirements, conversion to natural gas is a viable alternative for power plant operators. Wärtsilä engines are future-proof and flexible, thus ideally suited for customers looking to gradually transition to gas-powered operations. Our engines can be easily adapted to using gas as a primary fuel, helping to cut operational costs and exhaust gas emissions while increasing fuel flexibility. Transition from diesel to gas as a primary fuel is but the first step; ultimately the switch is to synthetic renewable fuels. Gas conversion is often considered to be a key feature in future-proofing one's power plant, as it enables transition to synthetic fuels at a later date. It is also likely to promote the addition of more renewables into the system.

The conversion concept follows the same principles as those of a new Wärtsilä gas power plant built to the latest design and engineering standards. We manage all phases, from feasibility studies, financing solutions, solution proposals, execution planning and implementation, to a full EPC solution.

Project Delimara in Malta is such an example, where the power plant owner decided to turn a plant running on HFO into a natural gas-powered solution

### Customer benefits

- Optimised OPEX
- Fuel flexibility
- Reduced environmental footprint
- Increased flexibility in plant operations

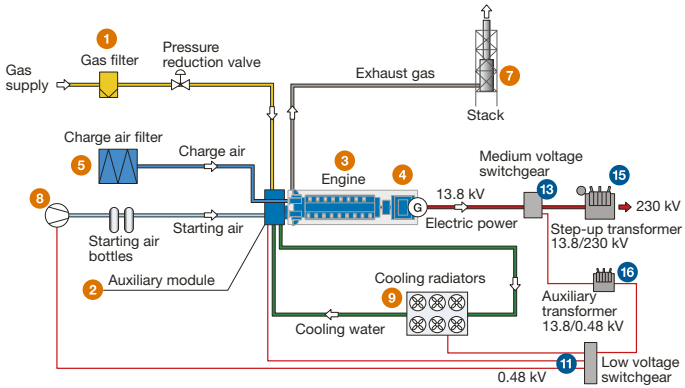
| THE CHALLENGE | SOLUTION | RESULTS |
|---|---|---|
| • Reducing the electricity production costs<br>• Reducing the emission levels<br>• A tight time schedule | • Gas conversion of eight Wärtsilä 18V46HFO engines to four Wärtsilä 18V50DF and four Wärtsilä 18V50SG including a UNIC C3 engine control system. | • Reduced operating and maintenance costs<br>• Reduced emission levels (in compliance with EU regulations) |

## Delimara, Malta

**We are very happy to be working with Wärtsilä on this gas conversion of Delimara 3 power plant. This project is Shanghai Electric Power's first step into Europe, and we look forward to a long and fruitful co-operation with Wärtsilä. Wärtsilä's team members' professionalism and customer-oriented spirit are truly impressive. Our power plant will benefit from a lower heat rate for the engines, increased efficiency, higher power output capacity, and lower emissions. This means reduced operational costs and lower emissions.**

*Tan Qing*
*Project Manager*
*Shanghai Electric Power (Malta) Ltd.*

# Typical flexible power plant




**Mechanical components**

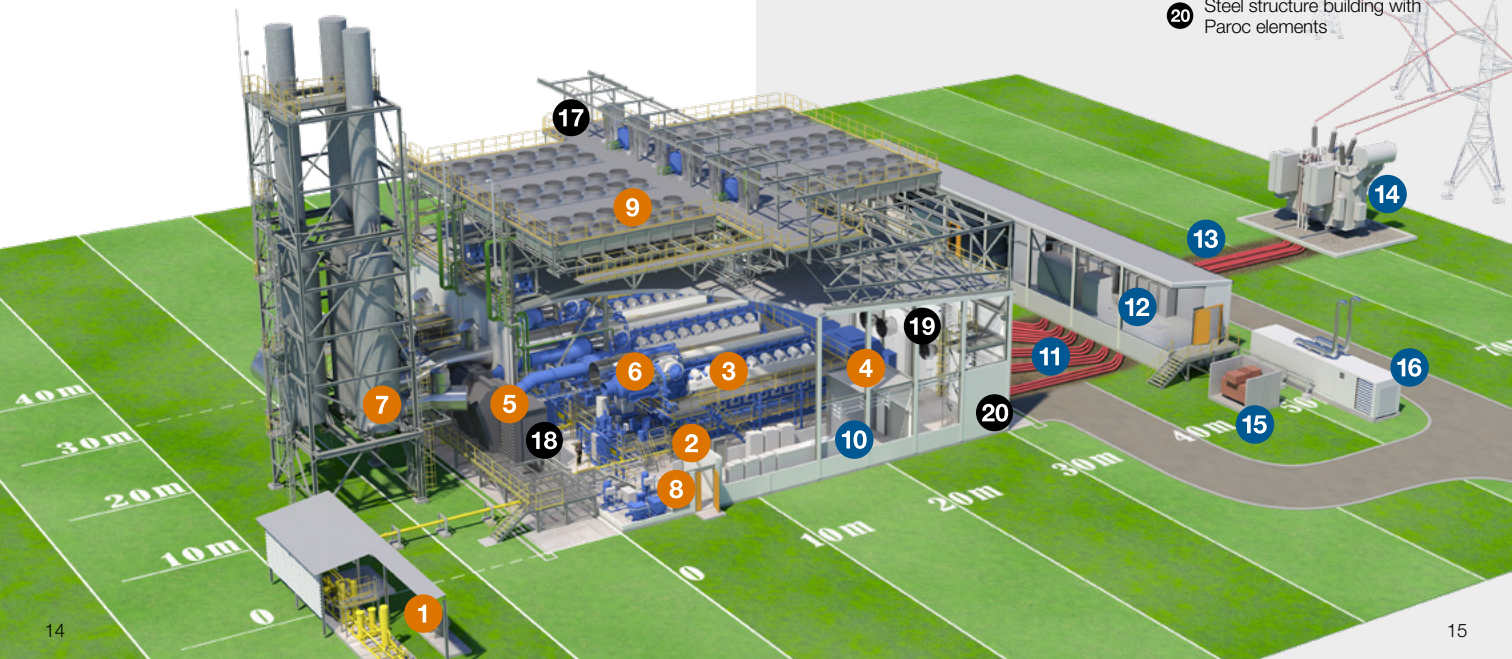
1. Natural gas inlet (filtration & pressure reduction station)
2. Auxillary module
3. Engine W18V50SG
4. Generator
5. Intake air filter
6. Exhaust gas module
7. Exhaust gas silencer
8. Starting air unit
9. Radiator

**Electrical components**

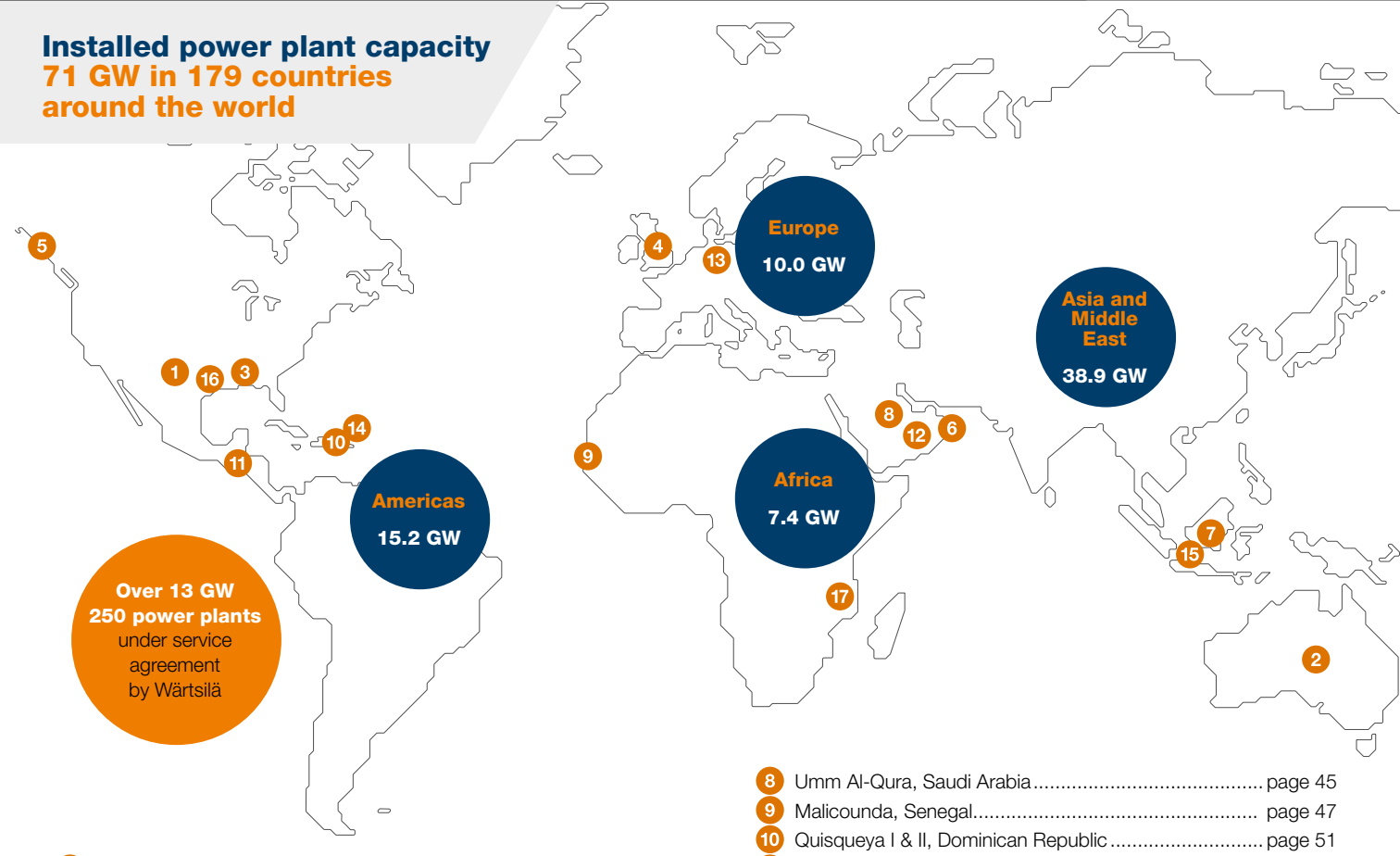
10. LV switchgear
11. Generator cables
12. MV switchgear
13. MV outgoing cables
14. Step-up transformer
15. Auxiliary trasformer
16. Black starting unit

**Auxiliary equipment**

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



## Installed power plant capacity
## 71 GW in 179 countries around the world

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6 Musandam IPP, Oman ..... page 37
7 PLTD Pesanggaran, Bali, Indonesia ..... page 39
8 Umm Al-Qura, Saudi Arabia ..... page 45
9 Malicounda, Senegal ..... page 47
10 Quisqueya I & II, Dominican Republic ..... page 51
11 Huinala, Mexico ..... page 53
12 Yamama Cement, Saudi Arabia ..... page 55
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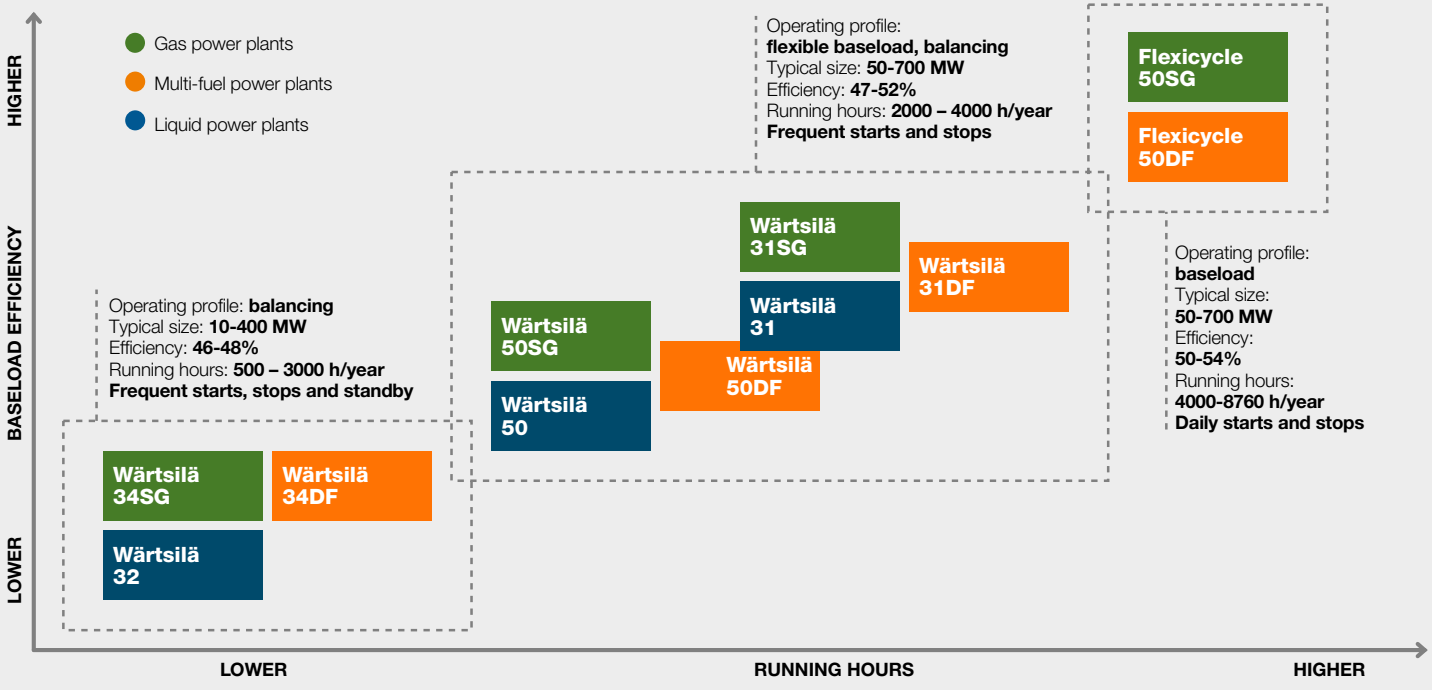
14 Estrella del Mar II, Dominican Republic ..... page 61
15 Bontang, Indonesia ..... page 63
16 Denton Municipal Electric, Texas, USA ..... page 77
17 KivuWatt, Rwanda ..... page 95

# A future-proof, flexible power plant solution for every need



## Flexible 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 3X family engines) 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 50 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 weight (tonne) |
|---|---|---|---|---|---|
| Gas | Wärtsilä 31SG (750/720 rpm) | 12V31SG | 7034 | 6779 | 127 |
| | | 16V31SG | 9403 | 9075 | 150 |
| | | 20V31SG | 11779 | 11377 | 182 |
| | Wärtsilä 34SG (750/720 rpm) | 12V34SG | 5840 | 5580 | 102 |
| | | 16V34SG | 7830 | 7491 | 125 |
| | | 20V34SG | 9795 | 9388 | 136 |
| | Wärtsilä 34SG-LPG (750/720 rpm) | 12V34SG-LPG | 4 380 | 4 185 | 102 |
| | | 16V34SG-LPG | 5 873 | 5 618 | 125 |
| | | 20V34SG-LPG | 7 346 | 7 041 | 136 |
| | Wärtsilä 50SG (500/514 rpm) | 18V50SG | 18434 | 18875 | 377 |
| Multi-fuel | Wärtsilä 31DF (750/720 rpm) | 12V31DF | 7034 | 6779 | 127 |
| | | 16v31DF | 9403 | 9075 | 150 |
| | | 20V31DF | 11779 | 11377 | 182 |
| | Wärtsilä 34DF (750/720 rpm) | 9L34DF | 4372 | 4181 | 82 |
| | | 12V34DF | 5840 | 5580 | 99 |
| | | 16V34DF | 7830 | 7491 | 130 |
| | | 20V34DF | 9795 | 9388 | 141 |
| | Wärtsilä 50DF (500/514 rpm) | 18V50DF | 17635 | 18190 | 377 |
| Liquid fuel | Wärtsilä 31 (750/720 rpm) | 12V31 | 7034 | 6779 | 127 |
| | | 16V31 | 9403 | 9075 | 150 |
| | | 20V31 | 11779 | 11377 | 182 |
| | Wärtsilä 32 (750/720 rpm) | 9L32 | 4374 | 4180 | 83 |
| | | 12V32 | 5840 | 5580 | 92 |
| | | 16V32 | 7819 | 7481 | 117 |
| | | 20V32 | 9795 | 9388 | 130 |
| | Wärtsilä 32TS (750/720 rpm) | 20V32TS | 10189 | 9781 | 151 |
| | Wärtsilä 50 (500/514 rpm) | 18V50 | 18434 | 18875 | 377 |

## Key figures

The key figures are used in tables describing the features of various power plant types, starting on page 24.

### 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 unit or plant level load that can be maintained for extended periods of time.
Lowest plant level load assuming a plant with 10 units with 1 unit in operation and 9 units in stand-by.

### Efficiency (%)
Approximate efficiency at generator without pumps based on ISO 3046 conditions and 5% tolerances.

### Ramp rate (%/min)
Percentage of the total load that the plant can increase in a minute (with an already running engine) 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.

### Stop time (min)
Time it takes to decrease output from 100% to 0%, disconnect from grid.

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.

# Gas power plants

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 footprint, making it the optimal solution for locations where minimising the environmental impact is a priority. As such, they can be placed close to consumption nodes, optimising the power system.

Wärtsilä gas power plants can run on natural gas, liquefied natural gas, liquefied petroleum gas 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.
- Low 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 31SG gas power plant

The highest available open-cycle efficiency as well as unparalleled dynamic capabilities. The Wärtsilä 31SG gas engine with an outstanding efficiency enables a reduced environmental footprint and a lower total cost of ownership.

**Suitable for:** Flexible baseload, balancing

## 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. It also gives extremely fast response to emergency situations, and is able to supply megawatts in a matter of seconds.

**Suitable for:** Flexible baseload, balancing, standby & emergency

## Wärtsilä 50SG gas power plant

High efficiency in a small footprint combined with high reliability and flexibility makes this solution perfect for flexible baseload applications including daily starts and stops.

**Suitable for:** Flexible baseload

## Wärtsilä 31SG gas power plant

The Wärtsilä 31SG gas engine generating set offers both the highest available open-cycle efficiency as well as unparalleled dynamic capabilities. The Wärtsilä 31SG's outstanding efficiency enables a reduced environmental footprint and a lower total cost of ownership. Specifically designed for flexible power generation, this generating set is a tool allowing for the integration of high levels of energy from renewable sources. It creates a balancing link between power generation and consumption, thus providing effective system level resilience.

The Wärtsilä 31SG is typically installed in medium sized de-centralised power plants having multi-engine configurations to provide a plant net load of from 20 to 200 MW.

- The highest simple-cycle efficiency.
- Fast start-ups, load changes and shutdowns allow the flexibility needed to balance renewable penetration.
- Full power achieved with a variety of gaseous fuels, without impacting the operation.
- The modular design of the W31 engine family enables easy conversions between pure gas, multi-fuel and liquid fuel variants, and can be adapted to run on renewable fuels.

### Key figures

| | | |
|---|---|---|
| **Plant output** | 20-200 MW | |
| **Configuration** | 2-18 x 20V31SG | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency** | 52% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 1 min | Full < 5 min |
| **Fast start time** | Sync < 0:30 min/sec | Full < 2 min |
| **Stop time** | < 1 min | |

## Benndale, Mississippi, USA

| | |
|---|---|
| Customer | Cooperative Energy (utility) |
| Type | Wärtsilä 31SG gas power plant |
| Operating mode | Grid support, renewable integration |
| Gensets | 2 x Wärtsilä 20V31SG |
| Total output | 22 MW |
| Fuel | Natural gas |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | Wärtsilä Optimised maintenance for ten years |
| Delivery | 2019 |

**There is a lot of variable generation in our market, such as our 52 MW solar plant. We need to match variable generation with more flexible capacity which can rapidly start up when needed. Wärtsilä's generation units meet this need. The Wärtsilä 31SG engines are top-of-the-line.**

*Jim Compton,*
*CEO of Cooperative Energy*

## 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 flexible baseload, wind and solar balancing, peaking and reserve power applications. This plant makes the most out of the cleanest fossil fuel available - natural gas.

- Always ready to deliver power to the grid instantly and efficiently in any operating profile.
- Fast start capability provides megawatts to the grid in 30 seconds and full plant output in 2 minutes.
- Supporting the grid with a variety of ancillary services.
- The flexibility of a hydro plant in a gas-fired plant.
- Able to provide grid blackstart capability and re-energise a grid even with low gas pressure.
- Best up– and down– ramp rates in the industry.
- Full power can be achieved with a variety of gaseous fuels, without affecting the operation.
- Genset is easily transported in one piece to challenging locations.

### Key figures

| | | |
|---|---|---|
| **Plant output** | 10-400 MW | |
| **Configuration** | 1-40 x 20V34SG | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency** | 48% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 1 min | Full < 5 min |
| **Fast start time** | Sync < 0:30 min/sec | Full < 2 min |
| **Stop time** | < 1 min | |

## Centrica, UK

| | |
|---|---|
| Customer | Centrica (utility) |
| Type | Wärtsilä 34SG gas power plant |
| Operating mode | Fast reserve and balancing markets |
| Gensets | 2 x 5 Wärtsilä 20V34SG |
| Total output | 2 x 50 MW |
| Fuel | Natural gas |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | Wärtsilä optimised maintenance solution for six years, with a three-year extension option |
| Delivery | 2018 |

**The under two-minute start up time is a rare feature and very important to the UK grid.**

*Mark Futyan,*
*Distributed Power Systems Director,*
*Centrica Business Solutions*

## 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.

- 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** | 3-38 x 18V50SG | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency** | 50% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 2 min | Full < 10 min |
| **Fast start time** | Sync < 1 min | Full < 5 min |
| **Stop time** | < 1 min | |

## Port Westward Unit 2, Oregon, USA

| | |
|---|---|
| Customer | Portland General Electric (utility) |
| Type | Wärtsilä 50SG gas power plant |
| Operating mode | Peak load/stand-by & emergency |
| Gensets | 12 x Wärtsilä 18V50SG |
| Total output | 224 MW |
| Fuel | Natural gas |
| Scope | Engineered equipment delivery (EEQ) |
| Delivery | 2014 |

**This flexibility allows us to adjust quickly when wind and solar energy rise and fall with natural variability.**

*Rick Tetzloff,*
*Project Director,*
*Portland General Electric*

# Multi-fuel power plants

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, liquified natural gas (LNG), biogas. Insensitive to gas quality.
- Liquid fuel only
  - Crude oil, diesel, residual oil (HFO), fuel-water emulsions, liquid biofuel
  - Switching seamlessly between liquid and gaseous fuels

Kiisa, Estonia

**Wärtsilä 31DF multi-fuel power plant**

Provides energy security through fuel flexibility, switching seamlessly between liquid and gaseous fuels, increasing resilience in times of unpredictable fuel supply.

**Suitable for:** Flexible baseload, balancing

## 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. 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:** Flexible baseload, balancing, standby & emergency

## Wärtsilä 50DF multi-fuel power plant

High efficiency in a small footprint combined with high reliability and flexibility. Can operate equally well on gas, heavy fuel oil (HFO) and liquid fuel oil (LFO); and switch between them on the run.

**Suitable for:** Flexible baseload

## Wärtsilä 31DF multi-fuel power plant

The world-class efficiency of Wärtsilä 31DF reduces your fuel consumption, environmental footprint and costs – all while providing the fast-start capabilities to provide the flexibility you need to integrate increased levels of renewables into your power system.

The Wärtsilä 31DF engine power plant solution provides.

- Energy security through fuel flexibility.
- Switches seamlessly between liquid and gaseous fuels.
- Increases resilience in times of unpredictable fuel supply.
- Additionally, the modular design of the power plant means you're prepared for using renewable fuels, Power-to-X.

### Key figures

| | | |
|---|---|---|
| **Plant output** | 10-400 MW | |
| **Configuration** | 1-37 x 20V31DF | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency**<br>**Gas**<br>**Liquid fuel** | <br>49%<br>48% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 1 min | Full < 5 min |
| **Fast start time** | Sync < 0:30 min/sec | Full < 2 min |
| **Stop time** | < 1 min | |

**With its reduced environmental footprint and operational flexibility, the introduction of the Wärtsilä 31DF engine for energy markets marks a further step towards the realisation of Wärtsilä's vision for a 100% renewable energy future.**

*Anders Smeds,*
*Product Manager,*
*W3X Power Plants at Wärtsilä*

## Wärtsilä 34DF multi-fuel power plant

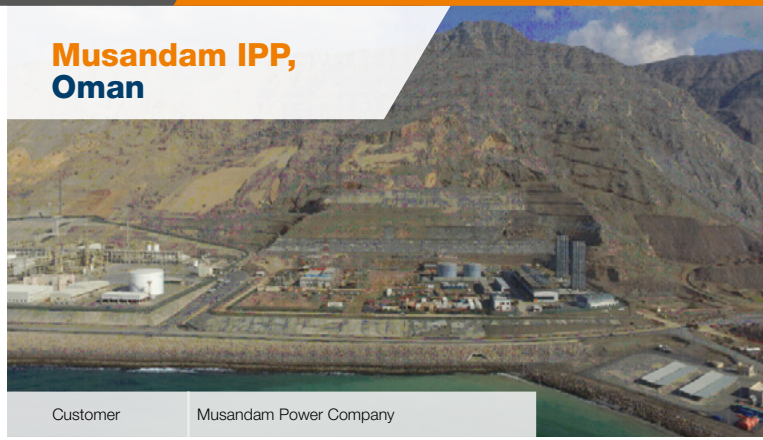
The most flexible power plant in all aspects, always ready to deliver power to the grid instantly and efficiently, on any fuel. Multi-fuel operation with full agility and flexibility combined with high efficiency over the whole load range and in any operating profile makes these plants excellent for both flexible baseload and peak load, and supporting the grid with a variety of ancillary services.

- Fast start capability provides megawatts to the grid in seconds and full plant output in 5 minutes.
- Able to provide non-spinning secondary reserve thanks to a 30-second fast sync time.
- Highest efficiency in pulse load (short-time on-off and part-load) operation.
- Able to provide grid blackstart capability and re-energise a grid on diesel or low-pressure gas.
- 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** | 1-40 x 20V34DF | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency**<br>**Gas**<br>**Liquid fuel** | <br>48%<br>46% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 1 min | Full < 10 min |
| **Fast start time** | Sync < 0:30 min/sec | Full < 5 min |
| **Stop time** | < 1 min | |

## Musandam IPP, Oman



| | |
|---|---|
| Customer | Musandam 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 | Engineering, procurement & construction (EPC) |
| Lifecycle solution | Wärtsilä Operations & Maintenance solution for five years and Wärtsilä Optimised maintenance solution for 15 years |
| Delivered | 2016 |

**This plant is a central part of the major integrated development of the Musandam Governorate. The project will play a significant role in meeting the power needs of the region's current and upcoming industries, while at the same time benefiting the local community.**

*Salim Al Hashmi,*
*Project Director,*
*Musandam Power Company*

## 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.

- 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** | 3-40 x 18V50DF | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency**<br>**Gas**<br>**Liquid fuel** | <br>49%<br>47% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 3 min | Full < 15 min |
| **Fast start time** | Sync < 3 min (gas) / 1 min (liquid) | Full < 10 min |
| **Stop time** | < 1 min | |

## PLTD Pesanggaran Bali, Indonesia

| | |
|---|---|
| Customer | PT Indonesia Power (utility) |
| Type | Wärtsilä 50DF multi-fuel power plant |
| Operating mode | Flexible baseload |
| Gensets | 12 x Wärtsilä 18V50DF |
| Total output | 200 MW |
| Fuel | Natural gas & HFO |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | Wärtsilä Optimised maintenance solution and Spare parts supply agreement for five years |
| Delivery | 2015 |

**Thanks to its superior operation and fuel flexibility, the addition of the PLTD Pesanggaran 200 MW plant to the grid has helped us improving significantly the reliability of electricity supply to Bali in an economical way.**

*Mr Igan Subawa Putra,*
*General Manager,*
*Indonesia Power, Pesanggaran Bali*

# Liquid fuel power plants

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 HFO, LFO, crude oil, emulsified fuels or liquid biofuels.
- Great dispatch ability supplies megawatts to grid within seconds, and reach full plant load in minutes.
- Utilising HFO in the most efficient way possible.

## Wärtsilä 31 liquid fuel power plant

Power plants based on the high-efficiency Wärtsilä 31 diesel engines are suitable for locations where gas is not available yet. The modular design of this solution supports future fuel conversions for gaseous fuels.

**Suitable for:** Flexible baseload, balancing

## Wärtsilä 32 liquid fuel power plant

Agile and flexible, this plant delivers fastest power in the whole market with high efficiency, even in the most challenging ambient and operational conditions. This plant is based on the Wärtsilä 32 genset with more than 100 million cumulative running hours.

**Suitable for:** Flexible baseload, balancing, standby & emergency

## Wärtsilä 50 liquid fuel power plant

High efficiency combined with high reliability and flexibility. This plant is 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:** Flexible baseload

Betano, Timor-Leste

## Wärtsilä 31 liquid fuel power plants

Power plants based on the high-efficiency Wärtsilä 31 diesel engines are suitable for locations where gas is not available yet. The modular design of this solution supports future fuel conversions for gaseous fuels.

### Key figures

| | | |
|---|---|---|
| **Plant output** | 50-400 MW | |
| **Configuration** | 3-36 x 20V31 | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency** | 49% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 1 min | Full < 5 min |
| **Fast start time** | Sync < 0:30 min/sec | Full < 2 min |
| **Stop time** | < 1 min | |

## 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 for supporting the grid with a variety of ancillary services.

- Fast start capability provides megawatts to the grid in seconds and full plant output in less than 2 minutes.
- Able to provide non-spinning secondary reserve thanks to a fast sync time.
- Able to provide grid blackstart capability and re-energise a grid.
- Extremely low standby consumption, < 1 kW per MW of installed power.
- 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
- Peaker application: the W32 engine running on light fuel oil can be configured to utilise increased output for peaking purposes.

### Key figures

| | | |
|---|---|---|
| **Plant output** | 50-200 MW | |
| **Configuration** | 3-24 x 20V32TS | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency** | 47% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 1:30 min | Full < 5 min |
| **Fast start time** | Sync < 0:30 min | Full < 2 min |
| **Stop time** | < 1 min | |

## Umm Al-Qura, Saudi Arabia

| | |
|---|---|
| Customer | Umm Al-Qura Cement Company (Industrial) |
| Type | Wärtsilä 32 liquid fuel power plant |
| Operating mode | Baseload |
| Gensets | 5 x Wärtsilä 20V32TS |
| Total output | 47 MW |
| Fuel | Heavy fuel oil |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | Wärtsilä Operation & maintenance solution |
| Delivery | 2009 |

**Our cement factory is dependent on reliable and efficient power. Wärtsilä 32TS engines give extremely high power output also during the hot summer periods where the temperature can rise above 50°C.**

*Mr. Fawaz Al-Mutairi,*
*General Manager*

## Wärtsilä 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 18V50 | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency** | 48% | |
| **Ramp rate** | >100%/min | |
| **Regular start time** | Sync < 2 min | Full < 10 min |
| **Fast start time** | Sync < 1 min | Full < 5 min |
| **Stop time** | < 1 min | |

## Malicounda, Senegal

| | |
|---|---|
| Customer | Matelec Group |
| Type | Wärtsilä 50 based Flexicycle™ power plant |
| Operating mode | Baseload power production for the national grid |
| Gensets | 7 x Wärtsilä 18V50 |
| Total output | 130 MW |
| Fuel | HFO (option to convert to gas when available) |
| Scope | Engineered equipment delivery (EEQ) |
| Lifecycle solution | 10-year maintenance agreement |
| Delivery | 2020 |

**”We needed a reliable and qualified partner to engineer and provide a flexible and reliable energy system now, and later as our energy infrastructure evolves. With its global and Pan-African experience, Wärtsilä fully meets the project requirements. This is a major energy project that is very important for Senegal.”**

*Sami Soughayar,*
*CEO, Matelec Group*

## Wärtsilä Flexicycle™

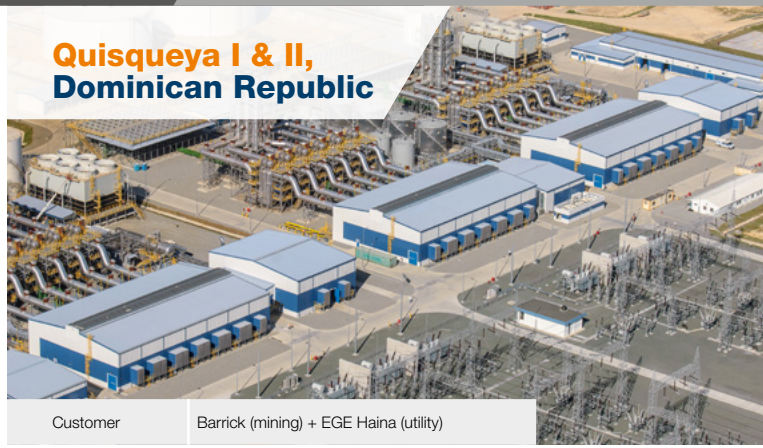
Flexicycle™ is an innovative concept by Wärtsilä, which combines the excellent dynamic capabilities of internal combustion engines with the superb efficiency offered by combined cycle solutions.

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, the total efficiency can be improved significantly by 3-4 percent units. The plant can switch between single or combined cycle modes upon request, acquiring the best composition of both.

When the steam cycle is equipped with a 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 limited resource. With 2.5 GW delivered to this day, Flexicycle represents the ultimate solution for flexible baseload plants, in either its gas-fired or multi-fuel configuration. One configuration, two switchable operational modes, and the advantages of both single and combined cycle enable excellent flexibility and unmatchable efficiency.

Wärtsilä's Flexicycle solution with radiators or air cooled condenser (ACC) is often the right choice for arid areas. Thanks to the closed-loop cooling system, water consumption is close to zero.

## Quisqueya I & II, Dominican Republic



| | |
|---|---|
| Customer | Barrick (mining) + EGE Haina (utility) |
| Type | Wärtsilä 50DF Flexicycle multi-fuel power plant |
| Operating mode | Flexible baseload |
| Gensets | 12 + 12 x Wärtsilä 18V50DF |
| Total output | 430 MW |
| Fuel | Natural gas, HFO |
| Scope | Engineering, procurement & construction (EPC) |
| Delivery | 2013 |

**Since we need to match the generation to the mine's load, the advantage of Wärtsilä's power plant is that we can vary the dispatch to match the load without sacrificing efficiency or suffering maintenance impacts.**

*Bernerd L. Grill,*
*Commercial Manager,*
*Barrick Gold Mine*

## 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 18V50SG + steam turbine | |
| **Minimum load** | | |
| **Unit level** | 10% | |
| **Plant level** | 1% | |
| **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 |
| **Stop time** | < 1 min | |

## 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 | 140 MW |
| Fuel | Natural gas |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | Wärtsilä Operations & Maintenance solution for 10 years |
| Delivered | 2016 |

**We chose engine technology for reliability and efficiency.**

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

## 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** | 50-700 MW | |
| **Configuration** | 3-36 x 18V50DF + steam turbine | |
| **Minimum load**<br>**Unit level**<br>**Plant level** | <br>10%<br>1% | |
| **Efficiency**<br>**SC**<br>**CC** | <br>48%<br>52% | |
| **Ramp rate** | >100%/min | |
| **Regular start time**<br>**SC**<br>**CC** | Sync<br>< 3 min<br>< 40 min | Full<br>< 15 min<br>< 60 min |
| **Fast start time**<br>**SC**<br>**CC** | Sync<br>< 3 min<br>< 30 min | Full<br>< 10 min<br>< 45 min |
| **Stop time** | < 1 min | |

## Yamama Cement, Saudi Arabia

| | |
|---|---|
| Customer | Yamama Cement Company (Industrial) |
| Type | Wärtsilä 50DF Flexicycle power plant |
| Operating mode | Baseload |
| Gensets | 10 x Wärtsilä 18V50DF |
| Total output | 161 MW |
| Fuel | Natural gas & LFO and crude oil (back-up fuels) |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | 5-year Wärtsilä Operation & maintenance solution and a 10-year spare parts solution |
| Delivered | 2019 |

**Wärtsilä has a reputable track record in Kingdom of Saudi Arabia and they have offered an efficient and reliable solution for a harsh operating environment. We consider this relationship a strategic partnership and hopefully it will be rewarding for both parties.**

*Jehad Abdul Aziz Al Rasheed,*
*General Manager,*
*Yamama Cement Company*

## Flexible combined heat and power & trigeneration solutions

Flexibility within the power system will be increasingly required in order to integrate growing shares of wind and solar energy in a cost-efficient and secure manner, while adhering to environmental requirements. Wärtsilä's combined heat and power (CHP) technology, with its fast starting and stopping capabilities, is a flexible complement to power production from wind and solar sources.

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.

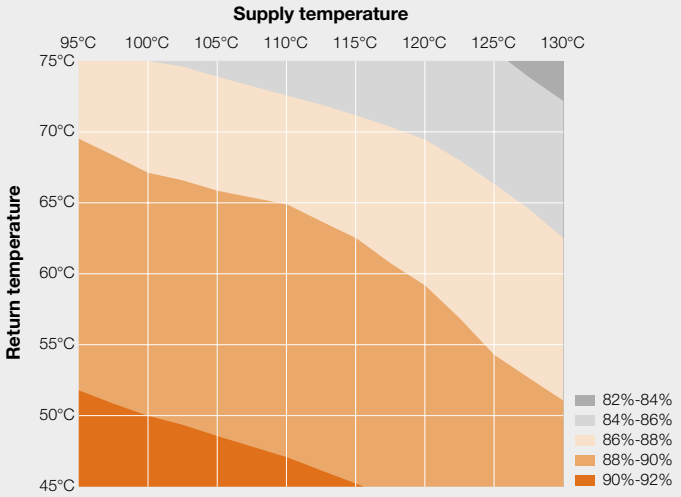
In trigeneration power plants, Wärtsilä can deliver three valuable products for the customer; electricity, heating and cooling – all this in just one power plant. This is possible without sacrificing the high reliability and superb flexibility of an ordinary Wärtsilä power plant.

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 utilise the Wärtsilä CHP and trigeneration solutions.

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

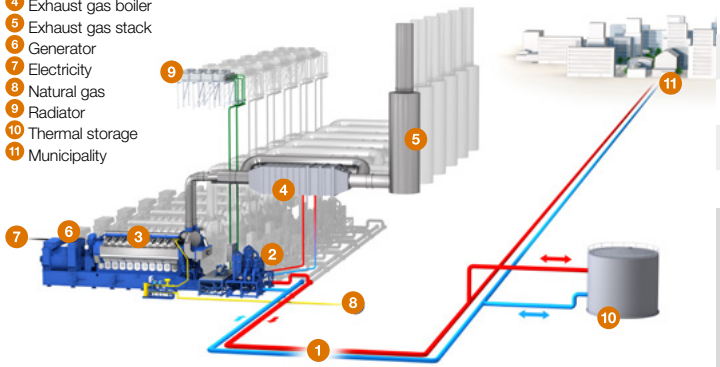
**Benefits of Wärtsilä CHP solutions:**

- Environmentally friendly and efficient solution with a small $CO_2$ footprint.
- Dynamically able to respond to electricity price variations.
- The most flexible power plant in the thermal power industry supports intermittent wind and solar energy.
- Flexibility can be further improved with heat storage.
- Multiple engine units with fast start and ramp rates enable dynamic operation at high efficiency during low heat demand.
- High efficiency and flexible operation over a wide load range. Typical plant sizes: 6-200 MWe.
- Multi-unit design enables optimised plant size with step-by-step investment.
- Flexible operation responds to changes in power, heat and cooling demands.
- On-site maintenance without production downtime.
- Lifecycle solutions optimise the efficiency and performance of the plant.
- Low capital and operational costs per output unit leading to high profitability.




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

1. District heating network
2. CHP module
3. Engine, Wärtsilä 20V34SG
4. Exhaust gas boiler
5. Exhaust gas stack
6. Generator
7. Electricity
8. Natural gas
9. Radiator
10. Thermal storage
11. Municipality



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

## KMW, Germany

| | |
|---|---|
| Customer | Kraftwerke Mainz-Wiesbaden AG |
| Type | Wärtsilä 34SG gas power plant |
| Operating mode | Combined heat and power, operating in the reserve markets |
| Gensets | 10 x Wärtsilä 20V34SG |
| Total output | 100 MWe + up to 96 MWth |
| Fuel | Natural gas |
| Scope | Engineering, procurement & construction (EPC) |
| Lifecycle solution | 15-year maintenance agreement with performance guarantees. The maintenance agreement also includes online monitoring and support. |
| Delivered | 2020 |

**Unlike traditional CHP power plants based on coal-fired units or gas turbines, Wärtsilä gas engines can be started and stopped without limitations within just 2 minutes. This is our answer to the increasingly volatile power market that results from greater levels of renewable energy. It makes us the future partner of renewables.**

*Dr. Lars Eigenmann,*
*CEO at Kraftwerke Mainz-Wiesbaden AG*

## 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.

**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

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

## Estrella del Mar II, Dominican Republic

| | |
|---|---|
| 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 | Engineering, procurement & construction (EPC) |
| Delivered | 2010 |

**We are a repeat customer, having built three successful power barge projects with Wärtsilä, Estrella del Norte, Estrella del Mar I and II located in the Dominican Republic.**

*Claudio Dabelic*
*Vice President,*
*Seaboard Corporation*

## Power Cubes

Are you looking for a great package deal for smaller power generation in the 5-30 MW range? Wärtsilä GasCube (34SG), Multi-fuel Cube (34DF) and OilCube (32) power generation solutions have all the great features of Wärtsilä gas or liquid fuel power plant in a compact, ready-to-use pre-engineered package designed for fast delivery time with minimal site work.

The solution consists of a self-contained design with one or several modules, each housing one Wärtsilä genset, plus all the auxiliaries needed to make up a working power plant.

- Easy-to-install, pre-designed solution for power needs of 5 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 grows with time.
- Quick building and commissioning time.
- Optimised engine-wise auxiliary equipment.
- Relocation friendly solution.
- Perfect for fast-track EPC deliveries.

## 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 | Engineering, procurement & construction (EPC) |
| Delivered | 2009 |

## Energy storage

### Renewables Integration

In working towards Wärtsilä's goal of a 100% renewable energy future, energy storage is becoming increasingly critical to help strengthen the reliability and flexibility of the grid and to integrate more renewable power into the system. For example, a paired storage and energy management software (EMS) solution at the University of Arizona Science and Technology Park provides frequency response and voltage control and can integrate a new 2 MW solar array. The project supports Arizona's Renewable Energy Standard's goal of delivering at least 30% of its power from renewable resources and demonstrates how a hybrid system offers energy shifting and ramp rate control capabilities, plus improves resilience while reaching clean energy goals.

20 MW energy storage solution with NextEra in Illinois, USA.

The combination of renewables and storage makes it possible to produce smooth power output when weather conditions are less than ideal, minimising impacts on grid stability. Solar and wind on its own are intermittent resources that can disrupt the grid with frequency and voltage fluctuations on cloudy days and when there is no wind. For example, fast-acting energy storage operating in concert with the solar system can control power quality by calibrating battery charging and energy exports to the grid. Consequently, storage mitigates the need for large-scale solar to curtail output as clouds come and go.

### Grid Reliability

Globally, there is a growing demand for resilience against power disruptions in an increasingly volatile climate, especially in vulnerable regions—such as California, USA, where high wind conditions force utilities to cut power in order to prevent wildfires, or Puerto Rico, where extreme weather conditions threaten the electric power grid.

Resilience is the ability to bounce back after a disruptive event, such as unusual weather patterns. Greater resilience lessens the short-term impact on the grid itself. Energy storage has the unique ability to provide a stable infrastructure by cost-effectively enhancing grid reliability and security. Storage does so by providing a buffer between supply and demand that enables electric systems to rebalance during and after a disturbance, including energy arbitrage, black start, and peak shaving capabilities. One key example is in rural Roscoe, Texas, USA. In a project with E.ON Texas Waves, Greensmith Energy integrated an intelligent energy storage solution at a wind farm. The system was able to provide rapid response to shifting power demand during an usually cold season in early 2018, delivering short-term energy to the Electric Reliability Council of Texas.

### Microgrids and Island Grids

Microgrids present a unique set of challenges, particularly the need for reliable energy to provide critical power needs. Energy storage solutions offer both economic and environmental benefits for grid-scale capabilities for localised energy.

Take the Northern Azores region, for example. Energy security was a concern for the island of Graciosa due to a high dependence on fossil fuel

Hybrid energy solution on the island of Graciosa in the Northern Azores region of Portugal.

imports in an isolated area. Storage is a sustainable alternative, bringing islanding capabilities that result in lower energy costs, a smaller carbon footprint, the ability to boost renewable energy consumption, and critically, increased reliability and sustainability of the grid. In the case of Graciosa, a hybrid approach to island grid energy generation – optimising multiple generation assets, including wind, solar, storage and thermal generation – addresses baseload supply requirements while accommodating fluctuations in output that are inherent to energy supplied from renewable sources. The entire system is optimised and monitored by Greensmith Energy Management System (GEMS), operating as the island grid controller, to maximise the performance and longevity of the Graciosa energy system.

## GEMS

GEMS is a propriety software integrated into the battery management system (BMS) that manages and optimises entire energy ecosystems to provide the desired outcomes at the lowest cost. The software can integrate multiple generation sources seamlessly, while also stacking and leveraging various applications, such as frequency regulation and microgrids, to create revenue streams and to mitigate grid issues. GEMS' flexible architecture – dynamically adjusting based on market conditions – addresses a critical need for intelligent and adaptable software.

Real-time optimisation can create new revenue streams by leveraging the available transmission capacity at existing sites while providing ancillary services. For example, GEMS optimises wind and solar on the Portuguese island of Graciosa, providing energy security and independence for the once fuel-dependent island. Likewise, the flexible software also analyses changes in market conditions and rate structures in the first energy storage installation in Hungary. The unique integration of energy storage and GEMS within an engine power plant – combining new energy generation with the existing three Wärtsilä 34SG engines – allows the plant to operate in a virtual mode, opening new opportunities in the Hungarian energy market. Finally, in a project with Duke Energy at a retired coal plant in Ohio, USA, GEMS provides precise and synchronised response to the PJM (Pennsylvania-New Jersey-Maryland) market, delivering quick power versus the lengthy ramp time of a traditional power plant.

Energy storage deployment optimised by GEMS.

Aerial view of containerised and standardised GridSolv energy storage solution.

## GridSolv

The adaptability and future-proof nature of a system are major factors that energy producers consider when looking to invest in energy storage. Wärtsilä's answer is a solution designed to offer maximum flexibility and speed of deployment for both standalone as well as integrated hybrid storage (solar plus storage systems, microgrids, interconnected utility scale systems) deployments: GridSolv.

GridSolv is a containerised energy storage solution that standardises the software, core hardware assets and technology functions of Wärtsilä energy storage systems. GridSolv consists of one International Organisation for Standardisation (ISO) 40 ft/12.2 m container and comprises pre-installed battery racks, safety and fire suppression systems, power distribution, and an air conditioning system. The solution increases energy density – achieving up to 6 MWh of storage capacity – and system reliability, while reducing logistics (e.g. shipping, procurement accuracy) and construction costs (i.e. site installation).

The modular design is unique not only in its compliance to ISO standards – streamlining and optimising economies of scale – but also its ability to augment grid assets by layering GEMS software controls on top of storage. The combination of GridSolv and our GEMS software platform is already deployed in Budapest, Hungary at ALTEO's existing power plant. GridSolv and GEMS provide frequency and secondary regulation to the national Hungarian grid, optimising our utility partner's participation in the local electricity market.

## Engine+ Hybrid Energy

Engine+ Hybrid Energy enhances the efficiency, flexibility, and speed of engine power plants by delivering power to the grid instantly, pairing engines with energy storage to form a fully integrated system. This solution primarily generates value by reducing engine power plant operational expenses through the GEMS power plant control platform – leveraging sophisticated forecasting and machine learning to provide real-time optimisation – flexible engines and GridSolv hardware.

The benefits provided by this integrated and automated smart renewable mix include: fuel savings through the improved efficiency of the engines' run time, spinning reserve replacement, which saves running hours and maintenance, as well as a fast return on investment – the typical payback period ranges from 2.5-4.5 years for an existing power plant. This is a power generation solution for islanded or isolated grids, small islands, and C&I sectors.

## Wärtsilä Hybrid Power Plant Solutions

Fast-starting, internal combustion engines – integrated with energy storage and renewables – offer considerable potential for fuel and cost savings. Especially in remote areas, such as island and isolated grids where fuel prices are generally high, these types of integrated hybrid power plants hold great promise.

The Wärtsilä hybrid power plant is configured and sized specifically for the customer needs to ensure maximum asset value in the specific operating environment. All integrated assets are controlled, monitored and dispatched through the Greensmith Energy Management System (GEMS), which seamlessly leverages the most cost-effective source in real-time, while maintaining system stability and respecting all operational requirements to meet the operator's goals.

## LPG to power

LPG (Liquefied Petroleum Gas, propane or butane) is an excellent choice of fuel for power plants where natural gas for various reasons is not available. There are a number of reasons for the increasing popularity of LPG for power generation:

- LPG is a cleaner fuel than diesel and heavy fuel oil.
- Transportation is easy by sea, rail or truck, regardless of batch size.
- Storage of LPG is relatively simple and does not require cryogenic storage tanks.
- Storage and distribution infrastructure for LPG is readily available in most counties.

Wärtsilä has fuel flexible power generation technologies allowing operation on various combinations of fuels such as propane, butane, methane, ethane and diesel.


EPIC BALTA, a 6,300 $m^3$ pressurised LPG tanker, discharging LPG at Roatan Electric Company's LPG terminal.


Roatan Electric Company 28 MW LPG power plant built by Wärtsilä under a fast-track EPC contract.

### LPG supply chain and storage

Already today, LPG is available worldwide and it is widely used in transportation, industry, residential and commercial applications. LPG is traded as a commodity across the world in both large and small quantities.

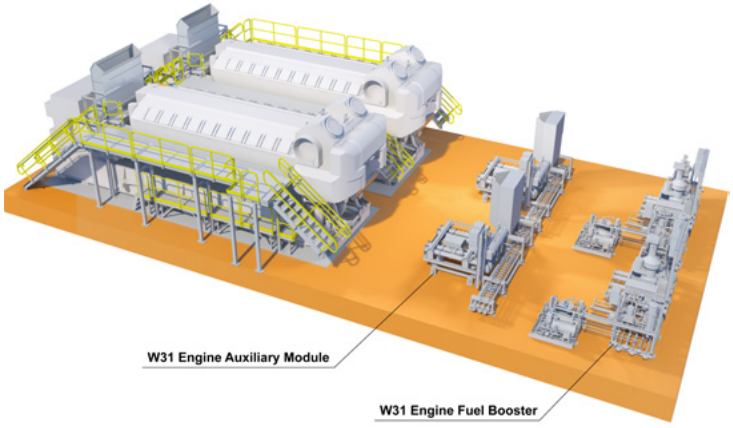
Shipping LPG in quantities suitable for power generation, especially for small and medium sized plants and power systems, is very cost efficient thanks to the large world fleet of small and medium-sized LPG tankers (in 2019 more than 1,000 vessels according to Clarksons). The large LPG tanker fleet as well as the strategically positioned land-based and floating storages used in the LPG industry, guarantee the security of supply for LPG. Furthermore, pressurized storage of LPG is simple and LPG terminals are significantly less costly than the equivalent terminals for importing LNG.

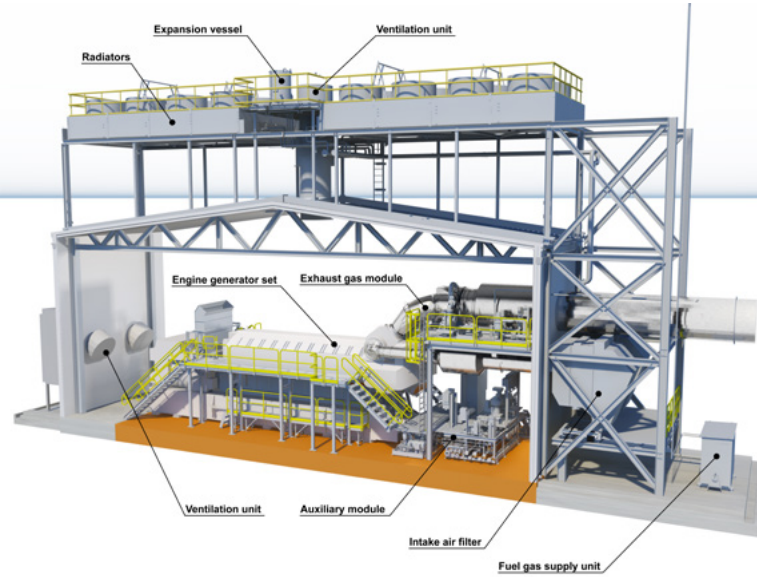
# Modularity

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.

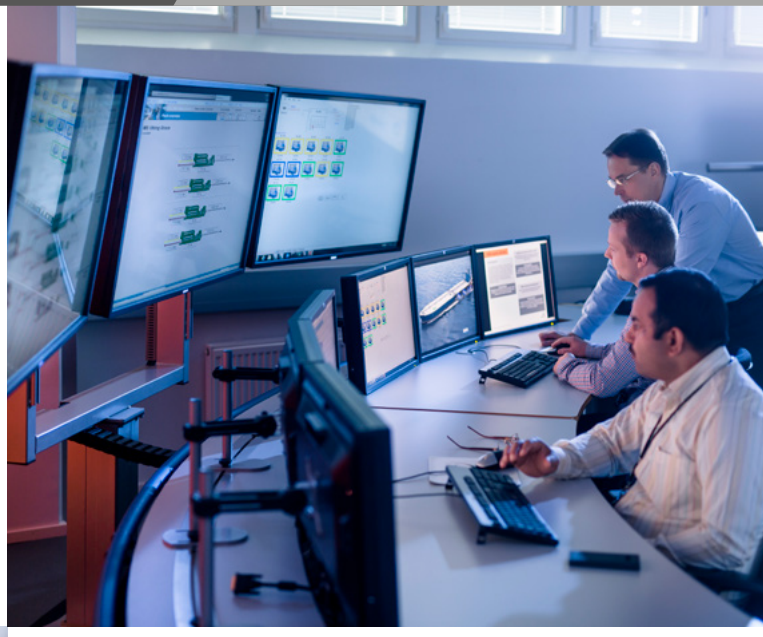
Some of the benefits of modularisation are:

- 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 & 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 third party interfaces.
- UNIC is the engine embedded control system, handling all the control, monitoring and protection functions of the engine, together with the Programmable logic control (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.



- Asset Diagnostics 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:

- System controlling the output 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 back-up and traditional operation mode.

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

# Emissions reduction and monitoring

Wärtsilä 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 lean 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.

IOXI
The 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.

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. Utilising advanced control strategies, emission levels can also be kept throughout the entire load range and in dynamic operation conditions.

### 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 (120-140 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.

## Denton Municipal Electric, Texas, USA

| | |
|---|---|
| Customer | Denton Municipal Electric |
| Type | Wärtsilä 50SG gas power plant |
| Operating mode | Energy procurement optimisation, ancillary services |
| Gensets | 12 x Wärtsilä 18V50SG |
| Total output | 225 MW |
| Fuel | Natural gas |
| Scope | Engineered equipment delivery (EEQ) |
| Delivered | 2017 |

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 Emissions Monitoring (CEMS)

CEMS is typically required only in very large engine power plants. Emissions from engines are stable and many emission components are directly related to fuel, which means that indirect monitoring normally provide best accuracy and reliability.

In case CEMS is obligatory due to lender or authority requirements, the choice of the system needs thorough evaluation. The installation specific features, such as measured emission components, fuel and stack configuration, are to be carefully considered. The integration of emission data handling and reporting into the plant system is a crucial part of a successful emissions monitoring system.

A well-designed CEMS system can reduce the operational needs related to emission monitoring

### Reducing contaminated water

Wärtsilä engine power plant solutions feature very low water consumption and effluent volumes. The focus on reducing the water consumption starts already at the incoming water purification where recycling of reject and effluent will be considered where feasible.

The oily water collection and treatment system is an essential part of the engine power plant. The system is designed to minimise constructed areas that can potentially be contaminated with oil or other impurities, resulting in reduced amounts of contaminated rain or washing waters. Before discharging, contaminated water can be either treated on-site by the oily water treatment unit (OWT), separation unit (oil trap) or transported off-site for treatment.

Plants without sewer connection can be provided with biological treatment of grey and sanitary waters.

# Lifecycle services

Wärtsilä provides high-quality lifecycle services and solutions that enhance customers' business.

Our broad range of services supports power generation companies, whenever and wherever needed. Solutions range from spare parts and maintenance services to long-term service agreements ensuring power plant performance and competitiveness in a safe, reliable and sustainable way.

Ensuring reliable and cost effective energy production is key. With Wärtsilä Lifecycle solutions for the energy industry, you get guaranteed operational reliability and efficiency, backed up by expert advice on optimising the operation and maintenance of your power plants.

With more than 13 GW of power plants under lifecycle solution agreement, Wärtsilä is recognised by customers as their preferred service partner in ensuring the availability and cost-efficient operation of their power plants. They benefit from having their entire power system fully serviced by one global partner. On the basis of our experience in operating and maintaining more than 1,000 marine and land-based installations located in more than 70 different countries, and through the know-how and support of Wärtsilä's worldwide organisation, a Wärtsilä Lifecycle solution agreement has become established as a proven and reliable service for customers.

By partnering with us, you can feel secure knowing where to get help and support – including for your existing installed base – when needed.

# Wärtsilä Lifecycle solutions

With Wärtsilä Lifecycle solutions, we maintain and optimise your power plant performance. This support encompasses our technology, software and service expertise as well as our holistic view and understanding of installations on a system level through a long-term service agreement.

**Choose the right level of support for your power plant:**

**Wärtsilä operation and maintenance**
PROTECT YOUR INVESTMENT
We take full responsibility for operating and maintaining your power plant and guarantee its performance.

**Wärtsilä guaranteed asset performance**
ENSURE POWER PLANT PERFORMANCE
We take full responsibility for maintaining your power plant and guarantee its performance.

**Wärtsilä optimised maintenance**
ENSURE SAFE & RELIABLE OPERATIONS
We take full responsibility for maintaining your power plant and improve performance, reliability and predictability of your operations and costs.

**With a Wärtsilä Lifecycle solution our experts and expertise centres will serve you all the way.**

A Wärtsilä Lifecycle solution agreement ensures power plant performance and competitiveness.

- Maximised return on investment
- Ensured operational efficiency
- Safe and reliable operations
- Operation and maintenance optimisation & cost predictability

**Each solution is customised to fit your operating profile:**

**Performance guarantees**
Power plant performance guarantees based on measured data and ensured throughout the duration of the service agreement.

**Business model**
Agreeing on an incentive and risk sharing model as well as service fee structure.

**Operation model**
Definition of responsibility for operations as well as needed on-site/remote and Wärtsilä Expertise centre support.

**Maintenance model**
Definition of the responsibility for scheduled and unscheduled maintenance, needed Wärtsilä Expertise centre support and maintenance matched with the operating profile.

**Service modules**
Included services for performance management, operational support, maintenance management and analytics.

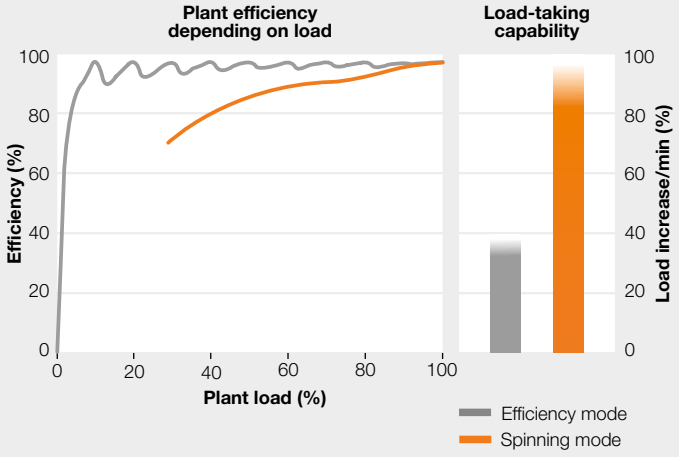
## Operation of a multi-unit power plant

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 depending on the situation at hand. Basically, there are two main operating principles:

In **spinning mode**, the gensets are synchronised and running, but at a reduced load providing spinning reserve. 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.




## Internal combustion engine maintenance

Maintenance of gas, multi-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.

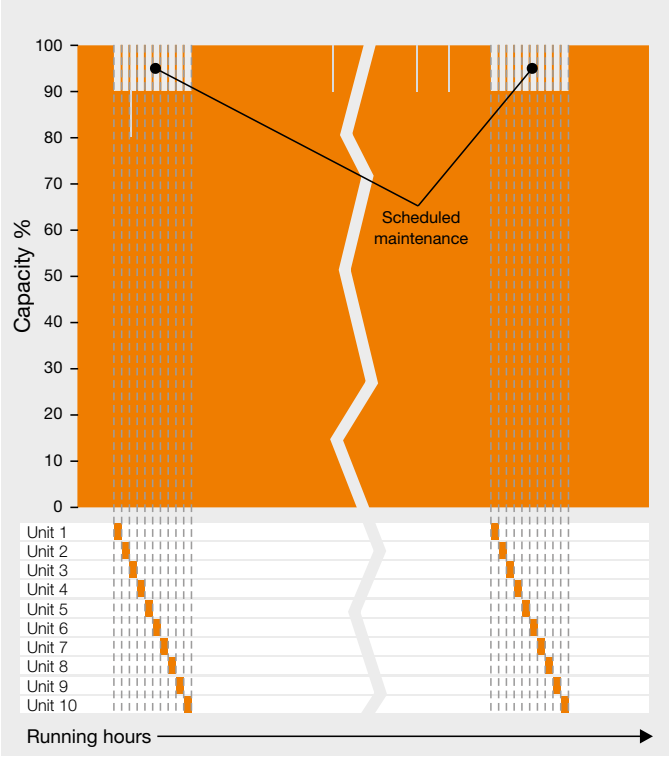
The multi-unit setup means that the annual average unit running hours, depending on the actual load profile, can be considerably lower than the annual plant running hours. In a multi-unit plant the units can be dispatched, so that the running hours are unequally spread on each unit. This allows for scheduling 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 Wärtsilä power plant.

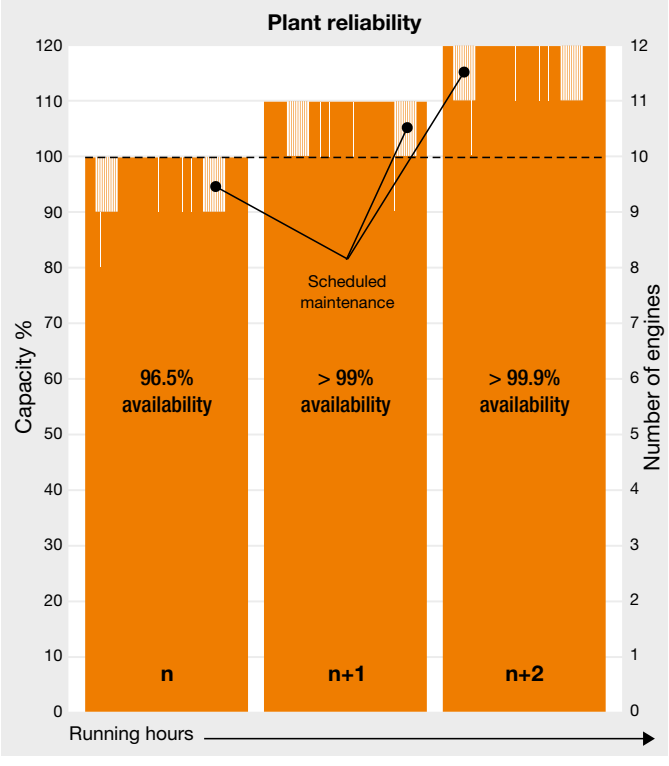
- Maximum firm capacity due to sequential maintenance of one unit at a time.
- High reliability and unsensitiveness to unscheduled maintenance outages thanks to multiple units.




## 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%.



## Wärtsilä Development and 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 (over 3,500 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 mobilise 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 Business 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 an 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 an EPC basis.

The challenging project locations have varied from Siberian tundra to African rain forest, and from the Caribbean shores to Himalayan mountains. Our aim is not only to deliver the project on time, but to work sustainably and enhance safety as well as 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 utilising 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 (M-files) 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 for scope of supply & contract types:

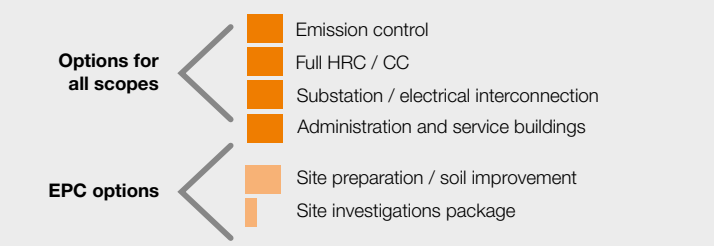
**Basic EEQ** (Basic Engineered Equipment Delivery) is the most basic service where only the main equipment and related auxiliaries are engineered and supplied. The service includes configuration and engineering for supplied equipment and materials, transport, and technical advisory for installation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

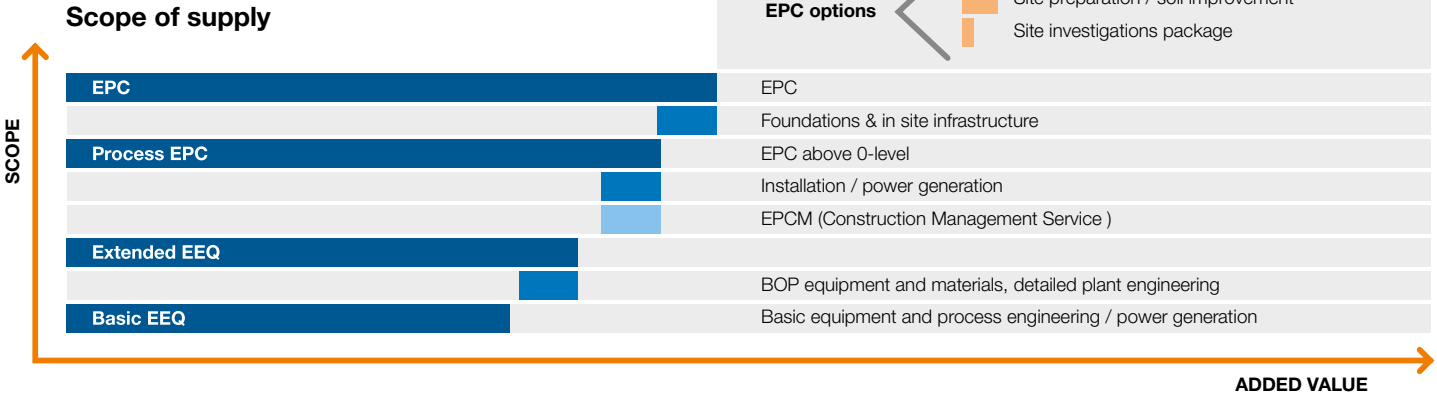
**Extended EEQ** (Extended Engineered Equipment Delivery) is a complete supply solution for defined scope including detailed engineering for total solutions, all materials and equipment plus technical advisory services for installation and commissioning. The customer needs to hire a contractor to perform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

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

- 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


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

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

## KivuWatt

In the heart of Africa, where the nature offers a sustainable and renewable energy source, Wärtsilä is proud to be part of the opportunity to utilise it for the present and future generations.

Wärtsilä was recognised as having delivered one of the world's top ten most influential renewable energy projects of the last 50 years. This recognition has been given by Project Management Institute (PMI), the world's premier association of project professionals. The award identifies efforts that have changed the world and transformed an industry or culture in ways that continue to reverberate. More than a thousand projects were considered before the winners were announced on October 7, 2019 at PMI's head office in Philadelphia, USA.

The 25 MW KivuWatt power plant in Kibuye, Rwanda was delivered and installed by Wärtsilä as a complete engineering, procurement, and construction (EPC) project in 2015. It operates using Wärtsilä 34SG engines running on methane gas lifted from the depths of Lake Kivu, known as the "killer lake" due to the large quantities of methane gas trapped under a layer of heavy water washed out of the nearby volcanoes.

## KivuWatt, Rwanda

| | |
|---|---|
| Customer | Contour Global Ltd. |
| Type | Wärtsilä 34SG gas power plant |
| Operating mode | Flexible baseload |
| Gensets | 3 x Wärtsilä 20V34SG |
| Total output | 25 MW |
| Fuel | Natural gas (methane gas extracted from the Lake Kivu) |
| Scope | Engineering, procurement & construction (EPC) |
| Delivered | 2012 |

**We are honoured to be awarded this prestigious recognition for our KivuWatt power plant project. The gas that can escape from the lake poses a threat to people living in the vicinity, so by utilising these natural resources we are not only adding much-needed electricity to the grid, but most importantly, we are increasing safety for the local community. This successful plant installation also highlights Wärtsilä's competences in project management, as well as the technical efficiency and flexibility of our engines.**

*Antti Kämi,*
*Vice President,*
*Project Management at Wärtsilä*

## 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 | Ethane | LPG (>97% propane) | Crude | LFO/diesel | Liquid biofuel | HFO | Fuel-water emulsion |
| Density (kg/m$^3$) | 0.7–0.8 | ~ 0.8 | 1.4 | 1.3–1.4 | 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 31SG | ● | ● | | | | | | | |
| Wärtsilä 34SG | ● | ● | ● | ● | | | | | |
| Wärtsilä 50SG | ● | ● | ● | | | | | | |
| Wärtsilä 31DF | ● | | | | | ● | | ● | |
| Wärtsilä 34DF | ● | ● | ● | | | ● | ● | ● | |
| Wärtsilä 50DF | ● | ● | ● | | | ● | ● | ● | |
| Wärtsilä 31 | | | | | | ● | | ● | |
| Wärtsilä 32/32TS | | | | | ● | ● | ● | ● | ● |
| 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 back-up 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.

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| Wärtsilä 31SG | ● | ● | | | | | | | |
| Wärtsilä 34SG | ● | ● | ● | ● | | | | | |
| Wärtsilä 50SG | ● | ● | ● | | | | | | |
| Wärtsilä 31DF | ● | | | | | ● | | ● | |
| Wärtsilä 34DF | ● | ● | ● | | | ● | ● | ● | |
| Wärtsilä 50DF | ● | ● | ● | | | ● | ● | ● | |
| Wärtsilä 31 | | | | | | ● | | ● | |
| Wärtsilä 32/32TS | | | | | ● | ● | ● | ● | ● |
| Wärtsilä 50 | | | | | ● | ● | ● | ● | ● |

## Future fuels

**Engines using future fuels are the key to 100% renewable power generation**

Wärtsilä is helping to create a 100% renewable energy future for electricity generation. Our flexible engine power plants are already capable of using 100% synthetic and carbon-neutral methane and methanol. They are also capable of combusting hydrogen/natural gas blends with up to 25% hydrogen – and we're working towards an engine and power plant concept for hydrogen operations.

The reason why is clear: the world needs to decarbonise in order to mitigate climate change. The big question is how can utilities decrease $CO_2$ levels while maintaining sufficient electricity generation capacity? The answer is that renewables – solar and wind in particular – will form the baseline for power production in the future, but their intermittent nature means that flexible solutions are needed for balancing. These include energy storage solutions for hour-level firming and dispatchable gas engines for unlimited periods of firming.

The good news is that the technologies for replacing fossil fuels already exist today. Power-to-X is a technology that can turn excess wind and solar electricity into carbon-neutral fuels such as synthetic methane and methanol or green hydrogen  using only water, air and electricity as raw materials. Power-to-X is one of the key components for reaching 100% renewable energy and achieving truly carbon-neutral electricity generation. Wärtsilä has several years of experience of working with Power-to-X technology and has established close to ten  partnerships to further explore this highly promising area .

Green hydrogen will also play a major role in developing future fuels. Currently it can be used as a blend with natural gas or as a base for producing other renewable synthetic fuels such as methane or methanol. In the future, it is possible that pure hydrogen will also be used as a fuel.

At Wärtsilä, we want to ensure that our engines run efficiently and reliably regardless of which fuel becomes the leading choice. Whatever the future holds, Wärtsilä's engines will be able to handle it – so you can invest in a more sustainable future with full confidence today.

**Benefits / Key messages**

- **Take advantage of existing technologies** Power-to-X technologies, which use excess solar or wind to create carbon-neutral future fuels like synthetic methane and methanol or green hydrogen out of water and air, already exist. Green hydrogen is likely to become a key part of fuel systems in the future and can already be combusted as part of a blend with natural gas to reduce emissions.
- **Harness our experience and continuous technology development** Wärtsilä has a long history of innovation and is continuously working on improving the efficiency of our engines while also developing Power-to-X. Wärtsilä has been researching hydrogen as a fuel for more than two decades and is working towards a hydrogen concept.
- **Ensure flexibility with engine power plants** Flexible engines can quickly ramp up and down as needed to balance the intermittent nature of renewables like solar and wind. Future fuels together with engines can take care of long-term energy storage needs for periods with persistently low wind or solar conditions, such as in winter or during the monsoon season.
- **Future-proof your investments** Wärtsilä engines are a future-proof investment that can already combust 100% synthetic carbon-neutral methane and methanol and  operate on blends of natural gas and hydrogen.

# Notes

WÄRTSILÄ

## WÄRTSILÄ ENERGY IN BRIEF

Wärtsilä Energy leads the transition towards a 100% renewable energy future. We help our customers in decarbonisation by developing market-leading technologies. These cover future-fuel enabled balancing power plants, hybrid solutions, energy storage and optimisation technology, including the GEMS energy management platform. Wärtsilä Energy's lifecycle services are designed to increase efficiency, promote reliability and guarantee operational performance. Our track record comprises 74 GW of power plant capacity and more than 80 energy storage systems delivered to 180 countries around the world.

**www.wartsila.com/energy**

**Worldwide contacts**



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