2010

POWER PLANTS PRODUCT CATALOGUE

ENERGY
ENVIRONMENT
ECONOMY

WÄRTSILÄ

BATAKAN, BALKIPAPAN, INDONESIA
Type .....Flexible baseload
Engines.....5 x Wärtsilä 20V32
Total output..... 44.6 MW
Fuel.....HFO
Delivered..... 2009

WÄRTSILÄ ENERGY MARKET

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CHANGE HAPPENS. STAY IN CONTROL.

The world is changing at an ever faster rate. Short term electricity demand fluctuates significantly even as long-term demand continues to grow. Fuel prices and availability vary, and environmental legislation keeps tightening. And of course major factors, from weather to technology, are constantly changing; nobody really knows what the future will bring.

What we do know, is that the way electricity is produced must become more flexible in order to meet these changes. And this is what Wärtsilä is all about. Wärtsilä is a leading supplier of flexible power solutions based on reciprocating engines. We have a track record of providing close to 43 GW of power in 165 countries. Whether you want to power a single industrial plant or an entire country in an economically and environmentally sound way, we have the solution that's right for you.

Wärtsilä solutions offer world-class **operational flexibility** – with uniquely fast starts, stops and restarts. Our **fuel flexibility** is also second to none since our power plants have the ability to run on a wide range of gases and oils, including liquid biofuel. In addition, our plants offer high **energy efficiency** over the whole load range. As importantly, our technologies are backed up by operations and management services that ensure efficiency and optimize lifecycle value for as long as you need.

At Wärtsilä, we understand the changes and challenges you face. Our solutions are designed to keep you in control. This is the Wärtsilä way of doing things.

ENERGY EFFICIENCY: EVERYWHERE AND ALWAYS.

Our solutions offer high output and efficiency, whatever the application – even in the most challenging conditions and locations. In the hottest deserts or high in the mountains, in city centres or jungles, energy output and efficiency is never in doubt. We deliver the highest simple cycle electrical efficiency in the business – converting almost half of your fuel energy into pure electricity. And the fact that a negligible amount of water is consumed in the process has obvious advantages, particularly in dry locations.

Our partial load efficiency is also extremely high, especially when several units are used together so that you can start and stop them one by one. In most cases, you can throttle back to 50% and still achieve over 40% electrical efficiency. Additionally, with several units, the reliability is much better than with a conventional solution. Both simple cycle and combined cycle solutions are available. You can choose whichever suits your needs – with no compromises on flexibility.

FUEL FLEXIBILITY: THE CHOICE IS YOURS

At Wärtsilä, the choice of fuel belongs to the customer. That's why we offer solutions for various liquid and gaseous fuels, including renewable ones. To keep your options open, you may wish to choose a solution that can easily be

converted later from liquid to gas, or from fossil to renewable. Or you might need a dual-fuel solution that allows you to change fuels instantaneously on line in response to changes in availability and price.

OPERATIONAL FLEXIBILITY: THE FASTEST WINS

Wärtsilä plants are capable of following daily load fluctuations. Whether you need baseload, intermediate, peaking or standby power generation, operational flexibility is crucial; and we can provide it. You can also use our solutions as a part of an optimal power system mix, adding flexibility to, for example, nuclear or coal based systems. Starting, stopping and restarting are uniquely fast. It takes just five minutes from the start order to ramp up to full load. This makes our power plants the perfect wind power backup and enabler. It also means that you can quickly supply electricity when the demand – and therefore the price – is peaking. Our solutions allow you to jump instantaneously from 70% loading to 100%.

As energy demand grows, the high modularity of our products makes it easy to expand your power plants to meet future changes. Last but not least, all of this can be done without risking operational reliability. After all, several smaller units are, by definition, always more reliable than one large one.

ENERGY, ENVIRONMENT AND ECONOMY GO HAND IN HAND

As the public debate about energy and the environment continues, many people still believe that we are faced with a choice between cutting emissions and increasing profit. At Wärtsilä, we know from experience that you can produce energy in a way that is both environmentally and economically sound. This is the key idea behind each and every one of our solutions.

The major challenge is reducing CO_2 emissions. High efficiency in converting fuel to electricity is the best way to do this, and it can be done for a relatively modest investment. Another important way is to have a variety of fuels with low carbon content to choose from.

As a general rule, Wärtsilä solutions convert almost half of the fuel into pure electricity, even during rapidly changing conditions. Our efficient and flexible plants can handle load variations, and enable baseload plants to run at a steady high load. This means that they can enable unflexible baseload plants

connected to the grid at their optimal performance point, which also reduces CO_2 emissions in these baseload plants. Flexible plants also open up the possibility of using more wind power which reduces emissions still further.

Cogeneration for district heating and industrial, large office or airport facilities is also to be recommended. With district heating plants total efficiencies of over 90% have been achieved. In addition, Wärtsilä engines produce heat from exhaust gases and cooling circuits without losing electrical efficiency. And the combined heat and power system can be built and operated without compromizing flexibility.

When it comes to fuel flexibility, Wärtsilä offers several possibilities that usually involve changing from coal to liquid fuels; and eventually to gas. Plants operating on fossil fuels like heavy fuel oil can easily be modified to operate on liquid biofuels.

POWER SCENARIOS 2023: GREEN EARTH, BLUE GLOBE OR GREY WORLD?

Never before has the power industry seen as many fundamental changes and challenges at the same time. On the one hand we have to produce enough electricity to cover the needs of a growing population, even as economic growth is spreading to new continents. On the other hand, we must curb climate change while managing the turmoil of a global financial crisis. In order to stay in control in these turbulent times, we must think about what the future might look like.

Wärtsilä has spent over 8,000 hours analyzing the question of electricity production and use in 2023. The project brought together the views of academics, NGOs, business leaders, government representatives and other experts. The end result was three scenarios describing alternative futures and how they might come about.

GREEN EARTH

What if consumers take it upon themselves to change – with the help of governments – the way we live and consume?

The Green Earth scenario is shaped by individual citizens, consumers and voters. Natural disasters associated with climate change have shown us that we, the consumers, must do something about the changing climate. Using natural gas as a transition fuel, we have focused on renewables such as wind and solar power. The world economy grows at a modest sustainable pace and the geopolitical situation is stable. We accept the scarcity of resources and live sustainably – not unwillingly.

BLUE GLOBE

What if the recession and environmental disasters give rise to a market oriented world powered by coal and nuclear power?

The Blue Globe is a market-oriented, prosperous world. Utilities power our lives with a focus on large-scale coal and nuclear plants. Policy is driven by two key factors: the need for economic growth and curbing emissions. Carbon capture and storage has become the key solution, allowing us to keep using coal in existing and new plants. Transportation has been electrified and thus transport has less impact on the environment. The subsequent reduction in oil demand has led to a restructuring in geopolitical networks.

GREY WORLD

What if resources get so scarce that energy security becomes a major issue for all governments?

The Grey World is ruled by governments. Scarcity of resources and energy security are major issues. Governments try to make the scarce supplies last, leading to considerable changes in society. Political tensions run high due to the uneven geographical distribution of energy resources. Natural gas is the most important energy source, and climate change has virtually dropped off the political agenda.

Please read more about our scenarios, share your views, challenge us and give us feedback at www.wartsila.com/scenarios or by e-mail to powerscenarios@wartsila.com or on the Power Scenarios fanpage on Facebook.

EXPERIENCE COUNTS

Wärtsilä has a long history and extensive experience in the design, building and turn-key supply of power plants, executing over 100 power plant projects each year. At the end of 2009, Wärtsilä had close to 43 GW of power installed in power plants in 165 countries around the world.

The supply and installation of these plants have provided Wärtsilä with a wealth of experience in the implementation of successful projects around the world, and in all kinds of ambient conditions. Most importantly, this has

enabled us to establish a worldwide network of our own dedicated service centres and workshops, able to support the operations and maintenance of our power plants throughout their lifecycle.

Adding to this vast experience of land-based installations, Wärtsilä has over 130 GWs installed as main or auxiliary engine applications in the active marine fleet, including merchant, offshore, navy, cruise and ferry and special vessels.

POWER PLANT OUTPUT RANGE

LFO = light fuel oil
HFO = heavy fuel oil
CRO = crude oil
FWE = fuel-water emulsion
LBF = liquid biofuel

UBUNGO, TANZANIA
Type .....Baseload
Engines..... 12 x Wärtsilä 20V34SG
Total output..... 105 MW
Fuel:.....Natural gas
Delivered:..... 2006

10
50
100
300
500

GAS POWER PLANTS

Wärtsilä gas power plants are designed for optimal production performance in a broad variety of peaking, intermediate and baseload applications. The power plants are based on engine units operating on natural gas.

The gas power plant's advantages include:

- Stepwise investment with smaller risks and optimized profit generation
- Excellent plant availability and reduced need for backup capacity due to multi-unit installation
- Net plant electrical efficiency over 44%

STEC POWER PLANT, PEARSALL, USA
Type: ..... Stability services
Engines: ..... 24 x Wärtsilä 20V34SG
Total output: ..... 202 MW
Fuel: ..... gas
Delivered: 2009

- Full plant output at high altitudes and in hot and dry ambient conditions
- High part-load efficiency
- Fast start-up, 5 min from hot standby to full plant load
- Minimal water consumption with closed-circuit radiator cooling
- Low gas fuel pressure requirement
- Maintenance schedule independent of the number of starts or trips.

BONTANG, INDONESIA
Type ..... Baseload, 2 x GasCubes
Engines ..... 2 x Wärtsilä 16V34SG
Total output ..... 13.9 MW
Fuel ..... Natural gas
Delivered 2009

GASCUBE

A Wärtsilä GasCube plant is a multiple of engine modules designed to meet a total power need of 6–30 MW. A GasCube based on the Wärtsilä 16V34SG or Wärtsilä 20V34SG, with all the auxiliaries and components needed to make up a working power production unit, provides 7–9 MWe per unit. Due to the self contained design, the GasCube is the optimal solution for agile, streamlined and exceptionally cost efficient project execution.

- High electrical efficiency
- Minimization of the plant's own electricity consumption
- Simple and reliable technical solutions
- Compact, pre-engineered plant design
- Perfect for EPC deliveries even to areas lacking infrastructure.

DUAL-FUEL POWER PLANTS

Wärtsilä dual-fuel power plants are based on engines that are able to run on natural gas, light fuel oil, heavy fuel oil or a number of other liquid fuels, offering the ultimate in fuel flexibility. The ability for power plant operators to switch to the most economical fuel is a capability of great value as fuel prices fluctuate. In addition the fuel can be switched whilst the engine is operating, for example if the gas supply is interrupted. This operational flexibility is a real advantage with the dual-fuel system.

The dual-fuel power plant's benefits include:

- Fuel and operational flexibility
- High efficiency
- Low emission rates
- Excellent reliability
- Operational cost advantage
- Easy adaptation to grid load variations.

ORCHARD PARK GENERATION STATION, CHAMBERSBURG, USA
Type ..... Peaking
Engines..... 4 x Wärtsilä 18V32DF
Total output..... 23.2 MW
Fuel:.....Dual-fuel
Delivered:..... 2004

OIL POWER PLANTS

Wärtsilä oil power plants stand for high efficiency and low emissions. Proven long-term reliability make these plants suitable for stationary and floating baseload and standby applications. Worldwide deliveries of our liquid-fuelled power plants exceed 36 GW.

NISHAT POWER LIMITED,
JAMBAR KALAN, PAKISTAN
Type .....Flexible baseload, heat recovery, combined cycle plant
Engines.....11 x Wärtsilä 18V46
Total output..... 200 MW
Fuel.....HFO
Delivered..... 2009

The benefits of our oil power plants include:

- Fuel flexibility, ability to run on heavy fuel oil, light fuel oil, crude oil, emulsified fuels or liquid biofuel
- Fast start-up, less than 5 min from hot standby to full plant load
- High efficiency resulting in low generation costs
- Excellent long-term reliability
- Large wordlwide reference base and proven performance.

Wärtsilä 20 Powerskid.

8 x Wärtsilä 9L20 containerized power plant next to the Nile river.

THE WÄRTSILÄ 20 POWERSKID

The Wärtsilä 20 Powerskid offers an innovative new concept for the 1–15 MW power plant range. The compact design is based on pre-manufactured modules ensuring fast and easy installation. The basic design comprises:

- Generating set: based on a 6-, 8- or 9-cylinder Wärtsilä 20 engine
- Fuel, lube oil cooling and control system mounted on a common skid.

WÄRTSILÄ 20 CONTAINERIZED POWER PLANT

The Wärtsilä 20 Powerskid containerized power plant has been developed in response to the increasing demand for small diesel power plants running on heavy fuel oil or liquid biofuel. Designed to meet a flexible power demand, the container power plant contains all the essential systems and equipment for the power plant in two 40 foot high containers.

OILCUBE

The Wärtsilä OilCube based on the Wärtsilä 12V32, Wärtsilä 16V32 or Wärtsilä 20V32 generating sets is a complete power plant unit designed to meet a power demand of 5 to 30 MW. The OilCube is an extremely flexible, streamlined and exceptionally cost-efficient solution for power production.

- High electrical efficiency through minimizing the plant's own consumption
- Simple and reliable technical solutions
- Compact, pre-engineered design
- Perfect for EPC deliveries even to areas lacking infrastructure.

Wärtsilä OilCube.

VEGETABLE OIL UTILIZATION

LIQUID BIOFUEL PLANTS

Liquid biofuel can be produced from practically any oil-rich crop, from oil palm, soy, rapeseed, jatropha and olive to sunflower seeds. Liquid biofuels can also be of non vegetable origin, for example oils or fats from fish or poultry.

In order to minimize the lifecycle impact on greenhouse gas emissions, Wärtsilä liquid biofuel plants are designed to operate on clarified crude vegetable oils – without any supplementary energy for fuel refinement needed. Wärtsilä offers liquid biofuel power plants in the range of 1–300 MW using Wärtsilä 20, Wärtsilä 32 and Wärtsilä 46 prime movers.

As of 2010 Wärtsilä has sold a total of approximately 800 MW of liquid biofuel power plants.

GREENPOWER, MERKSPLAS, BELGIUM
Type ..... CHP Baseload
Engines ..... 1 x Wärtsilä 20V32
Total output..... 9 MWe + 8.5 MWth (hot water)
Total efficiency..... 85%
Fuel..... Liquid biofuel
Delivered..... 2009

GRID STABILITY MANAGEMENT

Wärtsilä provides the flexible power solutions needed to support the grid and manage seamless distribution of electricity in all situations:

- peaking power
- reserve power
- load following
- ancillary services incl. regulation, spinning and non-spinning reserve
- frequency and voltage control
- black-start capability.

Where competing technologies take a long time to start up, a Wärtsilä power plant is the first to start when a gap between supply and demand appears. For example, a Wärtsilä light fuel oil power plant takes 30 seconds to synchronize and reaches full capacity in just 3 minutes. A Wärtsilä gas power plant offers 30 second synchronization time and takes 5 minutes to reach full load. Being able to stabilize the grid this quickly is a great benefit to the system operator.

The efficiency of a Wärtsilä power plant also remains high at almost any load, cutting operational costs considerably in part load operation. It can also be used as a baseload plant if needed, which enables real operational flexibility. Frequent starts and stops have no impact on costs or maintenance schedules, which makes the Wärtsilä solution perfect for grid support use.

- Total PSCo wind generation
- PSCo obligation load
- PSCo total coal generation-PI calculation
- Total PSCo gas generation (calc)
- Plains End net MW
- PSCO.PCOG.NO-T.GEN.PEAG

The Plains End power plant is used to balance Colorado's 1000 MW wind power capacity.

PLAINS END I and II, COLORADO, USA
Type ..... Grid stability
Engines..... 20 x Wärtsilä 18V34SG
+ 14 x Wärtsilä 20V34SG
Total output..... 231 MW
Fuel..... Gas
Delivered..... 2002 and 2008

CHP AND COMBINED CYCLES

Wärtsilä's combined heat and power (CHP) plants incorporate both power and heat generation. The system for heat generation in parallel with electricity production, producing steam, hot water or chilled water, is optimally designed for the customer's needs and requirements. Total plant efficiencies can rise to 85% and even higher. These CHP plants can run on various fuels while maintaining low emissions and high efficiency. The heat recovery systems can be defined as post engine "hang-on" types, and do not directly affect either engine performance or running. The engine will give the same high electrical efficiencies and output, regardless of the rate of heat production. The CHP plants run with significantly less fuel input than separate power and heat generation.

Wärtsilä's CHP solutions for district cooling and trigeneration are attractive solutions for large facilities such as airports, shopping centres, housing areas and other building complexes with substantial heating and cooling demands. Depending on customers heating and/or cooling requirements, plant location and the seasonal variations in ambient conditions, the plant can be equipped with standardized heat recovery and chiller solutions, with absorption chillers for heat recovery and electrically driven chillers for covering the peak demands.

IT'S ALL ABOUT COMFORT!

ENGINE COMBINED CYCLE (ECC)

Both diesel and gas medium-speed engines are already from design and construction efficient in terms of power production. Engine gross electrical efficiency at alternator is 46-47%. This electrical efficiency is remarkably high, even compared with large-sized power plants based on other technologies. The rest of the engine fuel input emerges in the form of heat in exhaust gases and engine cooling. These engine waste heat sources can be utilized for valuable heat production. However, in many places there is no “heat sink” where the waste heat can be used, and therefore, secondary power generation is preferred, recovering all waste heat for generating additional power, as in an engine combined cycle (ECC) configuration.

The most common technique in ECCs is based upon conventional steam bottoming cycles with engine wise steam generators, common steam turbine and cooling system. Nevertheless, very high total plant efficiencies are easily obtainable and with this ECC technique an addition in plant power output of 8–10% is achievable by using standardized steam cycle designs.

MAKUHARI, JAPAN
Type ..... Trigeneration
Engines ..... 1 x Wärtsilä 20V34SG
1 x Wärtsilä 16V34SG
Total output..... 16 MW
Fuel.....Natural gas
Delivered..... 2007

TRIGENERATION

Picture courtesy of Jung Bu City Gas and JB Enertek Co., Ltd

CHEONG SOO, KOREA
Type ..... Trigeneration
Engines..... 2 x Wärtsilä 20V34SG
Total electricity output.....16.9 MW_e
Total heat output.....14.2 MW_{th}
Fuel.....Natural gas
Delivered..... 2009

HOT WATER GENERATION FOR DISTRICT HEATING APPLICATIONS

HOT WATER GENERATION FOR DISTRICT HEATING APPLICATIONS

FLOATING POWER PLANTS

The strengths of Wärtsilä – marine technology and power generation – are successfully integrated in floating power plants.

Floating power plants are constructed cost effectively and rapidly in a well controlled industrial setting. Floating plants can be moved from one location to another when needed, and connected to the grid to alleviate local shortages. Floating power plants can also provide a rapid answer to an increase in power demand in advance of new, land-based plants coming online.

The floating power barge Dr Bird II equipped with 3 x Wärtsilä 18V46 engines.

KHULNA, BANGLADESH
Type ..... Floating power plant
Engines..... 13 x Wärtsilä 18V32LN
Total output ..... 110 MW
Total efficiency..... 43.5%
Fuel.....Heavy fuel oil
Delivered..... 1997

UTILIZATION OF FLARE GASES

The World Bank led Global Gas Flaring Reduction partnership (GGFR) estimates that globally, around 150 billion cubic meters (bcm) of gas are flared or burned every year, causing some 400 million tons of carbon dioxide in annual emissions. That is equivalent to 30% of the European Union's gas consumption. Gas flaring not only harms the environment but also deprives countries of an energy source that is often cleaner and cheaper than others available. During the production of crude oil, gas usually comes to the surface as well and is often vented or flared instead of used, particularly in locations that lack effective gas markets, and the necessary infrastructure to utilize the gas.

Wärtsilä gas-diesel technology is the solution for the power generating needs of the oil and gas industry. Thanks to the unique pilot fuel injection method for initiating combustion, associated gas can be used for power generation or gas reinjection at the oil field. If the supply of gas varies in quantity and quality, the answer is fuel sharing – the Wärtsilä innovation that revolutionizes the concept of fuel flexibility.

WÄRTSILÄ 32GD FUEL SHARING WINDOW

POWER GENERATION

RE-INJECTION

PUMPING

The basic concept provides electrical power generation for the field facility processes, from upstream to downstream oil shipping pumps. This power generation can even be provided with a combined heat and power (CHP) system, if needed.

The excess of associated gas can be injected into the hydrocarbon reservoir to maintain the pressure, to enhance oil recovery, or even to be stored for later gas production. The separated water can also be injected using GD-engine driven high pressure pumps.

The injection of excess associated gas underground is the ultimate flaring reduction solution, unless other gas utilization systems are available.

GAS ENGINES
Wärtsilä 34SG

Technical data 50 Hz/750 rpm	Unit	9L34SG	16V34SG	20V34SG
Power, electrical	kW	4343	7744	9730
Heat rate	kJ/kWh	7843	7819	7779
Electrical efficiency	%	45.9	46.0	46.3
Technical data 60 Hz/720 rpm				
Power, electrical	kW	4169	7434	9341
Heat rate	kJ/kWh	7843	7819	7779
Electrical efficiency	%	45.9	46.0	46.3
Dimensions and dry weight of generating set				
Length	mm	10400	11300	12890
Width	mm	2780	3300	3300
Height	mm	3840	4240	4440
Weight	tonne	77	120	130

Heat rate and electrical efficiency at generator terminals, including engine driven pumps, ISO 3046 conditions and gas LHV > 28 MJ/m^3_N. Tolerance 5%. Power factor 0.8. Gas Methane Number > 80. Nm^3 defined at NTP (273.15 K and 101.3 kPa).

DUAL-FUEL ENGINES
Wärtsilä 32GD

Technical data 50 Hz/750 rpm		6L32GD	9L32GD	12V32GD	16V32GD	20V32GD
Power, electrical	kW	2636	3974	5299	7124	8924
Heat rate	kJ/kWh	8304	8260	8091	8066	8049
Electrical efficiency	%	43.4	43.6	44.5	44.6	44.7
Technical data 60 Hz/720rpm						
Power, electrical	kW	2579	3888	5184	6970	8730
Heat rate	kJ/kWh	8304	8260	8091	8066	8049
Electrical efficiency	%	43.4	43.6	44.5	44.6	44.7
Dimensions and dry weight of generating set						
Length	mm	8400	10400	10200	11300	12890
Width	mm	2780	2780	3300	3300	3300
Height	mm	3840	3840	4470	4240	4440
Weight	tonne	58	77	92	120	130

Heat rate and electrical efficiency at generator terminals, including engine driven pumps, ISO 3046 conditions and gas LHV > 36 MJ/m^3_N. Lower LHV can be compensated by liquid fuel. Tolerance 5%. Power factor 0.8. Gas pressure at engine inlet 350 bar. Nm^3 defined at NTP (273.15 K and 101.3 kPa).

Wärtsilä 34DF

Technical data 50 Hz/750 rpm		6L34DF	9L34DF	16V34DF	20V34DF
Power, electrical	kW	2579	3888	6970	8730
Heat rate	kJ/kWh	8347 (8517)*	8303 (8214)*	8048 (8146)*	8031 (8127)*
Electrical efficiency	%	43.1 (42.3)*	44.4 (44.3)*	44.7 (44.1)*	44.8 (44.3)*
Technical data 60 Hz/720rpm					
Power, electrical	kW	2493	3758	6737	8439
Heat rate	kJ/kWh	8347 (8437)*	8303 (8175)*	8048 (8107)*	8031 (8127)*
Electrical efficiency	%	43.1 (42.7)*	43.4 (44.0)*	44.7 (44.4)*	44.8 (44.3)*
Dimensions and dry weight of generating set					
Length	mm	8400	10400	11300	12890
Width	mm	2780	2780	3300	3300
Height	mm	3840	3842	4240	4440
Weight	tonne	58	77	120	130

Heat rate and electrical efficiency at generator terminals, including engine driven pumps, ISO 3046 conditions and gas LHV > 28 MJ/m^3_N. Tolerance 5%. Power factor 0.8. Gas Methane Number > 80. Nm^3 defined at NTP (273.15 K and 101.3 kPa). *In oil mode.

Wärtsilä 50DF

Technical data 50 Hz/500 rpm	Unit	18V50DF
Power, electrical	kW	16621 (16621)*
Heat rate	kJ/kWh	7616 (8195)*
Electrical efficiency	%	47.3 (43.9)*
Technical data 60 Hz/514 rpm		
Power, electrical	kW	17076 (17076)*
Heat rate	kJ/kWh	7618 (8186)*
Electrical efficiency	%	47.3 (44.0)*
Dimensions and dry weight with generating set		
Length	mm	18780 (18780)*
Width	mm	4090 (4090)*
Height	mm	6020 (6020)*
Weight	tonne	355 (355)*

Heat rate and electrical efficiency at generator terminals, including engine driven pumps, ISO 3046 conditions and gas LHV > 28 MJ/m^3_N. Tolerance 5%. Power factor 0.8. Gas Methane Number > 80. Nm^3 defined at NTP (273.15 K and 101.3 kPa). *In oil mode.

LIQUID FUEL ENGINES

Wärtsilä 20

Technical data 50 Hz/1000 rpm	Unit	6L20	8L20	9L20
Power, electrical	kW	1026	1368	1539
Heat rate	kJ/kWh	8561	8647	8604
Electrical efficiency	%	42.0	41.6	41.8
Technical data 60 Hz/900 rpm				
Power, electrical	kW	969	1292	1454
Heat rate	kJ/kWh	8519	8604	8561
Electrical efficiency	%	42.3	41.8	42.0
Dimensions and dry weight of generating set				
Length	mm	5400	6540	6820
Width	mm	1850	1950	1950
Height	mm	2375	2620	2620
Weight	tonne	18	23	24

Heat rate and electrical efficiency at generator terminals, including engine-driven pumps. ISO 3046 conditions and LHV. Tolerance 5%. Power factor 0.8.

Wärtsilä 32

Technical data 50 Hz/750 rpm		6L32	9L32	12V32	16V32	18V32	20V32
Power, electrical	kW	2636	3974	5327	7124	8032	8924
Heat rate	kJ/kWh	8048	8006	7840	7815	7799	7799
Electrical efficiency	%	44.7	45.0	45.9	46.1	46.2	46.2
Technical data 60 Hz/720rpm							
Power, electrical	kW	2579	3888	5211	6970	7841	8730
Heat rate	kJ/kWh	8048	8006	7840	7815	7820	7799
Electrical efficiency	%	44.7	45.0	45.9	46.1	46.0	46.2
Dimensions and dry weight of generating set							
Length	mm	8766	11200	10030	11239	11500	12200
Width	mm	2418	2410	3050	3300	3300	3300
Height	mm	3738	3740	4420	4343	4220	4420
Weight	tonne	58	82	92	119	127	130

Heat rate and electrical efficiency at generator terminals, including engine-driven pumps. ISO 3046 conditions and LHV. Tolerance 5%. Power factor 0.8.

The Wärtsilä 20V46F-based power plant solution.

Wärtsilä 46

Technical data 50 Hz/500 rpm	Unit	12V46*	18V46*	20V46F/600 rpm
Power, electrical	kW	11384	17076	22425
Heat rate	kJ/kWh	7732	7732	7698
Electrical efficiency	%	46.6	46.6	46.8
Technical data 60 Hz/514 rpm				**600 rpm**
Power, electrical	kW	11384	17076	22425
Heat rate	kJ/kWh	7732	7732	7698
Electrical efficiency	%	46.6	46.6	46.8
Dimensions and dry weight of generating set				
Length	mm	15400	18260	20710
Width	mm	5090	5090	6275
Height	mm	5700	5885	6230
Weight	tonne	265	358	424

Heat rate and electrical efficiency at generator terminals, including engine-driven pumps. ISO 3046 conditions and LHV. Tolerance 5%. Power factor 0.8.

* Gas diesel version available.

Performance data as guidelines for CHP calculations

Wärtsilä gas fuelled generating sets at 50 and 60 Hz

Performance data			Wärtsilä gas engines at frequency 50 Hz				
Engine			**9L34SG**	**16V34SG**	**20V34SG**		**20V34DF**
						Gas mode	Liquid fuel mode
Engine optimization: NO_X (dry @ 15 vol-% O_2)		mg/ Nm^3	95–190*	95–190*	95–190*	190–380*	1460 - 2000* (LFO) 1600 - 2000 (HFO)
Electric power		kW	4343	7744	9730	8730	8730
Heat rate [1]		kJ/ kWh	7843	7819	7779	8031	8127
Efficiency [1]		%	45.9	46.0	46.3	44.8	44.3
Cooling circuit inlet/outlet [2]		°C	36/59	36/62	36/62	36/69	36/77
– HTCAC temperature inlet/outlet		°C	42/52	47/62	48/62	47/59	49/65
– Cylinder temperature inlet/outlet		°C	84/91	84/91	83/91	81/91	83/91
– Lubrication oil circuit inlet/outlet		°C	63/74	63/79	63/80	63/78	63/80
– LTCAC temperature inlet/outlet		°C	36/37	36/39	36/40	36/39	36/41
Charge air flow	± 5%	kg/s	6.7	12.0	15.0	14.1	17.5
Exhaust gas flow	± 5%	kg/s	6.9	12.3	15.4	14.5	17.9
Exhaust gas temp.	± 15	°C	390	390	390	380	335
Exhaust gas energy	± 10%	kW	2797	5002	6252	5714	5975
Cooling circuit-energy	± 10%	kW	2340	4169	5199	4595	5631
– HTCAC energy	± 10%	kW	1000	1634	1972	1710	2238
– Cylinder cooling energy	± 10%	kW	689	1229	1540	1404	1587
– Lubrication oil energy	± 10%	kW	528	941	1179	1065	1149
– LTCAC energy	± 10%	kW	123	365	508	416	662
Heat losses by radiation	± 20%	kW	135	240	300	350	350

Note: Heat and mass balances are dependent of ambient conditions and plant application, above given figures are for guidance only and calculated at ISO 3046 reference conditions; 25°C ambient temperature, 100 m above sea level and 30% relative humidity. Nm^3 defined at NTP (273.15 K and 101.3 kPa)

1) Heat rate and electrical efficiency at generator terminals, including engine-driven pumps, ISO 3046 conditions and LHV. Tolerance 5%. Power factor 0.8. Gas Methane Number >80

2) Single-circuit cooling system.

		Wärtsilä gas engines at frequency 60 Hz						
18V50DF		**9L34SG**	**16V34SG**	**20V34SG**	**20V34DF**		**18V50DF**	
Gas mode	Liquid fuel mode				Gas mode	Liquid fuel mode	Gas mode	Liquid fuel mode
500	2000	95–190*	95–190*	95–190*	190–380*	1460–2000* (LFO) 1600–2000 (HFO)	500	2000
16621	16621	4169	7434	9341	8439	8439	17076	17076
7616	8195	7843	7819	7779	8031	8127	7618	8186
47.3	43.9	45.9	46.0	46.3	44.8	44.3	47.3	44.0
36/68	42/83	36/55	36/61	36/62	36/68	36/75	36/68	42/85
45/59	54/72	43/55	47/61	48/62	46/58	48/64	45/59	55/73
80/85	79/85	85/91	84/91	83/91	81/91	83/91	80/85	78/85
63/74	63/78	63/76	63/79	63/80	63/78	63/79	63/74	63/78
36/38	42/46	36/37	36/39	36/40	36/39	36/40	36/38	42/46
26.2	32.5	6.4	11.5	14.4	13.5	16.7	26.1	32.5
27.0	33.5	6.6	11.8	14.8	13.9	17.2	26.6	33.5
395	377	390	390	390	380	335	401	369
11061	12705	2677	4800	6008	5486	5718	11379	12415
7403	9504	2245	4003	5030	4432	5404	7409	9991
3232	4129	964	1585	1952	1659	2168	3219	4117
2101	2514	662	1179	1477	1354	1517	2238	2925
1528	1967	507	903	1131	1035	1108	1538	2048
542	894	112	336	470	384	611	539	901
630	670	130	230	288	340	340	640	670

* Adjustable NO_X range according to local requierments. Heat rate given at the marked NO_X optimization level. Heat rates at other NO_X optimization levels to be checked case by case.

1 ppm-v @ 15% O_2 ≈ 2054 mg/Nm^3 dry @ 15% O_2, NO_X calculated as NO_2, Nm^3 defined at NTP (273.15 K and 101.3 kPa)

Wärtsilä liquid fuelled generating sets at 50 and 60 Hz

Performance data			Wärtsilä diesel engines at frequency 50 Hz				
Engine			**9L20**	**12V32**	**16V32**	**18V32**	**20V32**
Engine optimization: NO_X (dry @ 15 vol-% O_2)		ppm-vol	710*–780	710*–780	710*–780	710*–780	710*–780
Electric power		kW	1539	5327	7124	8032	8924
Heat rate [1]		kJ/kWh	8604	7840	7815	7799	7799
Efficiency [1]		%	41.8	45.9	46.1	46.2	46.2
High temperature circuit inlet/outlet [2]		°C	84/91	79/96	80/96	80/96	80/96
– HTCAC temperature inlet/outlet		°C		87/96	87/96	88/96	87/96
– Cylinder temperature inlet/outlet		°C	84/91	79/87	80/87	80/88	80/87
Low temperature circuit inlet/outlet		°C	34/47	38/49	38/49	38/49	38/49
– Lubrication oil circuit inlet/outlet		°C	63/78	63/77	63/78	63/78	63/79
– LTCAC temperature inlet/outlet		°C	34/44	38/43	38/43	38/43	38/43
Charge air flow	± 5%	kg/s	3.5	10.2	13.6	15.3	17.0
Exhaust gas flow	± 5%	kg/s	3.6	10.5	14.0	15.7	17.5
Exhaust gas temperature	± 15	°C	303	347	348	349	349
Exhaust gas heat	± 10%	kW	1052	3629	4849	5472	6082
High temperature circuit-energy	± 10%	kW	371	1891	2453	2726	3030
– HTCAC energy	± 10%	kW		1044	1319	1443	1604
– Cylinder cooling energy	± 10%	kW	371	847	1134	1283	1426
Low temperature circuit-energy	± 10%	kW	832	1246	1668	1885	2093
– Lubrication oil energy	± 10%	kW	246	657	877	988	1097
– LTCAC energy	± 10%	kW	586	589	791	897	996
Heat losses by radiation	± 20%	kW	68	185	247	278	308

Note: Heat and mass balances are dependent of ambient conditions and and plant application, above given figures are for guidance only and calculated at ISO 3046 reference conditions; 25°C ambient temperature, 100 m above sea level and 30% relative humidity.

1) Electrical output at generator terminals, including engine-driven pumps (LHV) at 100% load. ISO conditions and LHV. Tolerance 5%. Power factor 0.8.

		Wärtsilä diesel engines at frequency 60 Hz						
18V46	**20V46**	**9L20**	**12V32**	**16V32**	**18V32**	**20V32**	**18V46**	**20V46**
900*–970	900	710*–780	710*–780	710*–780	710*–780	710*–780	900*–970	900
17076	22425	1454	5211	6970	7841	8730	17076	22425
7732	7698	8561	7840	7815	7820	7799	7732	7698
46.6	46.8	42.0	45.9	46.1	46.0	46.2	46.6	46.8
80/91	85/91	84/91	80/96	80/96	80/96	80/96	80/91	85/91
83/91	51/68		87/96	87/96	88/96	88/96	83/91	51/68
80/83	85/91	84/91	80/87	80/87	80/88	80/88	80/83	85/91
42/55	42/68	34/48	38/49	38/49	38/49	38/49	42/55	42/68
63/80	58/73	63/77	63/77	63/78	63/78	63/79	63/80	58/73
42/47	49/51	34/44	38/43	38/43	38/43	38/43	42/47	49/51
30.3	42.4	3.3	9.7	13.0	14.6	16.2	30.3	42.4
31.2	43.5	3.4	10.0	13.3	15.0	16.7	31.2	43.5
360	333	302	352	352	354	354	360	333
11212	14394	991	3515	4698	5306	5897	11212	14394
5135	2265	345	1805	2427	2654	2949	5135	2265
3484	6164		971	1309	1388	1543	3484	6164
1651	2265	345	834	1118	1266	1407	1651	2265
3750	9464	776	1205	1623	1829	2032	3750	9464
2249	2490	221	646	862	972	1080	2249	2490
1501	810	556	559	761	857	951	1501	810
451	810	68	180	240	270	300	451	810

2) Two-circuit cooling system.

* Adjustable NO_X range according to local requierments. Heat rate given at the marked NO_X optimization level. Heat rates at other NO_X optimization levels to be checked case by case.

1 ppm-v @ 15% O_2 ≈ 2054 mg/Nm^3 dry @ 15% O_2, NO_X calculated as NO_2, Nm^3 defined at NTP (273.15 K and 101.3 kPa)

PUMPING AND COMPRESSION APPLICATIONS

Wärtsilä solutions for mechanical drives are tuned to meet the special needs of gas compression and pumping applications in the industry.

Our prime movers can run on most available liquid and gaseous fuels. The main component is the complete factory-assembled power train, with the engine and a gearbox and pump or a compressor mounted on a structural baseframe.

Systems for fuel treatment, cooling, control, automation and other supporting equipment are delivered as pre-tested factory-assembled modules.

From wellhead to refinery feed – Wärtsilä can offer the total power solution with guaranteed reliability and outstanding lifecycle economy.

The BTC pump station PT1 in Turkey is equipped with Wärtsilä 18V34SG pump sets.

DRIVER UNIT SIZES

PUMPING APPLICATIONS

Wärtsilä is the world's leading provider of diesel and gas engines for crude oil pumping applications. Wärtsilä's pumping units are designed for pipelines conveying various fluids such as crude oil, petroleum products, fresh water and waste water.

Our diesel engines are multifuel engines able to run on crude oil, heavy fuel oil, light fuel oil, gas or gas/oil combination. The gas engines (Wärtsilä 34SG and Wärtsilä 32GD) can be utilized as pump drives as well.

Wärtsilä's pump units comprise a complete train of engine, gearbox and pump on the baseframe along with the required auxiliary units. Pumps are selected according to the required pumping duty.

The Paramo Pump Station for Oleoducto de Crudos Pesados, Ecuador, is equipped with six Wärtsilä 12V32 pump sets.

The benefits of engine driven pump units include:

- Power for pumps always available
- Power generated with highest efficiency
- Fuel directly from pipeline (crude oil pumping)
- Multitude of fuels can be utilized
- Dependency on electrical grid minimized
- “One stop supply” of the pump train
- Close cooperation with major pump manufacturers
- Maintenance agreements available for entire pump train
- Renowned track record worldwide.

COMPRESSION APPLICATIONS

Wärtsilä compressor drives are based on proven Wärtsilä engines optimized to meet the special needs of gas compression, including a variable speed range of 70–100%, and constant torque range from 30 to 100%. Wärtsilä gas compressor units contain a variety of compression solutions for the natural gas industry, perfect for applications such as gas gathering, underground storage, gas processing, and pipeline transmission. Wärtsilä gas engines coupled with reciprocating or rotating compressors are considered the most modern and reliable technology on the market.

Wärtsilä gas compression concept's advantages:

- Modularized solution:
  - Cost efficient
  - Fast delivery
  - Minimized fieldwork
- User friendly operation environment:
  - Piping under floor level
  - All equipment located inside the compression hall
  - Easy access to all maintenance targets
  - Each compression train is in an individual hazardous area
  - Compression trains in own cells provide comfortable and safe conditions for operators during maintenance, while other cells are still producing.

Gas is stored under high pressure in underground, used gas reservoirs or in salt dome caverns.

PUMP DRIVES

GAS ENGINES
Wärtsilä 34SG

Technical data	750 rpm	9L34SG	16V34SG	20V34SG
Shaft power	kW	4050	7200	9000
Shaft power	hp	5431	9655	12069
Heat rate	kJ/kWh	7724	7724	7724
Shaft efficiency	%	46.6	46.6	46.6
Dimensions and dry weight				
Length	mm	6844	7803	8925
Width	mm	2366	3619	3670
Height	mm	3437	4100	4404
Weight	tonne	46.1	70.8	78.3

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 28 MJ/m^3_N. Tolerance 5%. Gas Methane Number > 80.
Nm^3 defined at NTP (273.15 K and 101.3 kPa).

DUAL-FUEL ENGINES
Wärtsilä 32GD

Technical data	750 rpm	6L32GD	9L32GD
Shaft power	kW	2760	4140
Shaft power	hp	3701	5552
Heat rate	kJ/kWh	7645	7645
Shaft efficiency	%	47.1	47.1
Dimensions and dry weight			
Length	mm	5297	7116
Width	mm	2300	2300
Height	mm	3421	3571
Weight	tonne	30	44

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 36 MJ/m^3_N. Lower LHV can be compensated by liquid fuel. Tolerance 5%.
Gas pressure at engine inlet 350 bar. Nm^3 defined at NTP (273.15 K and 101.3 kPa).

Wärtsilä 32GD

Technical data	750 rpm	12V32GD	16V32GD	20V32GD
Shaft power	kW	5520	7360	9200
Shaft power	hp	7402	9870	12337
Heat rate	kJ/kWh	7523	7523	7523
Shaft efficiency	%	47.9	47.9	47.9
Dimensions and dry weight				
Length	mm	6837	8206	9276
Width	mm	2870	3296	3233
Height	mm	3595	3595	4139
Weight	tonne	54	63	89

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 36 MJ/m^3_N. Lower LHV can be compensated by liquid fuel. Tolerance 5%.
Gas pressure at engine inlet 350 bar. Nm^3 defined at NTP (273.15 K and 101.3 kPa).

Wärtsilä 34DF

Technical data	750 rpm	6L34DF	9L34DF	16V34DF	20V34DF
Shaft power	kW	2700	4050	7200	9000
Shaft power	hp	3621	5431	9655	12069
Heat rate	kJ/kWh	7971 (7889)*	7971 (7889)*	7790 (7889)*	7790 (7889)*
Shaft efficiency	%	45.2(45.6)*	45.2 (45.6)*	46.2 (45.6)*	46.2 (45.6)*
Dimensions and dry weight					
Length	mm	5297	6844	7803	8925
Width	mm	2780	2366	3619	3670
Height	mm	3840	3437	4100	4404
Weight	tonne	30	46.1	70.8	78.3

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 28 MJ/m^3_N. Tolerance 5%. Gas Methane Number > 80.
Nm^3 defined at NTP (273.15 K and 101.3 kPa). *In oil mode.

PUMP DRIVES

LIQUID FUEL ENGINES

Wärtsilä 20

Technical data	1000 rpm	6L20	8L20	9L20
Shaft power	kW	1080	1440	1620
Shaft power	hp	1448	1931	2172
Heat rate	kJ/kWh	8113	8198	8156
Shaft efficiency	%	44.4	43.9	44.1
Dimensions and dry weight				
Length	mm	3108	3783	4076
Width	mm	1557	1691	1691
Height	mm	1972	2075	2073
Weight	tonne	8.8	10.4	10.9

Technical data is based on mechanical output at shaft, including engine-driven pumps, ISO conditions and LHV. Tolerance 5%.

Wärtsilä 32

Technical data	750 rpm	6L32	8L32	9L32	12V32	16V32	18V32	20V32
Shaft power	kW	2760	3680	4140	5520	7360	8280	9200
Shaft power	hp	3701	4935	5552	7402	9870	11104	12337
Heat rate	kJ/kWh	7767	7767	7767	7645	7645	7645	7645
Shaft efficiency	%	46.3	46.3	46.3	47.1	47.1	47.1	47.1
Dimensions and dry weight								
Length	mm	5297	6510	7116	6837	8206	8766	9276
Width	mm	2300	2300	2300	2870	3296	3296	3233
Height	mm	3421	3571	3571	3595	3595	3595	4139
Weight	tonne	30	40	44	54	63	70	89

Technical data is based on mechanical output at shaft, including engine-driven pumps, ISO conditions and LHV. Tolerance 5%.

BTC pump station with five pump sets driven by Wärtsilä 18V34SG gas engines.

Wärtsilä 46

Technical data	500 rpm	9L46	12V46	16V46
Shaft power	kW	8775	11700	15600
Shaft power	hp	11767	15690	20920
Heat rate	kJ/kWh	7726	7726	7726
Shaft efficiency	%	46.6	46.6	46.6
Dimensions and dry weight				
Length	mm	10750	10320	12460
Width	mm	3270	4520	4420
Height	mm	5070	5560	5160
Weight	tonne	133	170	217

Technical data is based on mechanical output at shaft, including engine-driven pumps, ISO conditions and LHV. Tolerance 5%.

COMPRESSOR DRIVES

GAS ENGINES

Wärtsilä 34SG

Technical data	750 rpm	9L34SG	16V34SG	20V34SG
Shaft power	kW	4050	7200	9000
Shaft power	hp	5431	9655	12069
Heat rate	kJ/kWh	7724	7724	7724
Shaft efficiency	%	46.6	46.6	46.6
Dimensions and dry weight				
Length	mm	6844	7803	8925
Width	mm	2366	3619	3670
Height	mm	3437	4100	4404
Weight	tonne	46.1	70.8	78.3

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 28 MJ/m^3_N. Tolerance 5%. Gas Methane Number > 80.
Nm^3 defined at NTP (273.15 K and 101.3 kPa).

DUAL-FUEL ENGINES

Wärtsilä 32GD

Technical data	750 rpm	6L32GD	9L32GD
Shaft power	kW	2760	4140
Shaft power	hp	3701	5552
Heat rate	kJ/kWh	7645	7645
Shaft efficiency	%	47.1	47.1
Dimensions and dry weight			
Length	mm	5297	7116
Width	mm	2300	2300
Height	mm	3421	3571
Weight	tonne	30	44

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 36 MJ/m^3_N. Lower LHV can be compensated by liquid fuel. Tolerance 5%.
Gas pressure at engine inlet 350 bar. Nm^3 defined at NTP (273.15 K and 101.3 kPa).

Wärtsilä 32GD

Technical data	750 rpm	12V32GD	16V32GD	20V32GD
Shaft power	kW	5520	7360	9200
Shaft power	hp	7402	9870	12337
Heat rate	kJ/kWh	7523	7523	7523
Shaft efficiency	%	47.9	47.9	47.9
Dimensions and dry weight				
Length	mm	6837	8206	9276
Width	mm	2870	3296	3233
Height	mm	3595	3595	4139
Weight	tonne	54	63	89

Heat rate and efficiency at shaft, including engine driven pumps, ISO 3046 conditions and gas LHV > 36 MJ/m^3_N. Lower LHV can be compensated by liquid fuel. Tolerance 5%.
Gas pressure at engine inlet 350 bar. Nm^3 defined at NTP (273.15 K and 101.3 kPa).

Wärtsilä engines are able to run on a wide selection of fuels, ranging from natural gas to fuel-water emulsions.

Fuels such as crude oil, fuel-water emulsions, associated gas, liquid biofuel, biogas and other fuels outside globally recognised standard fuel specifications, should be carefully analyzed for each power plant project prior to use. Due to the nature of these types of fuels their quality might vary over time and consequently fuel quality analysis should be done on a regular basis.

GASEOUS FUELS

NATURAL GAS

Natural gas of commercial pipeline quality. These gases consist mainly of methane and are processed to meet guaranteed specifications for heating value, Wobbe index and cleanliness.

ASSOCIATED GAS

Associated gas is a constituent that is separated from crude oil in the degassing equipment at the oil fields. The methane content is less than in

natural gas, but the concentration of heavier hydrocarbons is higher, thus normally producing a high heating value. Gas-diesel engines are very suitable for burning associated gas, either in normal gas-diesel mode or using the “fuel sharing” mode.

BIO GASES

Bio gases are the result of treating biological matter in digesters or through other decomposing processes. The resulting gas consists of methane and carbon dioxide.

COAL BED NATURAL GAS

Coal bed natural gas is gas that is collected from underground coal layers. It contains methane, water and carbon dioxide in varying concentrations.

LIQUID FUELS

LIGHT FUEL OIL

Light fuel oils or diesel oils are high value distillates and have traditionally been the fuels for diesel engines power plants both for standby operation and baseload applications. The use of light fuel oils in baseload applications has decreased since it has become possible to use cheaper lower grade fuels. There are however still applications such as backup power plants, islands and installations in arctic conditions where light fuel oil is the preferred alternative.

HEAVY FUEL OILS

Heavy fuel oils are blended products based on the residues from various 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 plants 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 ambient temperature. Crude oil can also be used as fuel in power plants with diesel engines, for example for power production in the oil field. Another application is pumping stations along a crude pipe line where fuel from the pipe line can be used for the prime movers.

LIQUID BIOFUEL

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 are 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 EMULSION

An emulsion of the oil-in-water type is one way of utilizing 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.

NATURAL GAS

Wärtsilä gas engines are designed and developed for continuous operation on natural gas, without reduction in the rated output, on gas qualities according to the specification below. Other gases than pipeline quality natural gas can also be used and are considered on a case by case basis.

Property	Unit	Limit
Lower heating value (LHV), min.	MJ/m^3_N [2]	28[1]
Methane number (MN), min.		80[3]
Methane (CH_4) content, min. [4]	Vol-%	70
Hydrogen sulphide (H_2S) content, max.	Vol-%	0.05
Hydrogen (H_2) content, max. [4]	Vol-%	3.0
Water and hydrocarbon condensate before engine, max. [5]	Vol-%	Not allowed
Ammonia content, max.	mg/m^3_N	25
Chlorine + Fluorine content, max.	mg/m^3_N	50
Particles or solids content in engine inlet, max.	mg/m^3_N	50
Particles or solids size in engine inlet, max.	μm	5
Gas inlet temperature	°C	0–60

1) The required gas feed pressure is depending on the LHV, e.g. for SG and DF engines 28 MJ/m^3 N requires 6 bar a pressure for full engine output. In GD engines low LHV can be compensated with fuel sharing.

2) Values for volume (m^3_N) are given at 0°C and 101.3 kPa.

3) SG and DF engine outputs is depending on the Methane Number. Full engine output at highest efficiency is achieved at MN80, lower MN can be used with an influence on engine performance and may cause derating of the engine. GD engines are not affected by MN.

Methane Number (MN) can be assigned to any gaseous fuel based on its composition and it gives a scale to compare the resistance to knock of different gases. The MN is calculated by Wärtsilä.

4) If the hydrogen content of gas is higher than 3.0 vol-%, or the methane content is lower than 70 vol-% the use of gas has to be considered case by case.

5) Dew point of natural gas is below the minimum operating temperature and pressure.

LIGHT FUEL OIL

The fuel specification is based on the ISO 8217:2005(E) standard and covers the fuel categories ISO-F-DMX, DMA, DMB and DMC.

Property	Unit	ISO-F-DMX	ISO-F-DMA	ISO-F-DMB	ISO-F-DMC [1]	Test method reference
Appearance		Clear and bright		–	–	Visual inspection
Viscosity, min., bef. injection pumps [2]	cSt	1.8–2.8 [5]	1.8–2.8 [5]	1.8–2.8 [5]	1.8–2.8 [5]	
Viscosity at 40°C, max. Viscosity, max. bef. injection pumps [2]	cSt cSt	5.50 24	6.00 24	11.0 24	14.0 24	ISO 3104
Density at 15°C, max.	kg/m³	–	890.0	900.0	920.0	ISO 3675 or 12185
Cetane index, min.		45	40	35	–	ISO 4264
Water max.	Vol-%	–	–	0.3	0.3	ISO 3733
Sulphur, max.	% m/m	1.00	1.50	2.00 [3]	2.00 [3]	ISO 8574 or 14596
Ash, max.	% m/m	0.01	0.01	0.01	0.05	ISO 6245
Vanadium, max.	mg/kg	–	–	–	100	ISO 14597 or IP 501 or 470
Sodium bef. engine, max. [2]	mg/kg	–	–	–	30	ISO 10478
Aluminium + Silicon, max.	mg/kg	–	–	–	25	ISO 10478 or IP 501 or 470
Aluminium + Silicon bef. engine, max. [2]	mg/kg	–	–	–	15	ISO 10478 or IP 501 or 470
Carbon residue on 10Vol-% distillation bottoms, max. Carbon residue, max.	% m/m	0.30 –	0.30 –	– 0.30	– 2.50	ISO 10370
Flash point (PMCC), min.	°C	60 [2]	60	60	60	ISO 2719
Pour point, max. – winter quality – summer quality	°C	– –	–6 0	0 6	0 6	ISO 3016
Cloud point, max.	°C	–16	–	–	–	ISO 3015
Total sediment existent, max.	% m/m	–	–	0.10	0.10	ISO 10307-1
Used lubricating oil [4] – calcium, max. – zinc, max. – phosphorus, max.	 mg/kg mg/kg mg/kg	 – – –	 – – –	 – – –	 30 15 15	 IP 501 or 470 IP 501 or 470 IP 501 or 500

1) Use of ISO-F-DMC category fuel is allowed provided that the fuel treatment system is equipped with a fuel centrifuge.

2) Additional properties specified by the engine manufacturer, which are not included in the ISO specification or differ from the ISO specification.

3) Following sulphur limits of the liquid fuel content or equivalent SO_2-levels will apply in Non-Degraded Airsheds (NDA) for reciprocating engine plants according to the "Thermal Power Plants EHS Guidelines" issued by International Finance Corporation (IFC) in 2008:

- 50 .. 300 MWth: maximum 2% m/m S
- > 300 MWth: maximum 1% m/m

For smaller plants there are other limits.

There may also be other national/local variations.4) A fuel shall be considered to be free of used lubricating oil (ULO), if one or more of the elements calcium, zinc and phosphorus are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO.

5) Min. limit at engine inlet in running conditions; Wärtsilä 20: 1.8 cSt, Wärtsilä 32: 2.0 cSt, Wärtsilä 46: 2.8 cSt, Wärtsilä 34DF: 2.0 cSt, Wärtsilä 50DF: 2.8 cSt

HEAVY FUEL OIL

The fuel specification “HFO 2” is based on the ISO 8217:2005(E) standard and covers the fuel categories ISO-F-RMA 30 – RMK 700. Additionally, the engine manufacturer has specified the fuel specification “HFO 1”. This tighter specification is an alternative and by using a fuel fulfilling this specification, longer overhaul intervals of specific engine components may be expected (See the Engine Manual of a specific engine type).

Property	Unit	Limit HFO 1	Limit HFO 2	Test method reference
Viscosity at 50 / 100°C, max. at 100°F, max.	 cSt Redwood No. 1 sec.	 700 / 55 7200	 700 / 55 7200	ISO 3104
Viscosity bef. injection pumps 4)	cSt	20±4	20±4	
Density at 15°C, max.	kg/m³	991.0 / 1010.0 1)	991.0 / 1010.0 1)	ISO 3675 or 12185
CCAI, max. 4)		850	870 2)	ISO 8217, Annex B
Water max.	Vol-%	0.5	0.5	ISO 3733
Water bef. engine, max. 4)	Vol-%	0.3	0.3	ISO 3733
Sulphur, max.	% m/m	1.50	4.50 5)	ISO 8754 or 14596
Ash, max.	% m/m	0.05	0.15	ISO 6245
Vanadium, max. 3)	mg/kg	100	600	ISO 14597 or IP 501 or 470
Sodium, max. 3, 4)	mg/kg	50	50	ISO 10478
Sodium bef. engine, max. 3, 4)	mg/kg	30	30	ISO 10478
Aluminium + Silicon, max.	mg/kg	30	80	ISO 10478 or IP 501 or 470
Aluminium + Silicon bef. engine, max. 4)	mg/kg	15	15	ISO 10478 or IP 501 or 470
Carbon residue, max.	% m/m	15	22	ISO 10370
Asphaltenes, max. 4)	% m/m	8	14	ASTM D 3279
Flash point (PMCC), min.	°C	60	60	ISO 2719
Pour point, max.	°C	30	30	ISO 3016
Total sediment potential, max.	% m/m	0.10	0.10	ISO 10307-2
Used lubricating oil 6) – Calcium, max. – Zinc, max. – Phosphorus, max.	 mg/kg mg/kg mg/kg	 30 15 15	 30 15 15	 IP 501 or 470 IP 501 or 470 IP 501 or 500

GERAMAR I & II, STATE OF MARANHÃO, BRAZIL
2 plants close to each other
Type ..... Grid stability
Engines..... Geramar I, 19 x Wärtsilä 20V32
Geramar II, 19 x Wärtsilä 20V32
Total output..... 331 MW
Fuel.....HFO
Delivered..... 2010

1) Max. 1010 kg/m^3 at 15°C, provided the fuel treatment system is designed accordingly.

2) Straight run residues show CCAI values in the 770 to 840 range and are very good ignitors. Cracked residues delivered as bunkers may range from 840 to – in exceptional cases – above 900. Most bunkers remain in the max. 850 to 870 range at the moment.

3) Sodium contributes to hot corrosion on exhaust valves when combined with high sulphur and vanadium contents. Sodium also strongly contributes to fouling of the exhaust gas turbine blading at high loads.

The aggressiveness of the fuel depends on its proportions of sodium and vanadium, but also on the total amount of ash. Hot corrosion and deposit formation are, however, also influenced by other ash constituents. It is therefore difficult to set strict limits based only on the sodium and vanadium content of the fuel. Also a fuel with lower sodium and vanadium contents than specified above, can cause hot corrosion on engine components.

4) Additional properties specified by the engine manufacturer, which are not included in the ISO specification.

6) A fuel shall be considered to be free of used lubricating oil (ULO), if one or more of the elements calcium, zinc and phosphorus are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO.

CRUDE OIL

Property	Unit	Limit	Test method reference
Viscosity, min., bef. injection pumps max. bef. injection pumps	cSt	2.8 24	
Viscosity at 50 / 100°C, max. at 100°F, max.	cSt Redwood No. 1 sec.	700 / 55 7200	ISO 3104
Density at 15°C, max.	kg/m³	991.0 / 1010.0 [1]	ISO 3675 or 12185
CCAI, max.		870	ISO 8217
Water bef. engine, max.	Vol-%	0.3	ISO 3733
Sulphur, max.	% m/m	4.50	ISO 8754 or 14596
Ash, max.	% m/m	0.15	ISO 6245
Vanadium, max.	mg/kg	600	ISO 14597 or IP 501 or 470
Sodium, max.	mg/kg	50	ISO 10478
Sodium bef. engine, max.	mg/kg	30	ISO 10478
Aluminium + Silicon, max.	mg/kg	30	ISO 10478 or IP 501 or 470
Aluminium + Silicon bef. engine, max.	mg/kg	15	ISO 10478 or IP 501 or 470
Calcium + Potassium + Magnesium bef. engine, max.	mg/kg	50	IP 501 or 500 for Ca and ISO 10478 for K and Mg
Carbon residue, max.	% m/m	22	ISO 10370
Asphaltenes, max.	% m/m	14	ASTM D 3279
Reid vapour pressure, max. at 37.8°C	kPa	65	ASTM D 323
Pour point, max.	°C	30	ISO 3016
Cloud point or Cold filter plugging point, max.	°C	60 [2]	ISO 3015 IP 309
Total sediment potential, max.	% m/m	0.10	ISO 10307-2
Hydrogen sulphide, max.	mg/kg	5	IP 399

1) Max. 1010 kg/m³ at 15°C, provided the fuel treatment system is designed accordingly.

2) Fuel temperature in the whole fuel system including storage tanks must be kept during standby, start-up and operation 10–15°C above the cloud point in order to avoid crystallization and formation of solid waxy compounds (typically paraffins) causing blocking of fuel filters and small size orifices. Additionally, fuel viscosity sets a limit to cloud point so that fuel must not be heated above the temperature resulting in a lower viscosity before the injection pumps than specified above

LIQUID BIOFUEL

Property	Unit	Limit	Test method reference
Viscosity, max. Injection viscosity, min. Injection viscosity, max.	cSt @ 40°C cSt cSt	100 [1)] 1.8 – 2.8 [2)] 24	ISO 3104
Density, max.	kg/m³ @ 15°C	991	ISO 3675 or 12185
Ignition properties [3)]			FIA test
Sulphur, max.	% m/m	0.05	ISO 8754
Total sediment existent, max.	% m/m	0.05	ISO 10307-1
Water, max. before engine	Vol-%	0.20	ISO 3733
Micro carbon residue, max.	% m/m	0.50	ISO 10370
Ash, max.	% m/m	0.05	ISO 6245 / LP1001
Phosphorus, max.	mg/kg	100	ISO 10478
Silicon, max.	mg/kg	15	ISO 10478
Alkali content (Na+K), max.	mg/kg	30	ISO 10478
Flash point (PMCC), min.	°C	60	ISO 2719
Cloud point, max.	°C	[4)]	ISO 3015
Cold filter plugging point, max.	°C	[4)]	IP 309
Copper strip corrosion (3 hrs @ 50°C), max.	Rating	1b	ASTM D130
Steel corrosion (24 / 72 hours @ 20, 60 and 120°C), max.	Rating	No signs of corrosion	LP 2902
Acid number, max.	mg KOH/g	15.0	ASTM D664
Strong acid number, max.	mg KOH/g	0.0	ASTM D664
Iodine number, max.	g iodine /100 g	120	ISO 3961
Synthetic polymers	% m/m	Report [5)]	LP 2401 ext. and LP 3402

1) If injection viscosity of max. 24 cSt can not be achieved with an unheated fuel, fuel system has to be equipped with a heater

2) Min. limit at engine inlet in running conditions; Wärtsilä 20: 1.8 cSt, Wärtsilä 32: 2.0 cSt, Wärtsilä 46: 2.8 cSt, Wärtsilä 34DF: 2.0 cSt, Wärtsilä 50DF: 2.8 cSt

3) Ignition properties have to be equal to or better than the requirements for fossil fuels, i.e., CN min. 35 for LFO and CCAI max. 870 for HFO.

4) Cloud point and cold filter plugging point have to be at least 10°C below fuel injection temperature.

5) Biofuels originating from food industry can contain synthetic polymers, like e.g. styrene, propene and ethylene used in packing material. Such compounds can cause filter clogging and shall thus not be present in biofuels.

BIODIESEL

Property	Unit	Limit	Test method reference
Viscosity, min. - max. Injection viscosity, min.	cSt @ 40°C cSt	3.50 – 5.00 1.8 – 2.8 [1]	EN ISO 3104
Density, min. - max.	kg/m³ @ 15°C	860 - 900	EN ISO 3675 / 12185
Cetane number, min.		51.0	EN ISO 5165
Sulphur content, max.	mg/kg	10.0	prEN ISO 20846 / 20884
Sulphated ash content, max.	% m/m	0.02	ISO 3987
Total contamination, max.	mg/kg	24	EN 12662
Water content, max.	mg/kg	500	EN ISO 12937
Carbon residue (on 10% distillation residue), max.	% m/m	0.30	EN ISO 10370
Phosphorus content, max.	mg/kg	10.0	EN 14107
Group I metals (Na + K) content, max.	mg/kg	5.0	EN 14108 / 14109
Group II metals (Ca + Mg) content, max.	mg/kg	5.0	prEN 14538
Flash point, min.	°C	120	prEN ISO 3679
Cold filter plugging point, max. (climate dependent requirement)	°C	-44 → +5 [2]	EN 116
Oxidation stability @ 110°C, min.	hrs	6.0	EN 14112
Copper strip corrosion (3 hrs @ 50°C), max.	Rating	Class 1	EN ISO 2160
Acid value, max.	mg KOH/g	0.50	EN 14104
Iodine value, max.	g iodine / 100 g	120	EN 14111
Ester content, min.	% m/m	96.5	EN 14103
Linolenic acid methyl ester, max.	% m/m	12.0	EN 14103
Polyunsaturated methyl esters, max.	% m/m	1	
Methanol content, max.	% m/m	0.20	EN 14110
Monoglyceride content, max.	% m/m	0.80	EN 14105
Diglyceride content, max.	% m/m	0.20	EN 14105
Triglyceride content, max.	% m/m	0.20	EN 14105
Free glycerol, max.	% m/m	0.02	EN 14105 / 14106
Total glycerol, max.	% m/m	0.25	EN 14105

1) Min. limit at engine inlet in running conditions; Wärtsilä 20: 1.8 cSt, Wärtsilä 32: 2.0 cSt, Wärtsilä 46: 2.8 cSt, Wärtsilä 34DF: 2.0 cSt, Wärtsilä 50DF: 2.0 cSt for pilot fuel & 2.8 cSt for main / backup fuel

2) Cold flow properties of renewable bio diesel can vary based on the geographical location and also based on the feedstock properties, which issues must be taken into account when designing the fuel system.

ENGINE WORKING PRINCIPLES

SPARK-IGNITED ENGINES (SG)

The SG engines are spark-ignited lean-burn otto cycle gas engines. In this process, the gas is mixed with air before the inlet valves. During the intake period, gas is also fed into a small prechamber, where the gas mixture is rich compared to the gas in the cylinder. At the end of the compression phase the gas/air mixture in the prechamber is ignited by a spark plug. The flames from the nozzle of the prechamber ignite the gas/air mixture in the whole cylinder. After the working phase the cylinder is emptied of exhaust and the process starts again.

DUAL-FUEL ENGINES (DF)

The dual-fuel engine utilizes a “lean-burn” otto combustion process when operating on gas. Here, the gas is mixed with air before the intake valves during the air intake period. After the compression phase, the gas/air mixture is ignited by a small amount of liquid pilot fuel (LFO). After the working phase the exhaust gas valves open and the cylinder is emptied of exhaust gases. The inlet air valves open when the exhaust gas valves close, and the process starts again.

The dual-fuel engine is also equipped with a backup fuel system. In the event of a gas supply interruption, the engine transfers from gas to fuel oil operation (LFO, HFO) at any load instantaneously and automatically. Futhermore, the separate backup fuel system makes it possible to switch over from LFO to HFO without load reduction. During fuel oil operation the DF engine utilizes the conventional diesel process.

GAS-DIESEL ENGINES (GD)

The GD engine utilizes the diesel combustion process in all operational modes. In **gas mode**, the gas is injected at high pressure after the pilot fuel and is ignited by the flame from the pilot fuel injection. The amount of pilot fuel is equivalent to approximately 5% of the fuel energy input at full engine load.

The gas-diesel engine can be switched over instantly to **liquid fuel mode** operation. The liquid fuel can be light fuel oil, heavy fuel oil or crude oil. In this case, the process is the same as the conventional diesel process.

In **fuel sharing mode**, the ratio between liquid and gas fuel amounts can be controlled and varied during operation. The operating window for the fuel sharing mode is 30 to 100% load and the gas/liquid fuel ratio can vary according to the fuel sharing window.

The gas-diesel process can tolerate big variations in the gas quality and is especially suitable for “non-pipeline quality gas”, such as associated gas in oil fields.

DIESEL ENGINES

In the diesel process, liquid fuel is injected into the cylinder at high pressure by camshaft-operated pumps. The fuel is ignited instantly due to the high temperature resulting from the compression. Combustion takes place under constant pressure with fuel injected into the cylinder during combustion. After the working phase, the exhaust gas valves open and the cylinder is emptied of exhaust gases. With the piston in its upper position, the inlet valves open just before the exhaust gas valves close, and the cylinder is filled with air. In Wärtsilä engines the inlet valves close just before the piston reaches the bottom dead centre. This method, called “Miller timing”, reduces the work of compression and the combustion temperature, which results in higher engine efficiency and lower emissions.

MODULAR SOLUTIONS

The main goal of modularized design is to achieve highest possible quality with a reasonable cost, thus ensuring better overall feasibility for the power plant investment. The key elements are standardised process solutions, component selection and interfaces, and effective, as well as flexible, change management.

The focus of modularization is around the engine and inside the power house, even though the modules can be found in most locations, starting from the unloading of fuel, lubricating oil and other process-related items.

Rapid installation time is one of the main benefits of using modules. It has been calculated that the use of non-standard modules compared to standard modules could increase delivery times by a factor of 1.5.

Prefabrication in combination with the use of well-proven components from the best suppliers ensures consistent high quality and less complex specifications during the procurement phase.

Compact and predefined sizes for container transportation make transportation simpler and smoother. With the modular design most components can also be standardised, thereby offering clear savings both in design and construction stage as well as in operation stage of the power plant. Using portfolio modules leads to higher documentation quality during the tender phase.

Through the stricter control it gives over the manufacturing, cleaning and painting processes, as compared to carrying out this work on site, modularization also has a positive impact on the environment.

OIL PLANT WÄRTSILÄ 46 (engine hall modules)

GAS PLANT WÄRTSILÄ 34SG (auxiliary area)

GAS PLANT WÄRTSILÄ 34SG (engine hall modules)

AUTOMATION

Wärtsilä Power Plant Automation is based on the following building blocks:

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

The systems have been developed with complete integration, and have clear and easy user interfaces providing a uniform interface and logic for the operators.

The latest automation equipment and innovations are introduced based on systematically field tested solutions.

Wärtsilä Power Plant Automation provides a complete plant management solution with standardized modules, which can be tuned to the operator´s particular needs.

OPERATIONAL FLEXIBILITY: ANY OPERATION MODE CAN BE MET

Operational flexibility is applied in the same package supporting either baseload, intermediate, peaking or standby power generation. Thanks to the intelligent controllers, the Wärtsilä solution provides:

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

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

Ergonomics have been taken into account in the design of the control room, giving the operator a comfortable and user friendly environment.

EMISSIONS REDUCTION TECHNOLOGIES

One of the principal aims of Wärtsilä's Power Plants business is to maintain a high level of expertise in cleaning methods for different effluents from power plants and to offer a variety of tested emissions reduction technologies for different market needs.

EMISSIONS REDUCTION – GAS ENGINES

SO_2 and PM emissions are insignificant for power plants running on natural gas. The NO_X emissions are also lower than with fuel oil-fired diesel engines.

DRY TECHNOLOGIES (PRIMARY)

Modern Otto gas engines use the lean-burn combustion method. In the lean-burn process natural gas and air are pre-mixed before being introduced into the cylinders. This low fuel/air ratio, called lean-burn, reduces NO_X emissions efficiently due to a lower combustion temperature. An added advantage with lean burn operation is the high output and efficiency of the engine.

Gas fired lean-burn engines have sufficiently low NO_X emissions to comply with most national/local regulations using lean burn primary methods only.

OXIDATION CATALYSTS

Gas-fired spark-ignited (SG) and dual-fuel (DF) engines are equipped with oxidation catalysts for the abatement of CO or hydrocarbon emissions if the national regulations or local conditions so determine.

WÄRTSILÄ IOXI

The Wärtsilä IOXI (Integrated Oxidation Catalyst) is a compact, cost efficient product that is applicable for moderate carbon monoxide and formaldehyde reduction from gas engines. By using the product with gas engines one complies with stationary regulations such as German TA Luft. Several commercial deliveries with a successful track-record have already taken place.

ULTRA LOW EMISSION (ULE) SOLUTION

In areas that are subject to stringent control of NO_X emissions due to, for example, existing pollution levels in non-attainment airsheds, gas fired engines can be equipped with SCR units. The SCR units can reduce NO_X emissions to a single digit level with lean-burn gas engines (in natural gas mode).

In some areas efficient multi-component emissions reduction is required.

The ULE system comprises a selective catalytic reduction (SCR) for NO_X emissions and catalytic oxidation for CO and hydrocarbon emissions. The ULE solution also includes a thorough optimization of engine operation in different conditions in order to obtain the best overall performance.

EMISSIONS REDUCTION – DIESEL ENGINES

Nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulate matter (PM) are the air emissions of main interest regarding stationary diesel engines. SO_2 and PM emissions are mainly related to the quality of the liquid fuel. Diesel engines used in the power industry have low carbon monoxide (CO) and hydrocarbon (HC) emissions thanks to their high thermal efficiency.

Wärtsilä's product development strategy for fuel oil-fired diesel power plants is to meet the stack emission limits set by the World Bank/IFC guidelines "General/Thermal Power Plants EHS Guidelines" for new stationary reciprocating engine installations up to 300 MWth in non-degraded airsheds by using dry primary methods.

Secondary flue gas treatment methods are available for installations located in polluted airsheds (degraded airsheds), those subject to stricter national/local emission limits or when only low grade liquid fuels are commercially available.

NO_X emissions formation in the combustion process can be minimized using primary or secondary abatement methods.

DRY PRIMARY METHODS

The target of dry primary methods in the Wärtsilä engine development process is to achieve the best overall emissions performance while maintaining the good thermal efficiency of the engine. The main elements of the Low-NO_X combustion process in Wärtsilä diesel engines are:

- Late fuel injection start
- High compression ratio
- Optimized combustion chamber
- Optimized 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 unit (SCR).

SELECTIVE CATALYTIC REDUCTION (SCR)

Wärtsilä's diesel engine power plants can be equipped with SCR products if required. Catalyst elements with a honeycomb structure are used to ensure a compact structure, when running on light or heavy fuel oil with sulphur content below 2%.

With lower grade fuel oils, a less dense element structure (plate type) in combination with efficient dust blowing are required to minimize fouling of the elements.

SCR is an effective method; NO_X emissions are typically reduced up to 80–90%. At higher NO_X reduction rates the control system is critical due to its operation within a narrow window. At high reduction rates the size of the SCR reactor increases and more complicated premixing and reagent injection systems are needed.

FLUE GAS DESULPHURIZATION (FGD)

Several FGD types are available for the power plant market. The most feasible methods in stationary engine plants have generally been shown to be wet NaOH FGD in smaller plants and wet $CaCO_3$ FGD in larger plants. Both these wet FGD systems are typically capable of removing up to 90% of the SO_2 emissions.

The FGD end-products produced, 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 used fuel oil,

lubrication oil, process water and reagents. The disposal and utilization options available for the end product should be examined in the environmental assessment of the project, by considering the existing infrastructure and legislation/regulations.

ELECTROSTATIC PRECIPITATOR (ESP)

A dry ESP unit reduces particulate matter (PM) flue gas emissions when burning high ash fuels. The ESP technique provides a stable, low pressure-loss option to reduce PM emissions. PM levels of 50 mg/m^3 (dry @ 15% O_2, NTP) (PM measurement method ISO 9096 or other mainly similar methods) can be achieved when using an ESP system in an HFO / FWE-fuelled power plant.

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 used fuel and lubrication oil. The disposal and utilization options available for the end product should be examined in the environmental assessment of the project by considering the existing infrastructure and legislation/regulations.

EMISSIONS MONITORING

The measurement of emissions on a regular basis, e.g. annually, in combination with strict compliance with fuel specifications is commonly used for showing compliance with emission requirements.

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

In some installations, continuous emissions monitoring based on analyzers is required. There are a multitude of different CEM systems on the market and the choice of system needs to carefully consider the installation specific features, such as measured components, fuel and stack configuration. The integration of emissions data handling and reporting into the plant system is a crucial part of a successful emissions monitoring system.

WÄRTSILÄ DEVELOPMENT & FINANCIAL SERVICES

Wärtsilä has a global team of power plant project developers, funding professionals and carbon finance experts in Wärtsilä Development & Financial Services (WDFS).

The WDFS scope of services includes:

- Vendor arranged funding and application of export credit guarantees
- IPP project development
- Carbon credit consulting
- Financial advisory services including financial modelling.

WDFS supports Wärtsilä's 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 uniquely situated to structure financing to suit each customer's requirements. A manufacturing presence in several countries provides a competitive advantage for accessing ECA-backed funding, especially through Finnvera (Finland) and SACE (Italy).

WDFS develops independent power producer (IPP) projects based on Wärtsilä reciprocating engine technology and know-how, supplying flexible and cost-efficient electric power to customers worldwide. The global organization focuses on developing environmentally responsible power projects with

sound financing structures. With a proven track record since 1991, WDFS has successfully developed and closed over 30 highly feasible IPP projects (approx. 3000 MW) around the world. For the IPP projects WDFS structures and negotiates project financing on a limited resource or non-resource basis. WDFS has over the years proven its ability to mobilize capital from multilateral and bilateral institutions, local and international commercial banks, and equity investors.

WDFS also provides a carbon financing service that supports clients in developing projects under the UN's Clean Development Mechanism and Joint Implementation. With in-house expertise WDFS offers a full suite of carbon finance services for power plant project developers; feasibility analyses, CDM

project documentation, project validation and registration support and carbon credit sales. Carbon financing can be used to improve the profitability and bankability of clean and efficient power solutions. The service particularly targets projects making a technological leap to best-available solutions, through gas conversions, utilization of biofuels or associated gas and introduction of high-efficiency greenfield capacity. Under a unique industry approach Wärtsilä offers its carbon financing service as an integrated part of technical project development and financing.

With WDFS's scope of services from project development to assistance with the most appropriate financial structure, Wärtsilä Power Plants can enhance its competitive product offering and its strategy of becoming a long-term partner to its customers.

PROJECT MANAGEMENT SERVICES

The professional Power Plants Project Management organization plans, leads, manages and executes projects for our customers. We support our customers with cost estimates, scheduling and project planning. The main project execution activities are engineering, purchasing, logistics and transport, contract management, risk management, site management and supervision, construction and installation, commissioning, training and management of document deliverables up to final documentation. The projects are managed by our professional personnel using prudent, professional project management methodology and best practices which have been developed over the years within Wärtsilä Power Plants.

We are able to offer a variety of service packages using alternative contract types:

- **EPC** (Engineering, Procurement, Construction) is a solution where the customer has only one point of contact, which minimizes the customer's risks. The contract covers project management , site management and supervision, engineering, materials and equipment, civil works, foundation and site infrastructure works, transport and installation, commissioning as well as schedule and performance guarantees for the entire solution.
- **Process EPC** includes the same features as for EPC, except installation is only done above floor level. Subsoil and foundation works, underground

materials supply and site area works are performed by the customer or by another contractor contracted by the customer.

- **Extended EEQ** (Extended Engineered Equipment Delivery) is a complete supply solution for defined scope including detailed engineering for total solutions, all materials and equipment, and technical advisory services for installation and commissioning. The customer needs to contract another contractor to perform installation and civil works on site.
- **Basic EEQ** (Basic Engineered Equipment Delivery) is the most basic service where main equipment and related auxiliary equipment and materials are engineered and supplied. The service includes configuration and engineering for supplied equipment and materials, transport, and technical advisory services for installation and commissioning.
- **EPCM** is a service contract providing Construction Management services to the customer. The service includes a variety of services: construction management and site management services, project and construction time scheduling services, sub-contracting services, site supervision, as well as documentation services for site works and sub-contracts. The service includes assistance to customers in local work sub-contracting, and in monitoring and reporting on the performance of sub-contractors. This service contract is made in connection with extended EEQ contracts.

SERVICES FOR POWER PLANTS

With more than 10 900 MW under service agreements, Wärtsilä is recognized as the preferred service supplier to its customers in ensuring the availability and cost-efficient operation of their installations. Customers benefit from having their entire power system fully serviced by one global supplier.

Wärtsilä Services provides full service throughout the product lifecycle for both marine and power plant customers, and is constantly developing its network worldwide. Our Services organization currently features more than 11 000 dedicated professionals in 70 countries.

For power plant applications, our Services solutions cover everything from basic support with parts, field service and technical support to complete service agreements; from installation and commissioning, performance optimization, including upgrades and conversions, to environmental solutions, training, technical information and online support.

The choice available extends from parts and maintenance services to a variety of comprehensive, customized long-term service agreements, including performance guarentees, and operations & management agreements.

On the basis of our experience in operating and maintaining close to 330 installations located in more than 45 countries, and through the know how and support of Wärtsilä's worldwide organization, we undoubtedly provide the best available agreement services in the industry.

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

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