ADD MORE CERTAINTY TO YOUR FUTURE

iCER

Delivering enhanced combustion control

Modified 10 August 2021

Contents page

WIN GD

Forging ahead

WinGD continues to push the boundaries of modern engine design in the search for smarter solutions to reduce emissions and improve efficiency.

This quest is encapsulated in X-DF2.0, a suite of next-generation technologies that further enhance WinGD's market leading X-DF dual-fuel engines.

Intelligent Control by Exhaust Recycling – iCER – is the first technology launched on the X-DF2.0 platform

By delivering enhanced combustion control through the use of inert gas, iCER delivers reductions to both fuel consumption and methane slip at a reduced CAPEX.

Introducing iCER

Innovative iCER technology

Thermodynamics

System layout

Why low-pressure recirculation?

The cooling process

Waste heat recovery

Benefits and performance improvements

Fuel consumption and emissions

Rollout

WIN GD

Introducing iCER

Heightened efficiency and control

WinGD's X-DF engines have been delivering highly efficient dual-fuel performance on vessels since 2015.

These ground-breaking engines follow the lean-burn Otto cycle combustion process to drive emissions down:

- **Low and stable combustion temperatures keep nitrogen oxides (NOx) emissions significantly minimised** - meeting Tier III NOx emission standards without the need for exhaust after-treatment.
- **LNG** is practically sulphur-free.
- **The lean combustion process** minimises particulate matter (PM).
- **LNG combustion reduces carbon dioxide (CO_2) emissions** due to the higher hydrogen-to-carbon ratio compared to liquid fuels.

To further enhance performance in X-DF engines, WinGD is rolling out next-generation technologies under the X-DF2.0 platform. The first such technology, Intelligent Control by Exhaust Recycling (iCER), targets superior combustion control, using inert gas to adjust the gas/air mix improving both fuel consumption and emissions.

The benefits are impressive:

- **≥3% less** energy consumption in gas mode.
- **5% less fuel consumption** in diesel mode.
- **Up to 50% less** methane slip.

Combustion control plays a critical role in guaranteeing high efficiency and lower emissions. By regulating the fuel-gas/air mix it is possible to **generate maximum power output with minimum methane slip.**

Menu

PDF

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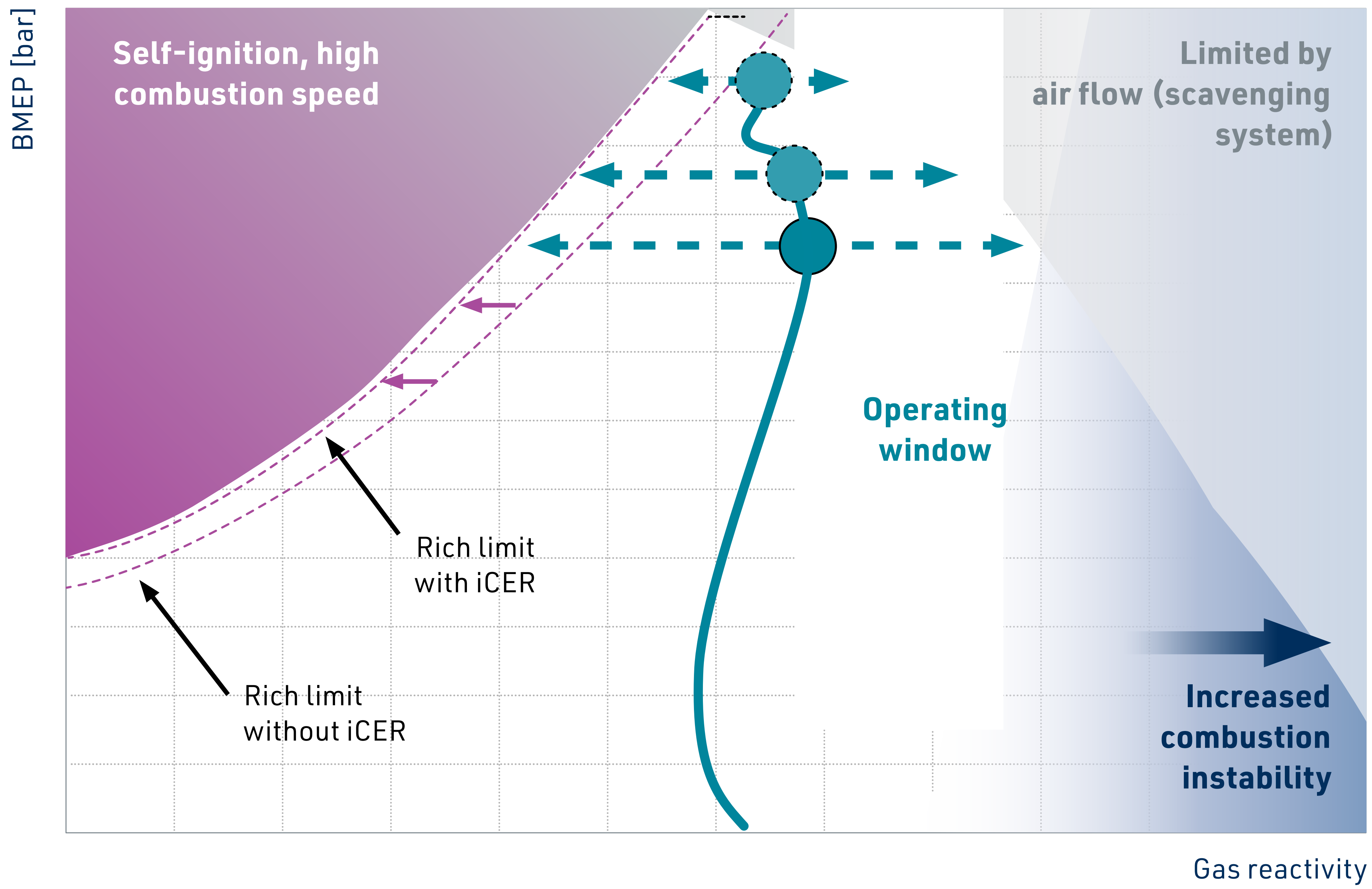
Innovative iCER technology

The iCER system is designed to cool and recirculate part of the exhaust gas when operating in gas mode.

When the recirculated exhaust gas is mixed with scavenge air, carbon dioxide partly replaces the oxygen in the fresh air, reducing the mixture's reactivity during combustion. This increases the ignition delay and stabilises the combustion speed.

By raising resistance to auto-ignition and reducing combustion speed, iCER enables combustion control phasing so that the geometric compression ratio (CR) can be increased and the thermal efficiency improved.

The iCER system is made up of a low-pressure exhaust recycling path with an efficient exhaust gas cooler (EGC). The amount of returned exhaust gas and the combustion are regulated in a closed loop control.



The iCER system extends the operating window of X-DF engines

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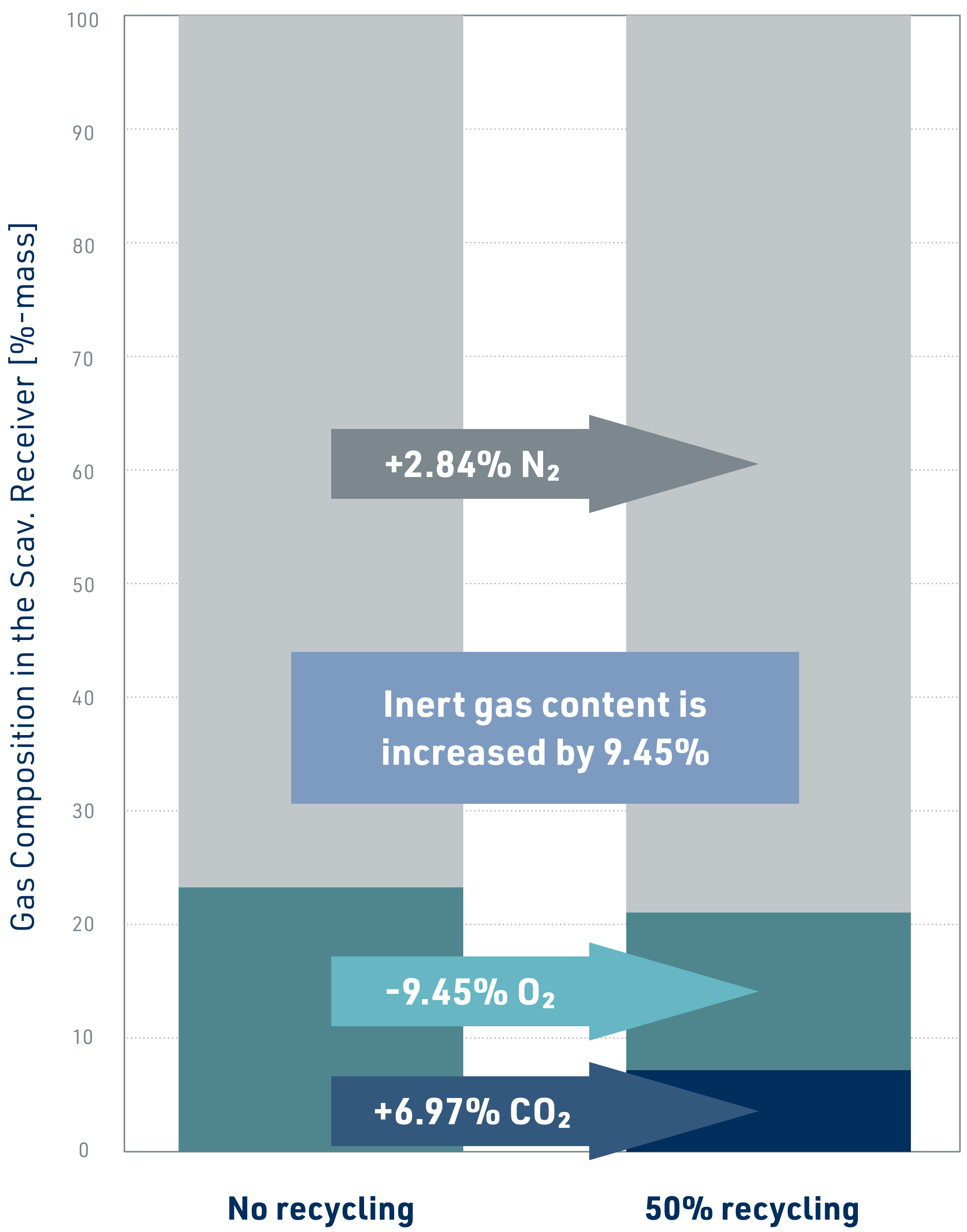
The thermodynamics in detail

As the percentage of recirculated gas increases, the amount of oxygen (O_2) replaced by CO_2 increases proportionately, as does the amount of nitrogen (N_2) in the mixture.

Because CO_2 has a higher heat capacity than O_2, the peak temperature in the cylinder is lowered. The lower level of O_2 in the scavenge air also lessens the reactivity of the premixed gas, leading to an increase of ignition delay and a slower combustion speed. All of which lead to smoother combustion.



How the gas mixture changes with the introduction of exhaust gas recycling.

Reducing unburned hydrocarbons emissions

Methane slip is inversely proportional to the exhaust gas recycling rate. During recycling, exhaust gas is divided between a recirculation path and a funnel path.

Increasing the rate of recycling gives methane in the recirculation path a second chance to burn in the combustion chamber.

A 50% exhaust recycling rate normally enables up to 50% of methane to burn again during the combustion.

Menu

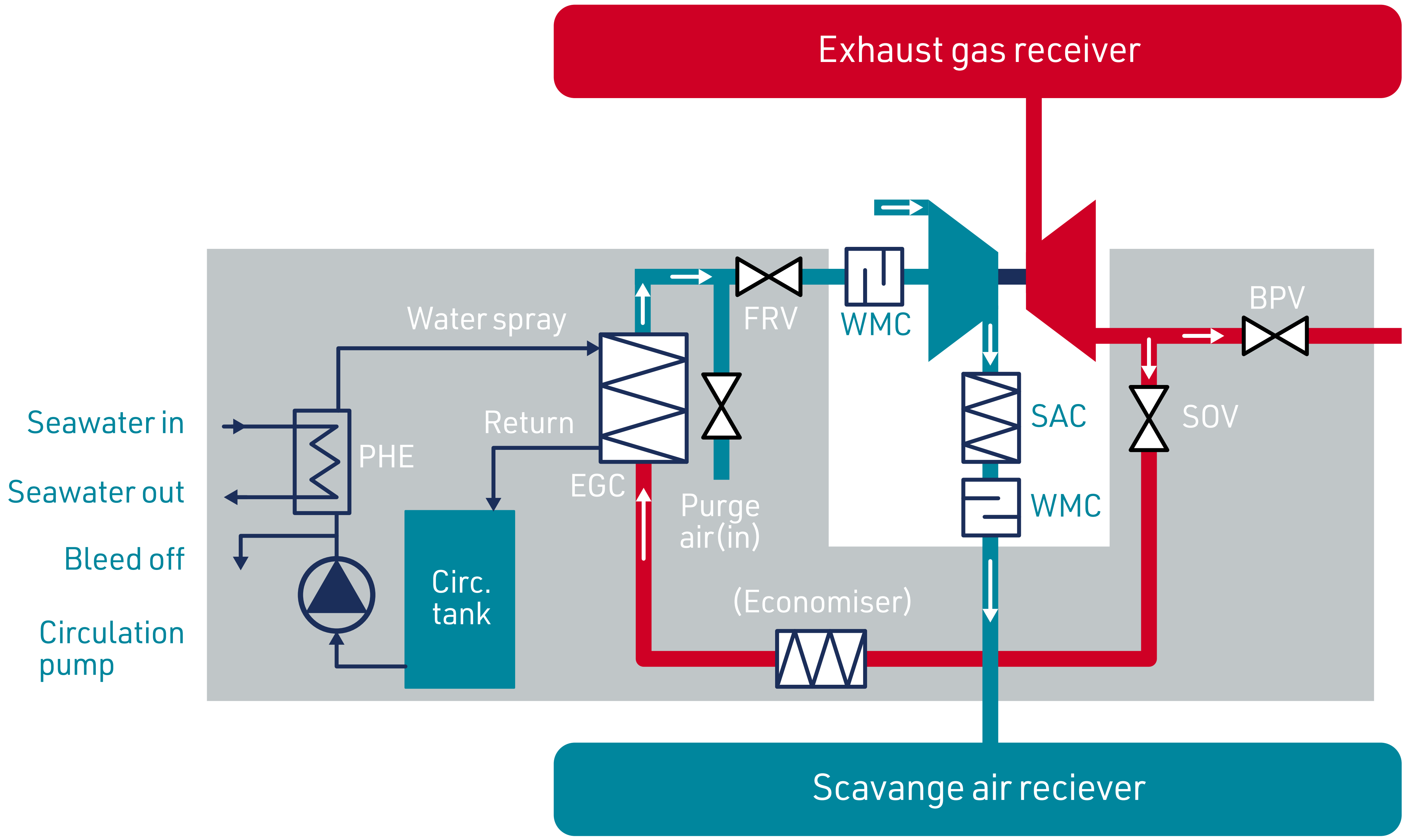
PDF

The system

iCER cools and recirculates part of the exhaust gas through a low-pressure path when operating in gas mode.

This enables full use of the turbocharger, making it possible to recirculate exhaust gas up to 50% mass flow.

The recirculation is handled by a system next to the engine that circulates part of the exhaust gas after the turbine through an exhaust gas cooler (EGC) to the compressor inlet. The exhaust gas and fresh air are mixed before entering the compressor wheel of the turbocharger.



System overview

Abbreviation explanations

BPV	Back Pressure Valve	**EGC**	Exhaust Gas Cooler
SOV	Shut Off Valve	**SAC**	Scavenge Air Cooler
EG	Exhaust Gas	**WMC**	Water Mist Catcher
PHE	Plate Heat Exchanger		

Menu

PDF

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Why low-pressure recirculation?

The low-pressure recirculation concept utilised by WinGD's iCER technology on X-DF2.0 engines has been tested with Otto cycle engines over several years.

It has several design and performance advantages compared to a high-pressure EGR, which remains relatively unproven on lean-burn engines.

When compared to an HP EGR system, the main benefits of WinGD's iCER technology are reduced fuel consumption, high methane slip reduction, combustion stability and zero risk of auto-ignition.

Design features

WinGD's iCER is a simple and reliable technology using components which have been used for decades in industry (for example in scrubber technology to cool and clean exhaust gases) and builds on the well proven X-DF engine technology. Together with the minimal number of moving parts, this brings maintenance costs down to the lowest level.

While iCER's low-pressure design recirculates exhaust after the turbine and before the compressor, high-pressure EGRs recirculate exhaust before the turbine and after the compressor. This has two important design consequences that add cost to high-pressure systems.

1. **iCER makes regulation of the exhaust flow recirculation simple and reliable** using the back pressure valve, without additional energy requirements for an extra blower or combined control for a cylinder bypass valve.
2. **Air and exhaust flows through the turbocharger depending on the level of recirculation for high-pressure EGR.** The low-pressure iCER can achieve full exhaust flow through the turbochargers on both the turbine and compressor side regardless of recirculation, ensuring best turbocharger efficiency in all operating conditions.

Performance advantages

Simple and accurate control of the recirculation rate by a back pressure valve is possible using iCER, even at transient loading. The adjustment of the recirculation rate is done by an intelligent control monitoring combustion.

There is no need for an additional electric blower applied for a high presser EGR system which needs to be adjusted dependent on load and cylinder bypass valve setting, meaning no additional electric energy consumption.

The cylinder bypass valve required by the high-pressure EGR decreases the scavenging performance, limiting the achievable in-cylinder exhaust gas recirculation rate as well as preventing application of measures to achieve optimal engine efficiency. With the iCER technology, combustion can be easily controlled to reach optimal engine efficiency. Higher thermal efficiency is possible by higher geometric compression ratio, leading to 2-3% lower fuel consumption.

Overall, the different combustion behaviour and the electricity consumption mean that high-pressure EGR requires 1.5% more fuel than iCER's well-proven low-pressure technology.

Further potential of iCER

WinGD's low pressure iCER technology is currently being prepared to run not only in gas mode but also in diesel mode following strong demand from the LNGC industry.

With this extension of the application range, WinGD will enable a significant reduction in ship owners' investment by eliminating the need to install a selective catalytic reactor (SCR).

This results in a significant CAPEX reduction of the vessel price, while allowing the LNGC engine to comply with IMO NOX Tier III regulation limits in gas and diesel modes.

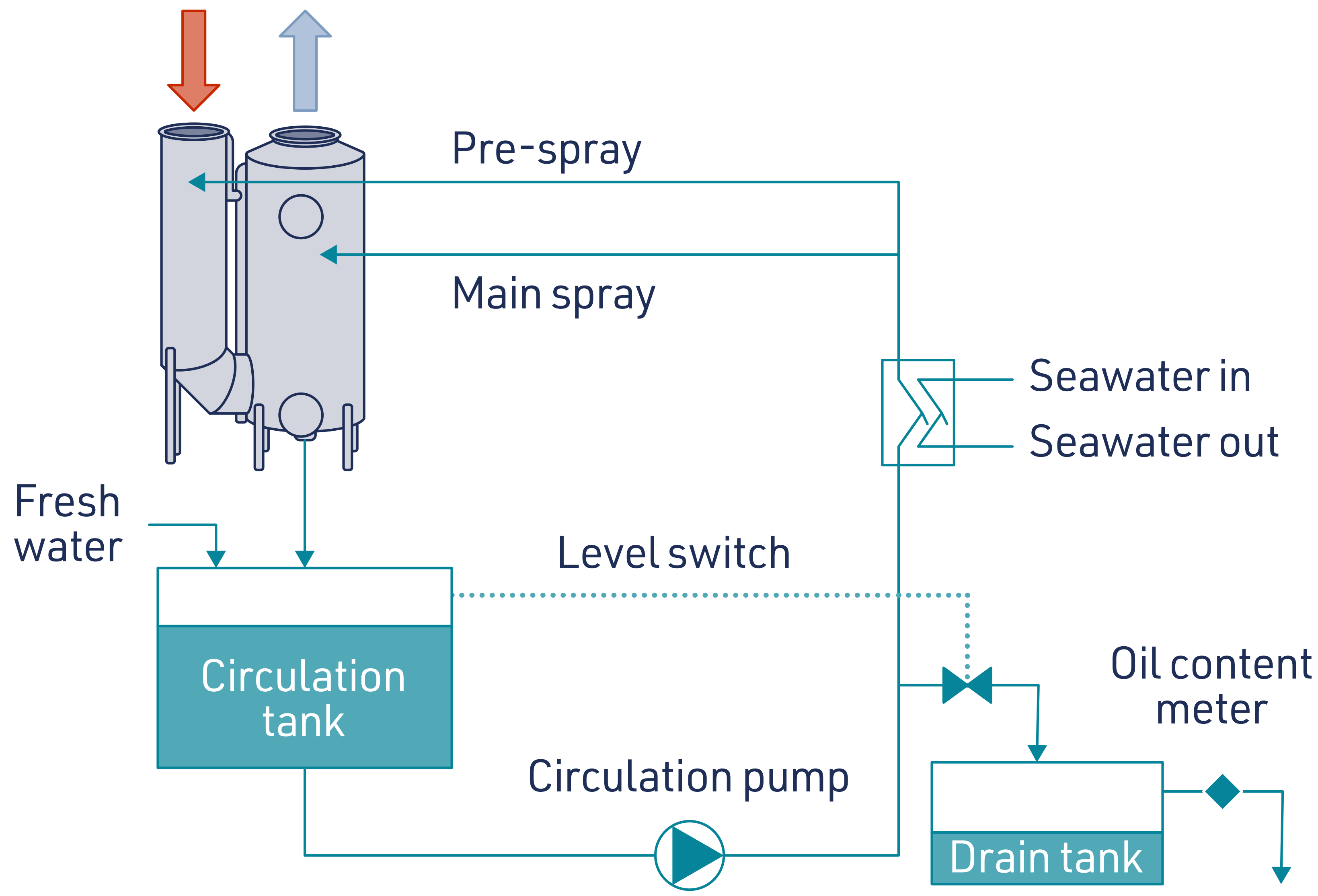
Menu

PDF

The cooling process

The iCER system is placed close to the engine as a stand-alone arrangement, including an EGC with a demister

The cooler tower contains a quench section and an absorber section. Hot exhaust gas enters at the top of the quench section, where spray nozzles introduce water cooling. The gas then flows to the bottom of the absorber section which handles the main cooling. The absorber contains filler which enlarges the cooling surface with water introduced from the top. A subsequent demister removes water droplets in the exhaust gas.



The process

The cooling process reduces the temperature of the exhaust gas below its dew point of around 40°C. Water in the exhaust gas starts to condense, leading to excess water in the system, which continuously dilutes the circulation water.

The system recirculates the cooling water and stores it in a circulation tank. Recirculated fresh water is cooled by sea water via a plate heat exchanger. Excess water is discharged to a drain tank and constantly monitored by an oil content meter.

Potential for waste heat recovery

To increase steam production, an optional economiser can be placed on top of the quench section of the exhaust cooler.

This can then harness the energy of the recirculated gas, and the economiser can be connected directly to the steam line.

As in gas operation the exhaust gas is essentially sulphur-free, **the outlet temperature can be lowered to below160-170ºC in order to increase steam production gain.**

Menu

PDF

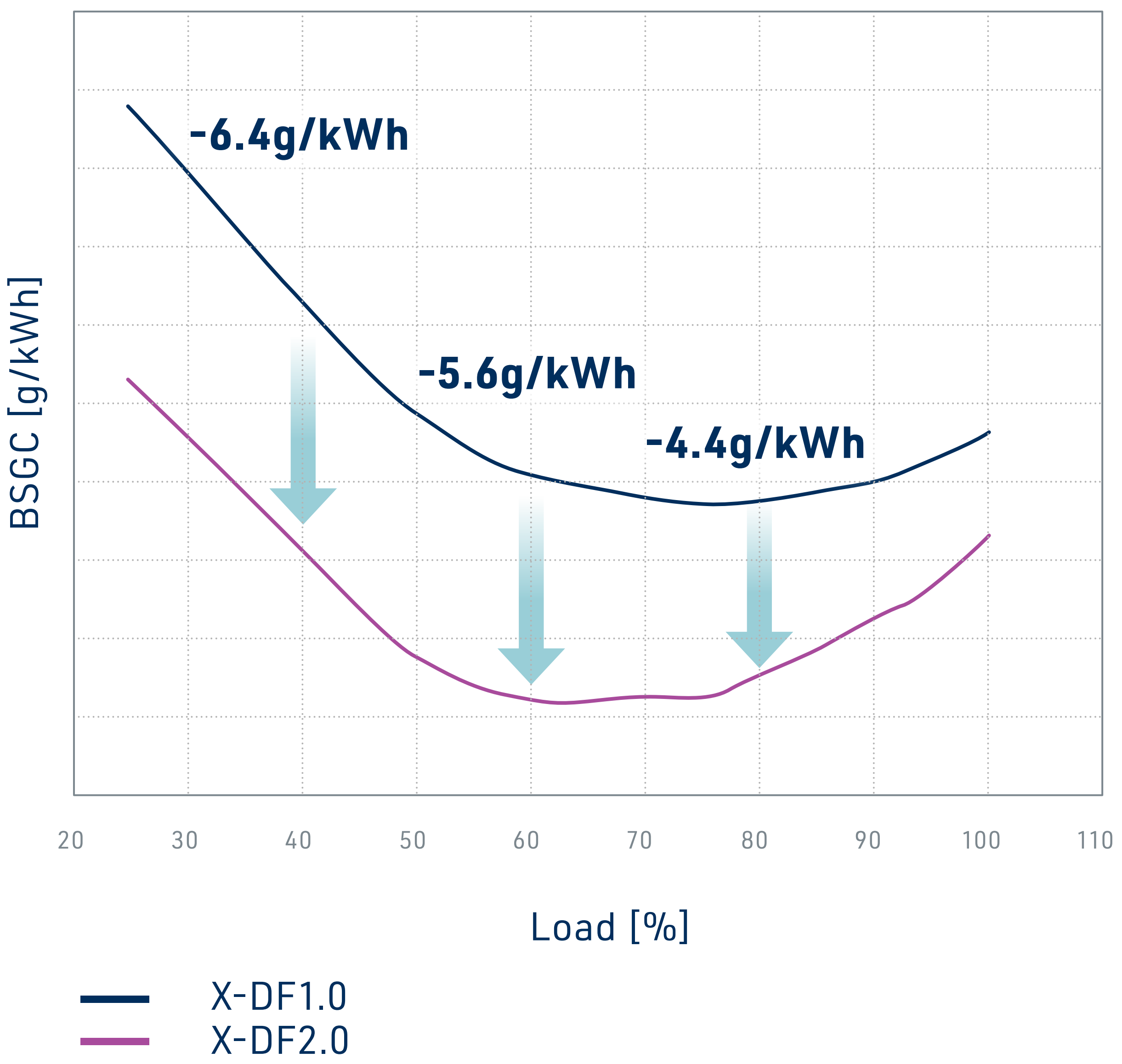
iCER benefits and performance improvements

Introducing iCER technology to X-DF engines leads to **greater gas combustion stability, more efficient fuel consumption and lower emissions.**

Fuel consumption and emissions

Exhaust gas recycling allows an increase in the geometric compression ratio (CR), leading to a higher thermal efficiency of the engine and consequently to reduced gas consumption.

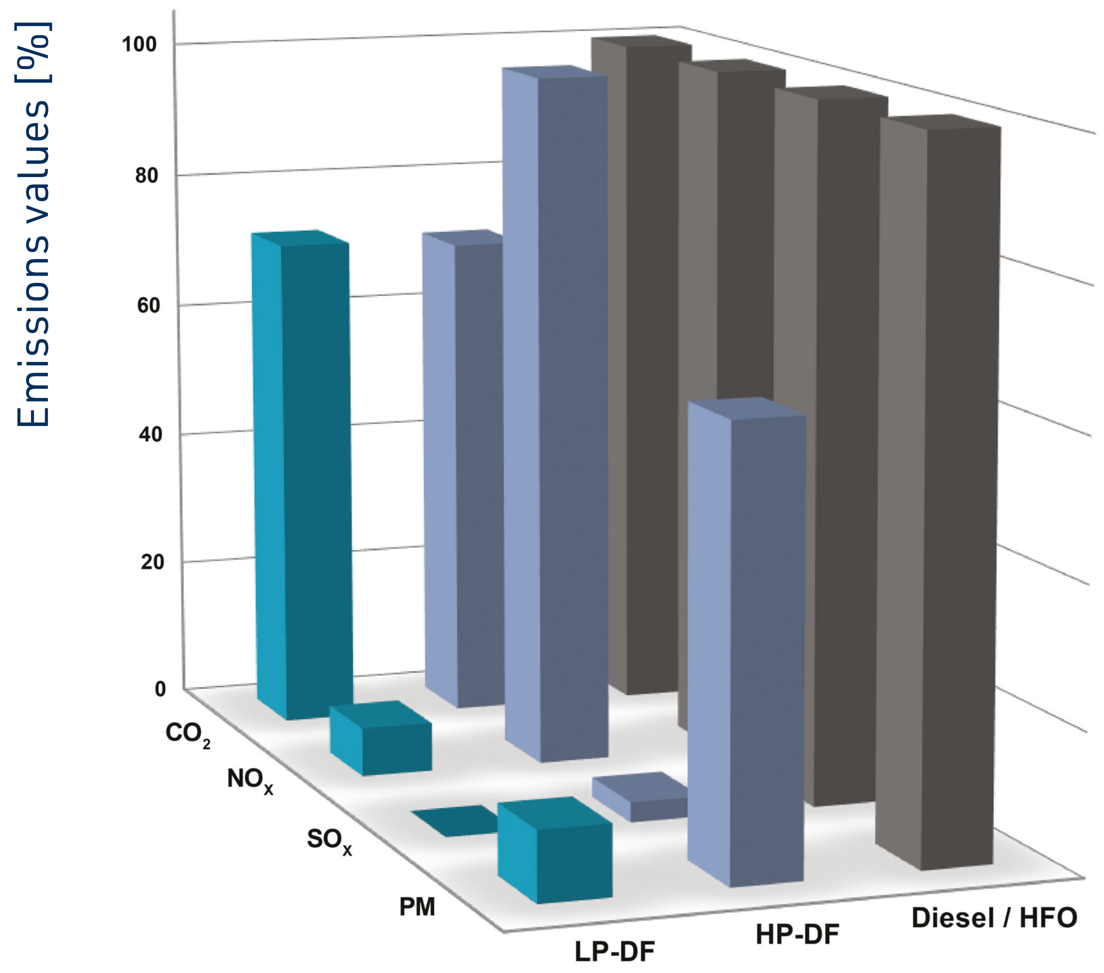
Gas mode [BSGC]



Fuel consumption improvement with increase of compression ratio for a typical 5X72DF engine

Thermal efficiency gains increase towards lower loads.

The combined reduction in CO_2 and methane emissions with the iCER system in operation lowers the greenhouse gas emissions of X-DF engines in gas operation by a further 8% approximately.



X-DF emission characteristics

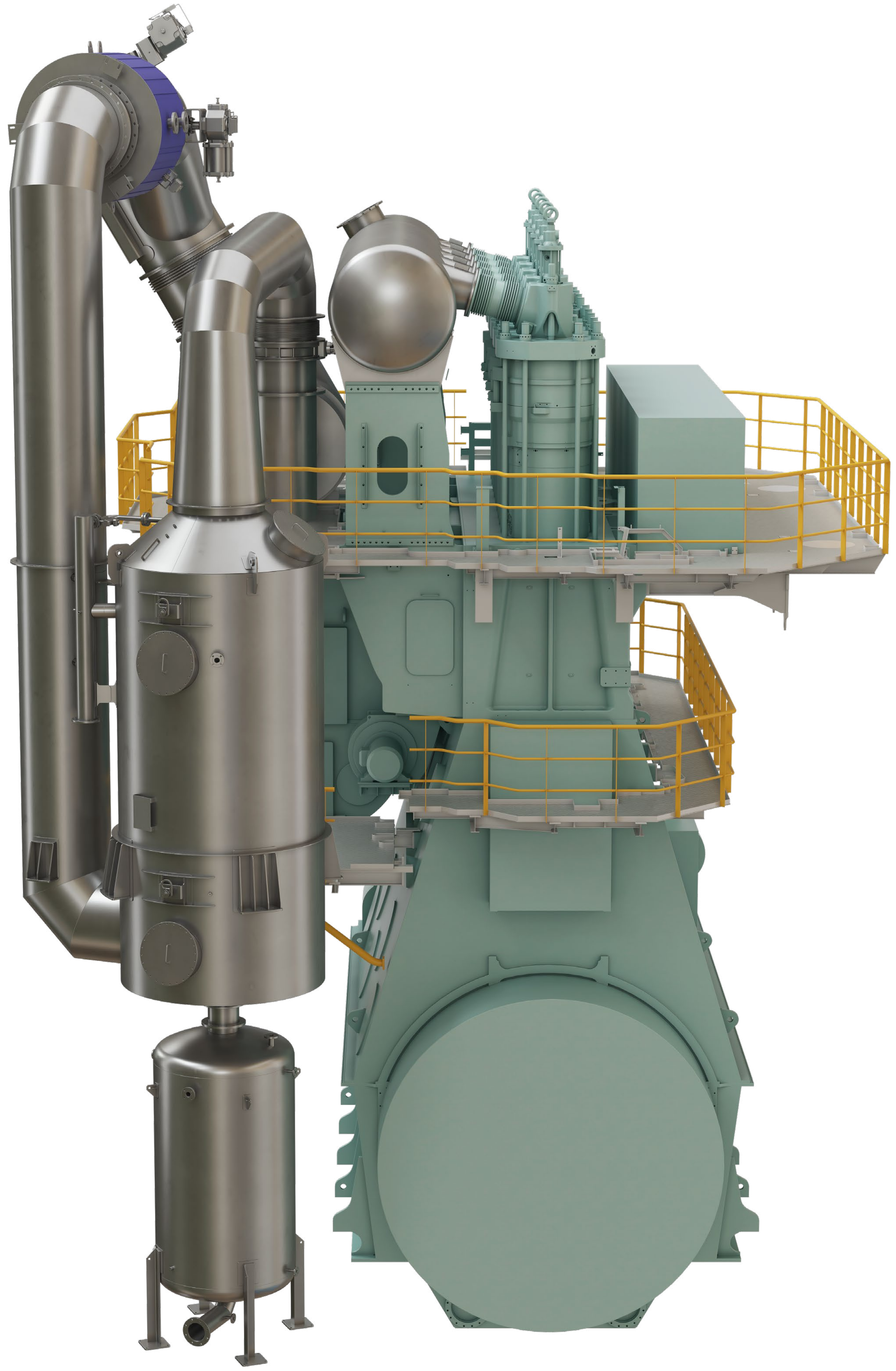
Menu

PDF

Rollout

iCER was introduced in 2020. A gradual roll out across the X-DF portfolio is underway.

The first X-DF engines to be equipped with iCER are scheduled to be delivered approximately 12 months after engine order date.



iCER system arrangement close to the engine

Specifications

The main hardware of the iCER system include the exhaust gas cooler (EGC), the circulation tank, a plate heat exchanger and an optional micro economiser for additional waste heat recovery and steam production.

The final layout in the engine room will depend on the selected engine type and the rated power as well as the specific arrangement in the vessel.

Exhaust Gas flow engine Turbine flow from GTD [kg/s]		11.5–14.4	14.4–18.3	18.3–22.8	22.8–30	30–38.3	38.3–51.2
EGC size #		**EGC 14**	**EGC 18**	**EGC 23**	**EGC 30**	**EGC 38**	**EGC 51**
EGC absorber diameter [mm]	**D**	1600	1800	2000	2300	2600	3000
EGC flange size [DN]	**I**	700	800	900	1000	1200	1400
EGC height [mm]	**H**	5000	5300	5500	5700	6000	6500
EGC width [mm]	**W**	2900	3200	3500	3700	4300	5000
Weight wet [kg]		2624	3141	3699	4542	5614	7098
Circulation tank size [m³]	2	3.29	3.29	5.07	5.07	8.07	8.07
Circulation pump [kW]	3	18.5	22.0	37.0	45.0	55.0	75.0

Estimated dimensions of the EGC sizes from approved supplier, across the X-DF portfolio; engine builders can select EGC size based on the turbine flow from GTD.

Menu

PDF