WinGD X-DF Power Plant Solution

WIN GD

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Introduction

WinGD's low-pressure, dual-fuel X-DF engines have become market leaders in the marine low-speed gas engine market. Now, in cooperation with a leading engineering, procurement and construction contractor in the power generation market, WinGD has developed a genset version of its highly capable X-DF engines.

Proven across many demanding marine applications, the genset's capabilities include robust performance across engine loads, rapid load acceptance, a large electrical inertia for grid stabilisation, minimised fuel consumption and emissions compliance without costly after treatment and urea injection.

In an island mode case study, a 7X82DF genset serving a mining operation outperformed power plants based on medium-speed engines or combined-cycle gas turbines in reliability, flexibility and cost.

1. From Sulzer to WinGD: The history of the reciprocating engine

Winterthur Gas & Diesel (WinGD), like its esteemed forerunner Sulzer before it, operates at the cutting edge of engine design. Just as the Sulzer brothers, in 1893, agreed to help Rudolf Diesel bring his new engine technology to market, WinGD has continued to innovate to deliver efficiency and value to customers.

Among a string of notable firsts, in 1972 Sulzer invented the low-pressure dual-fuel two-stroke engine, harnessing the Otto cycle to overcome the challenges of efficiently burning gas fuel. Following its acquisition by Wärtsilä in 1997, the company went on to apply modern control strategies to the low-pressure dual-fuel engine, introducing the RT-flex50DF – the first electronically controlled low-pressure dual-fuel engine – in 2013.

Under new ownership since 2015, WinGD has continued to innovate. That year it released the first in a new, modern series of low-pressure dual-fuel engines with lower fuel consumption and higher power: the X-DF series. The company now boasts an orderbook of more than 300 X-DF engines.

2. A leader in low-speed gas engines

WinGD is well known in the marine market for the success of the X-DF engine, which remains the only low-speed gas engine developed with low-pressure gas admission. Its cost efficiency and reliable performance has seen it become the market leader for natural gas-powered vessels.

Every LNG carrier ordered in 2019 will be powered by X-DF engines. So too will a series of nine ultra large container ships (ULCCs) being built for French container line CMA CGM. These vessels, the largest and most environmentally sustainable container ships in the world, will feature the biggest low-speed gas engines ever built, the 12X92DF.

The global shipping market faces ambitious targets for reducing greenhouse gas as well as sulphur and nitrous oxide emissions. As shipowners increasingly assess how their new vessels will meet these tough emissions targets, the X-DF engine is being selected to power an increasingly diverse range of vessels. WinGD's low-pressure engine concept sets the standard for cost-effective gas-fuelled power in the large merchant shipping sector.

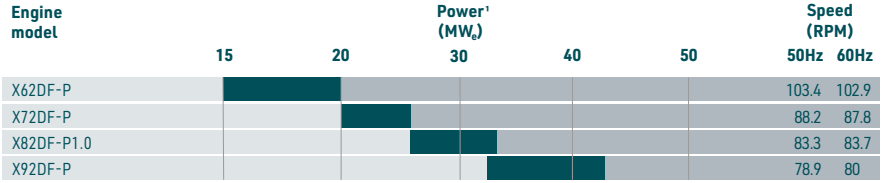
3. A tailored solution for power plants

The power generation and shipping markets face many similar challenges, including how to achieve even greater emissions reductions and energy efficiency in order to protect the planet from both climate change and local air pollution.

In power generation as in shipping, the X-DF engine is well placed to meet these demands. WinGD's solution for power plant has been developed to accommodate critical power generation project needs. The X-DF genset features a modular pre-engineered concept designed in collaboration with a major engineering, procurement and construction company. Other benefits of the X-DF engine for power plant projects include:

- Lowest possible OPEX
- Best emission profile
- High part-load efficiency
- Genset design enables renewable power use and grid stabilization thanks to the large electrical inertia
- Fuel flexibility: Rapid switch from gas to liquid fuel in case of gas supply shortage
- Simplicity: Servicing can be carried out by local labour with a long-term service contract
- WinGD and CSSC can provide full financial services

WinGD dual-fuel engines for power plant applications



[1] Expected MWe at generator terminal assuming a generator efficiency of 97.5%

4. Power plants with WinGD low-speed engines

• Unelco (Union Electrica de Canarias)	12 engines	220 MW
• EDF Martinique / EDF Vazzio (France)	8 engines	211 MW
• Central Electricity Board (Mauritius)	2 engines	29 MW
• Guernsey Electricity Ltd. (Guernsey)	5 engines	66 MW
• Jamaica Rockfort (Jamaica)	2 engines	41 MW
• Commission Federal de Electricidad (Mexico)	2 engines	66 MW
• BEC (Bahamas)	4 engines	45 MW
• Cemento Andino (Venezuela)	4 engines	13 MW
• Public Power Corporation SAD (Greece)	15 engines	157 MW

Total: 800 MWe

" The Sulzer/ WinGD low-speed 9RTA76 genset in Fuerteventura has achieved over **200'000 running hours** and is still the most profitable genset in our fleet with **8% less fuel consumption** compared with medium speed engines.

We feel confident conducting **self-maintenance on the engine** together with a local service partner and the **time between overhaul is twice as long** as other thermal movers.

The engine is very easy to operate and the loading acceptance procedure is comparable to medium speed engines."

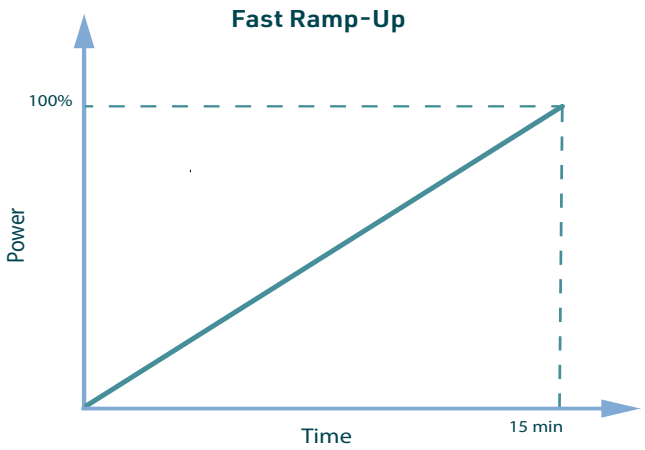
Endesa's plant manager of Fuerteventura

5. The WinGD X-DF genset

With high efficiency, low maintenance costs and low emissions, WinGD's X-DF engine and genset is the optimal solution for flexible gas-fuelled power plants.

The superior efficiency across all loads makes X-DF engines ideal for island applications with high variable load and spinning a big reserve demand. Its mission-critical design has been proven across several marine applications where it is the sole main engine.

X-DF engines can reach 100% load in 15 minutes.



Thanks to their large electrical inertia, the engines also bring stability to the grid and thus help to enable the use of renewable energy sources.

WinGD's X-DF low-pressure gas engines do not require after treatment to meet NO_X emissions limits. This minimises capital investment as well as reduces operational cost (by eliminating the need for urea as a reductant) and complexity. Combined, these advantages make the X-DF the most sustainable power generation technology on the market.

WinGD's portfolio of well-proven engines provide a modular design with common components to simplify construction, maintenance and parts replacement. These engines benefit from a high power output and an optimal speed for power plant applications. Engine tunings can be further tailored to a project-specific load profile to optimise fuel consumption.

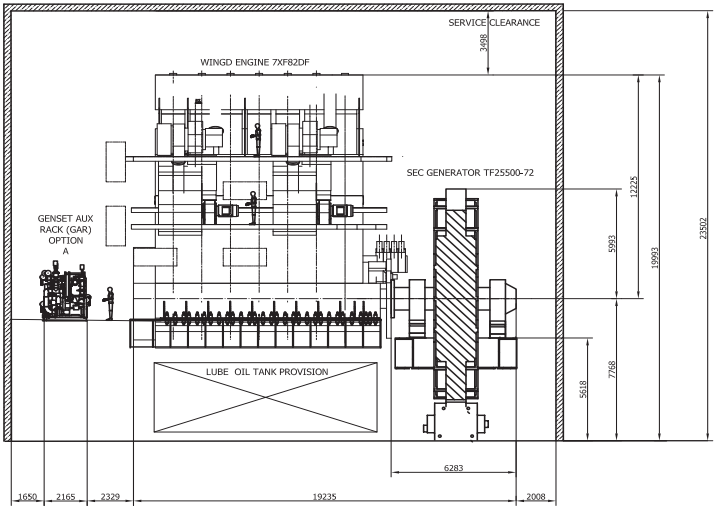
As an example, the 7X82DF is ideal for power plant applications, combining optimal engine dimensions and the highest possible efficiency in a simple cycle. Together this provides a cost effective solution.

7X82DF genset data

Electrical output*	25,448 kWe
Electrical efficiency*	52.2%
Heat rate*	6,892 kJ/kWh
NO_X limits	75 mg/Nm^3 (@15% O_2)
Urea consumption	0
Power factor	0.9
Liquid pilot fuel max	1.0 g/kWh

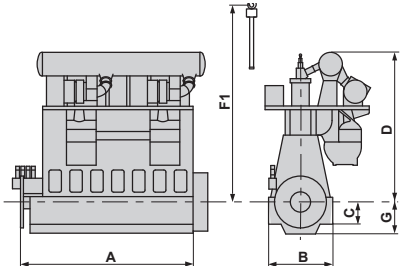
**Note: ***Output and efficiency at generator terminals (ISO 3046); efficiency at lower heating value; natural gas methane number >65; all direct driven pumps included.

7X82DF genset dimensions



7X82DF engine data

Cylinder bore	820 mm	
Piston stroke	3,375 mm	
Speed	83.3 rpm	83.7 rpm
Frequency	50 Hz	60 Hz
Stroke/bore	4.12	
Mean effective pressure	17.3 bar	
Max fuel gas feeding pressure	10.5 bar @ 100% load	



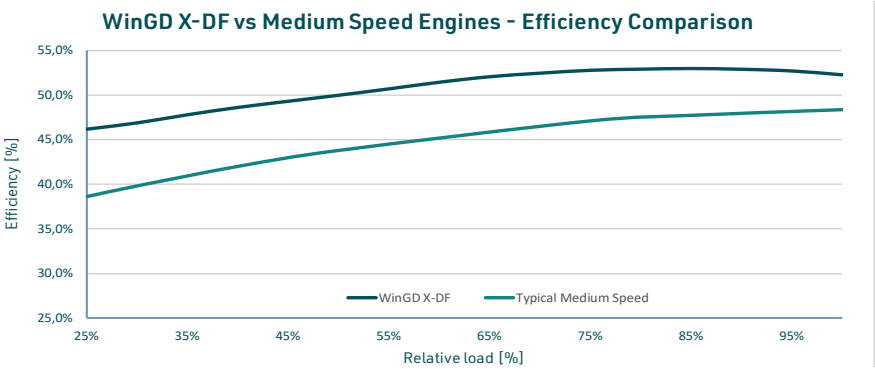
DIMENSIONS (MM) AND WEIGHTS (TONNES)

A	B	C	D	F1	Weight
11,860	5,020	1,800	12,225	15,150	910

6. Operating cost benefits

Outstanding fuel efficiency and a simple, robust build mean that WinGD gensets provide operators with a very competitive operating cost base.

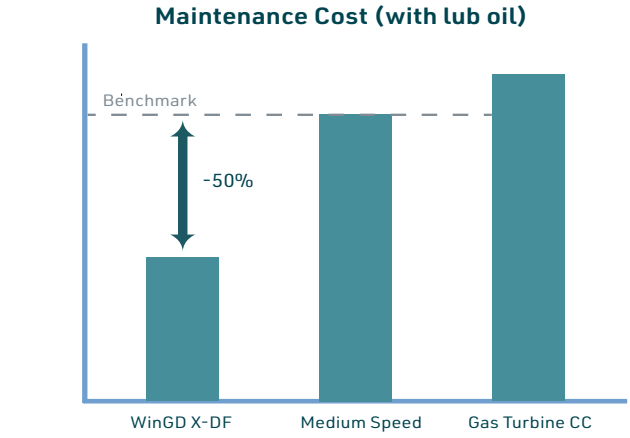
Low gas consumption at any load: X-DF gensets have a simple cycle efficiency value of up to 53%. This is similar across engine loads, helping to optimise the plant's energy management system and overall energy efficiency.



Low maintenance cost: Maintenance work on the X-DF low-speed genset is typically carried out by the same crew that operates the engines. Low-speed engines have fewer parts than their medium-speed counterparts and gas turbines. This simplicity contributes to a much greater time between overhauls compared to rival technologies. Spare parts are also available at very economical prices from several vendors due to the widespread use of the X-DF engine in the marine market.

As the data highlights, WinGD's low-pressure, low-speed gas engines feature a much lower maintenance cost than either medium-speed engines or gas turbines.

Note: Typical maintenance cost for different technologies



7. Emission profile

WinGD's X-DF engines feature top-of-the-range environmental performance across many regulated emissions, including sulphur, nitrous oxides (NO_X), carbon dioxide and particulate matter (PM).

SCR (and urea) not needed

Control of NO_X emissions is a crucial factor for determining overall efficiency, given the costs associated with abatement. These include the capital cost of a selective catalytic reduction system as well as the operational costs of regularly replacing the catalytic element and injecting urea as a reductant. The typical consumption of urea alone in a medium-speed engine is equivalent to a 4% increase in fuel costs.

Unlike medium-speed engines, X-DF engines meet EU NO_X limits without SCR and therefore offer significant capital and operating cost savings in this area.

NO_X LIMIT	X-DF	MEDIUM SPEED ENGINE
World Bank limits: 400 mg/Nm^3	No SCR	No SCR
EU limits: 75 mg/Nm^3	No SCR	SCR, UREA ~4.0 g/kWh (which equate to an approx. equivalent fuel efficiency loss of 4.0 %)

Low greenhouse gas emissions

WinGD X-DF engines offer lower CO_2 emissions than medium-speed gas engines. Low-pressure engines also have a low methane emission output compared to four-stroke medium-speed engines. This low methane emission level is inherent to low-speed two-stroke engine physics and is achieved by optimising the engine's internal combustion process as well as the combustion chamber design. The fuel efficiency of X-DF engines and their minimised methane slip result in a greenhouse gas footprint that compares favourably to other power generation options. This could mean that operators are eligible for deductions on carbon tax (if applicable).

Minimal SO_X and PM

As only a very small amount of diesel is need for pilot fuel, X-DF engines generate no SO_X emissions. At the same time, the Otto-cycle operation means that only a minimal level of fine particulate matter particles are released.

8. X-DF: Modular power plant concept

WinGD's power plant concept has been designed in partnership with a leading company in the power plant sector to ensure a seamless integration of the low-speed genset into the power plant.

A simple and easy-to-build power island concept has been defined. WinGD's scope includes all performance-related equipment, which are modular and ready to be connected. All mechanical and electrical interfaces are designed to reduce the number of tie-in points, minimising on-site installation work.

The three main modules of WinGD's supply are:

- Genset: X-DF engine and synchronous alternator with integrated oil pan base frame
- Genset auxiliary rack: Containing all engine-related auxiliaries including heat exchangers, pumps, filters, thermostatic valves and sensors
- intelligent Control by Exhaust Recyling(iCER): A combustion stability system that improves performance and reduces exhaust gas emissions, including a heavy-duty engine air intake filter and 35dB(A) sound attenuation silencer

WinGD also provides:

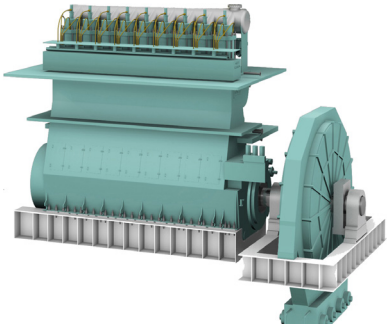
- The genset control panel (GCP)
- Installation and commissioning
- A project-specific engineering package
- Engineering Procurement Construction (EPC) design integration and optimisation support

The EPC is usually responsible for the installation package and project, site-specific designs and balance of plant (BoP) systems including:

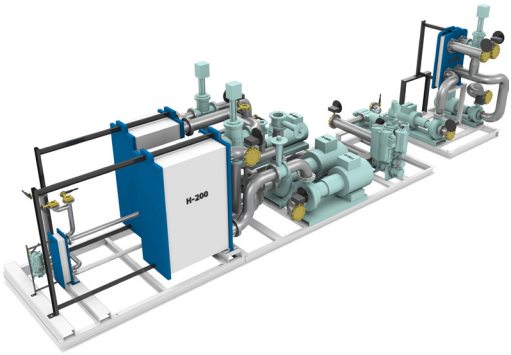
- Fuel gas station
- Start-air vessel, lube oil tanks and water service tanks
- Exhaust gas stack with silencer
- Power control with MV distribution, LV distribution and auxiliary transformer
- Step-up and Auxiliary transformer
- All civil works (e.g., foundations, interconnect piping and wiring, plant control, parts storage, workshop containers)

Typical overview of WinGD scope of supply:

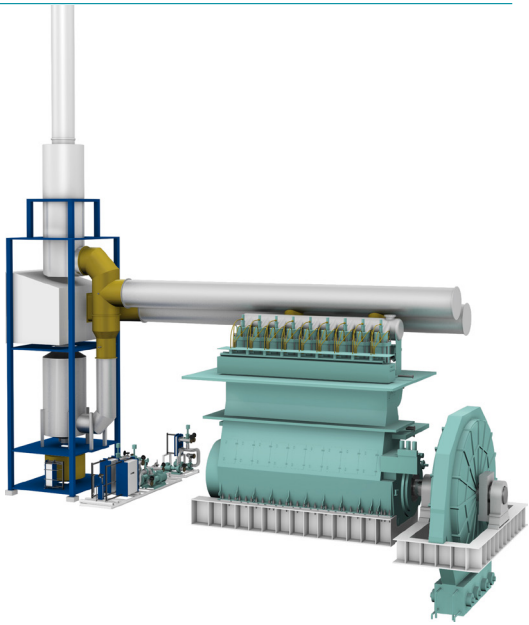
GENSET
X-DF engine and synchronous alternator and integrated oil pan base frame



GENSET AUXILIARY RACK (GAR)
All the engine related auxiliaries (heat exchangers, pumps, filters for all the services, thermostatic valves and sensors)



INTELLIGENT CONTROL BY EXHAUST RECYCLING (iCER)
Combustion stability system that improve performance and reduce all exhaust gas emissions. It includes the heavy duty engine air intake filter and 35dB(A) sound attenuation silencer



9. Power plant service and maintenance options

The low-speed X-DF engines are easy to maintain and in many cases operators themselves handle maintenance work. However, WinGD offers **several service and maintenance model options** to suit the customers' project-specific needs. WinGD can, for example:

- Conduct all service work
- Supervise service work by customer or local contractor
- Engage an authorized service partner to perform service works
- Supervise work by an authorised service partner

10. Island mode case study

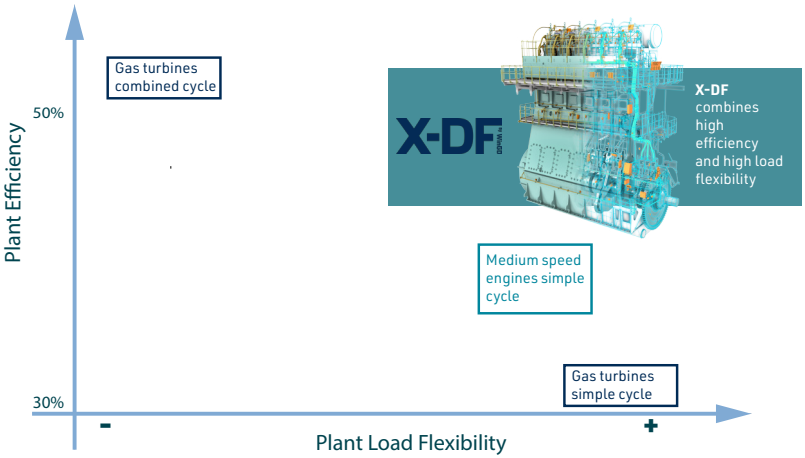
In this section WinGD's genset solution is compared to other thermal power options for a typical 200MW power plant island operation feeding a large mine consumer. The crucial requirement for a captive power plant of this kind is to reduce the energy bill while providing a reliable solution that can deliver consistent performance for at least 20 years.

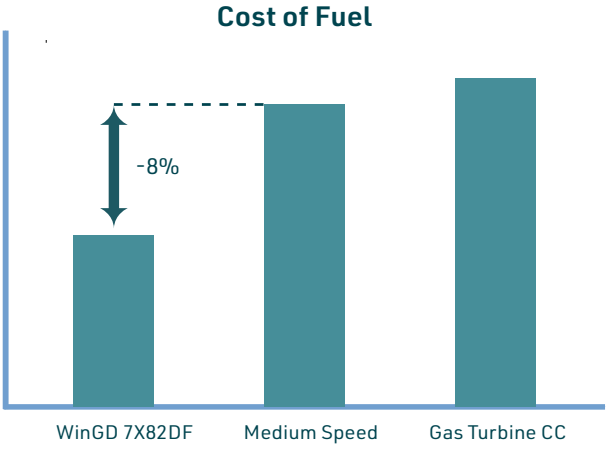
Other important requirements for this application include fast load acceptance and rejection. The plant will need to be capable of managing load variations and being coupled with a local "soft" grid that is subject to significant frequency and voltage variations. The plant should also comply with stringent EU emission regulations governing NO_X, CO and SO_X. It should burn primarily natural gas but can operate with liquid fuel (such as diesel) in case of gas shortage. And it should be able to integrate renewable power at a later stage.

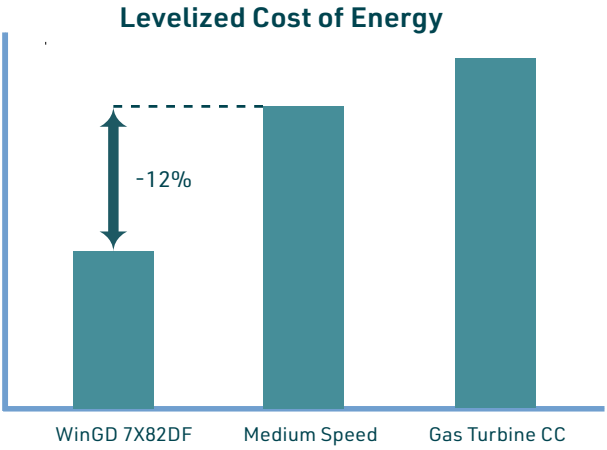
The 7X82DF low-speed, dual-fuel genset is the best solution for this application since it combines high efficiency and load flexibility. For this reason, at the site conditions, the 7X82DF genset offers the lowest operational cost and 52% efficiency.

A plant powered with the WinGD 7X82DF genset also provides a very large electrical inertia that stabilizes the grid network. This is particularly important in this project because of the variations in production due to the mining process. It is also a necessity for operations where the customer wishes to combine the production of thermal energy with renewable energies.

The 7X82DF meets all customer requirement and represents the best solution for this project.


Gas turbines combined cycle
50%
Plant Efficiency
30%
X-DF
X-DF combines high efficiency and high load flexibility
Medium speed engines simple cycle
Gas turbines simple cycle
-
+
Plant Load Flexibility


Cost of Fuel
-8%
WinGD 7X82DF
Medium Speed
Gas Turbine CC


Levelized Cost of Energy
-12%
WinGD 7X82DF
Medium Speed
Gas Turbine CC

Island mode case study: critical operational aspects

DESCRIPTION	WinGD 7X82DF	GTCC
Sensitivity to site conditions (temperature, humidity, etc.)	Very low, no derating required	High, reduced power output, lower efficiency
'Soft' grid code compliance (capacity to synchronize with large variations in grid frequency and voltage)	High	Medium
Thermal stress of sudden load changes	Low	High
Maintenance impact of frequent start/stop cycles	Very low	High impact on schedule and cost
Capacity to respond to sudden load variation	Very high, no variation in performance	Limited by the water steam cycle, reduced plant performance
Dusty environment combustion air (mining environment)	Heavy duty air intake filter, little maintenance cost	High risk of filter clogging, high maintenance cost
Integration with renewable energies	Very high	Critical

CUSTOMER NEEDS	WinGD 7X82DF	MEDIUM SPEED ENGINES	GAS TURBINES IN COMBINED CYCLE
Best of OPEX/CAPEX ratio	●		
Low energy cost	●	◐	●
Power plant load flexibility	●	●	◐
Easy maintenance Involve local workforce	●	○	○
Fast power availability	●	●	◐
Long time between overhauls	●	◐	◐
Low CO_2	●	◐	●
No urea	●	○	●
Long term service agreement	●	●	●
Flexible service agreement	●	◐	○
Purchasing of spare parts from multiple vendors	●	◐	○

● Yes
◐ Partially
○ No

Winterthur Gas & Diesel Ltd. (WinGD) is a leading developer of two-stroke low-speed gas and diesel engines.

WinGD sets the industry standard for reliability, efficiency and environmental sustainability.

WinGD is headquartered in Winterthur, Switzerland, where, as one of the earliest developers of diesel technology, it started the design of large internal combustion engines in 1893 under the "Sulzer" name.

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