Exhaust Gas Recirculation (E.G.R.) system

– NO_x Reduction Solution for Diesel Engines

Introduction

- Environment and climate require sustainable solutions for marine exhaust emissions
- Usual solutions (LNG conversions or SCR retrofits) are coming with high CAPEX and OPEX
- AES provides an E.G.R. system for any possible marine or stationary application
- Our **E**xhaust **G**as **R**ecirculation E.G.R. system is a proven design
- Robust and reliable NO_x reduction solution
- Verified functionality, performance and durability

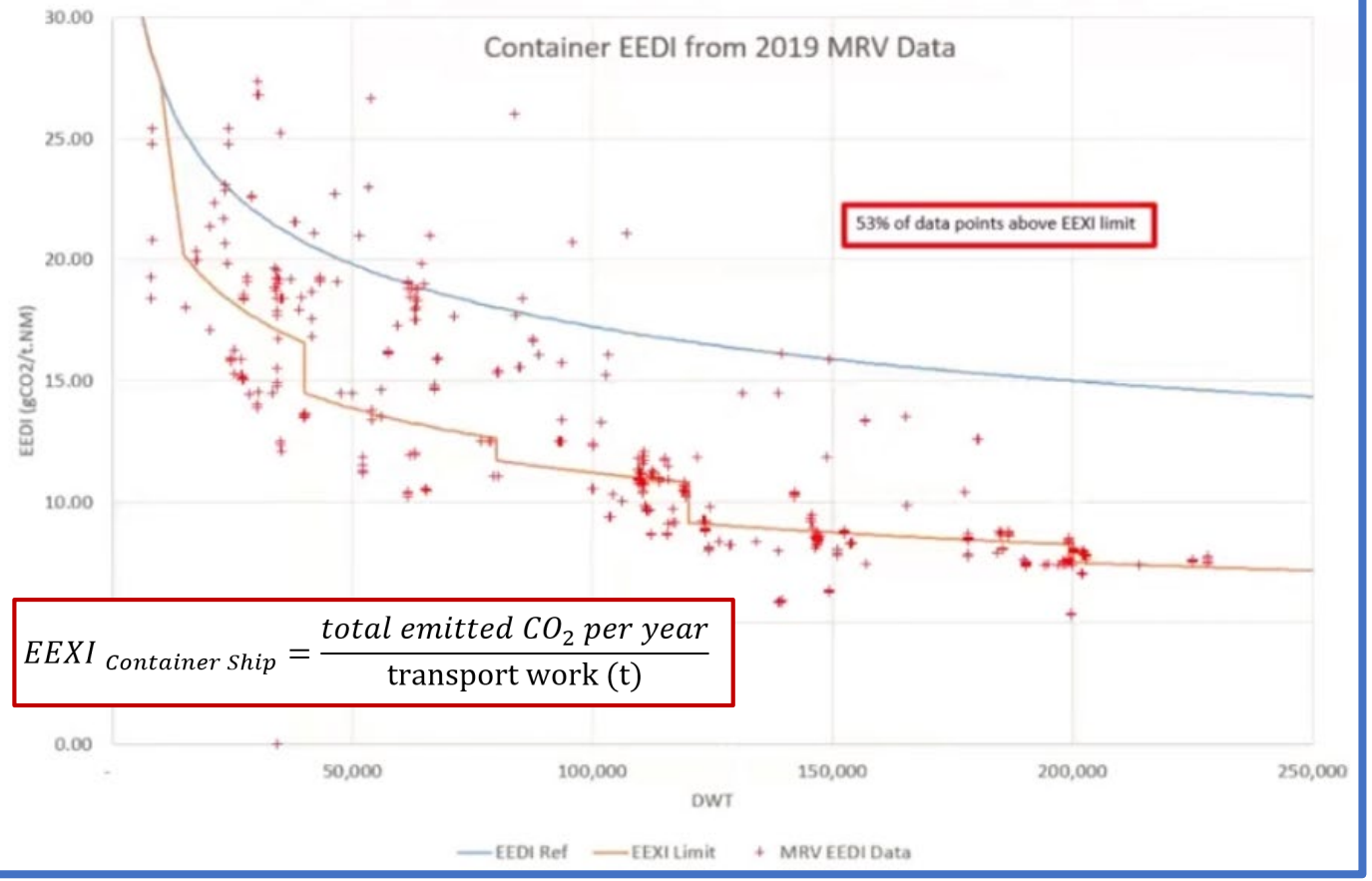
Background

- IMO’s mandatory measures approved by MEPC to cut the carbon footprint of all ships
- two new measures are: Energy Efficiency Existing Ship Index (EEXI) & Carbon Intensity Indicator (CII)
- the new amendments are expected to be adopted by 2023

About the **Energy Efficiency Existing Ships Index** (EEXI)

- for the majority of ship types, the requirements follow the EEDI phase relevant for new ships in 2023
- EEXI compliance to be documented by all ships
- EEDI compliant vessels most likely have to add further documentation
- pre-EEDI certified vessels may obtain further documentation if EEXI cannot be fulfilled

Indicative impact on the global container ship fleet



$$EEXI_{\ Container\ Ship} = \frac{total\ emitted\ CO_2\ per\ year}{\text{transport work (t)}}$$

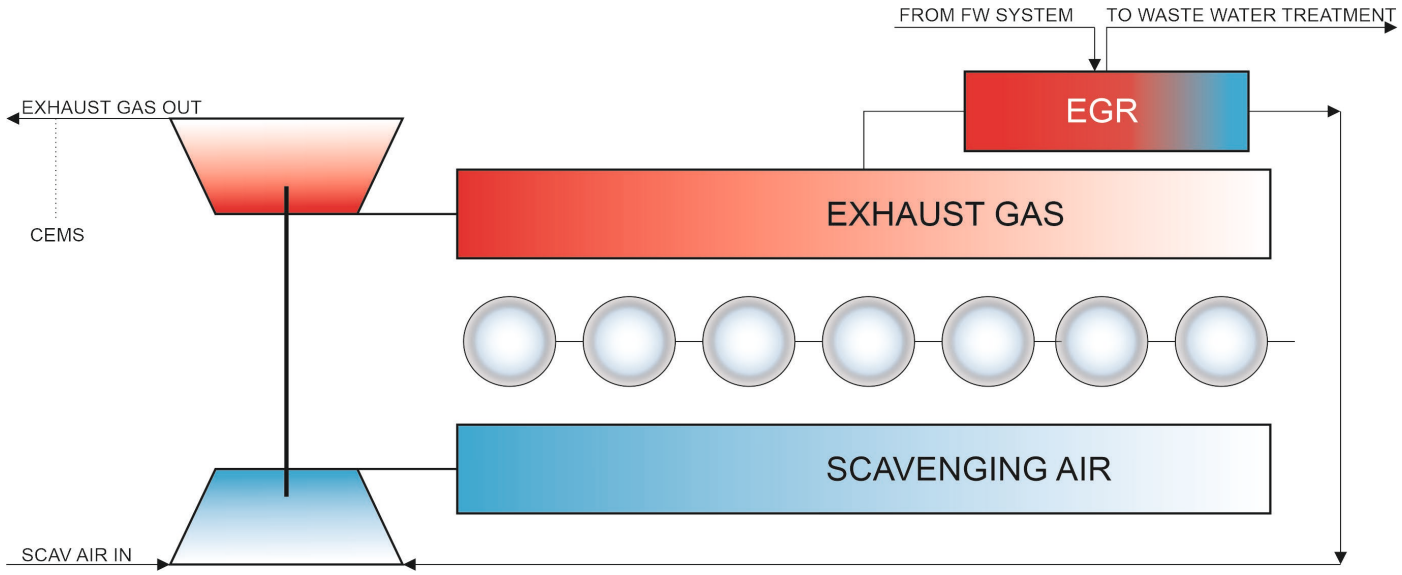
EEXI Compliance Retrofit Solution:

E.G.R.
plus
Fuel **S**aving **O**ption (FSO)
from IMO Tier 0+ to II

Source: Lloyd's Register Webinar March 2021

E.G.R. system - working principle and technical set-up

- E.G.R. installation on top of the engine
- Regulated exhaust gas extraction depending on engine load
- Exhaust gas cooling and cleaning
- Recirculation to the scavenging air intake
- NOx reduction through lower temperatures
- Constant Emission Monitoring System (CEMS)



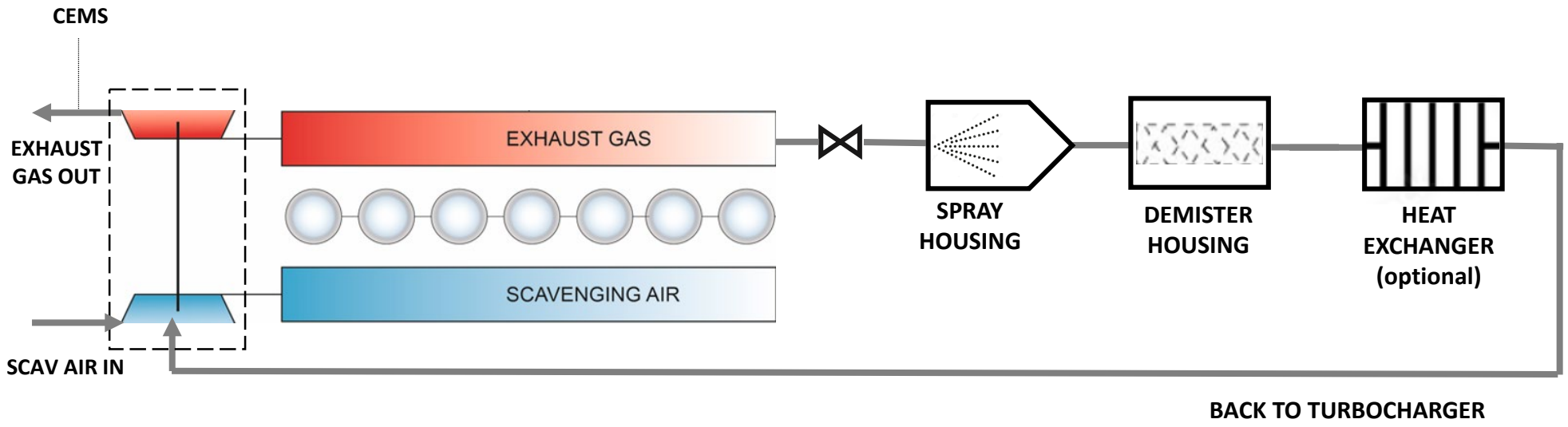
E.G.R. system – sized design

E.G.R. system is designed in dependency of:

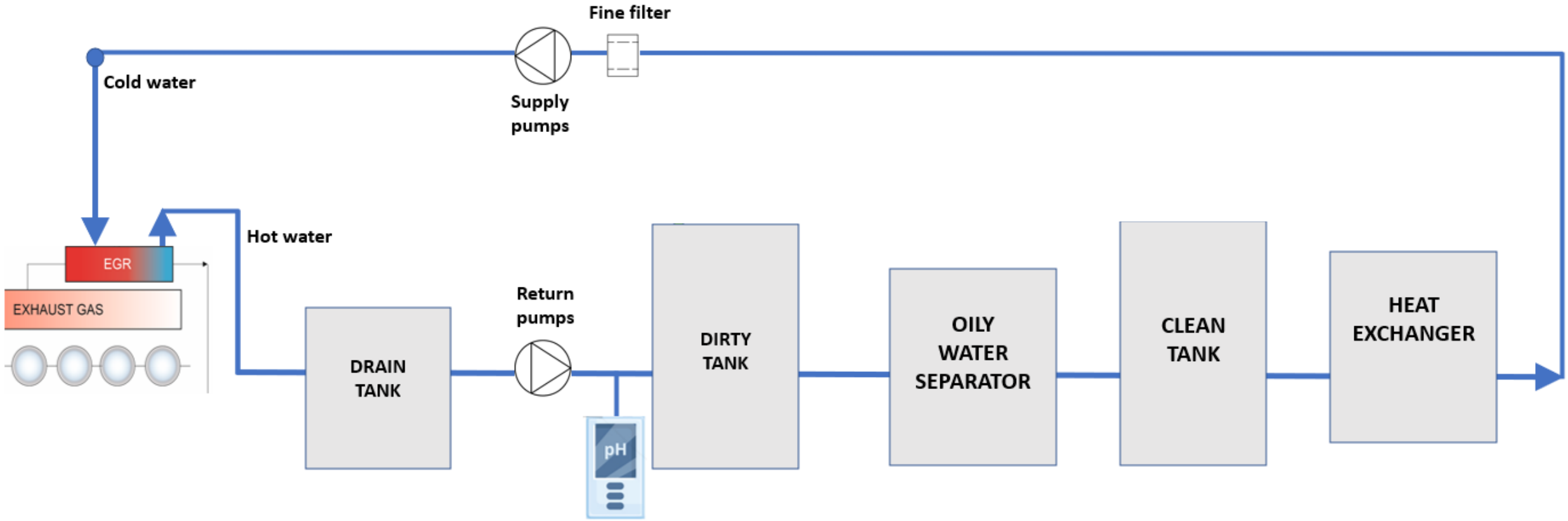
- Actual and target IMO Tier level
- Engine Power at MCR

E.G.R. size	Engine power	Exhaust Gas cooling	NOx reduction target
E.G.R small-system	From 500 kW to 1,5MW	No water, only heat exchanger	From IMO Tier I to II
E.G.R. light-system	From 500 kW to 1,5 MW	Water cooling with injection nozzles	From IMO Tier I to III
E.G.R. full-system	From 1,5 MW	Water cooling with more injection nozzles	Up to IMO Tier III

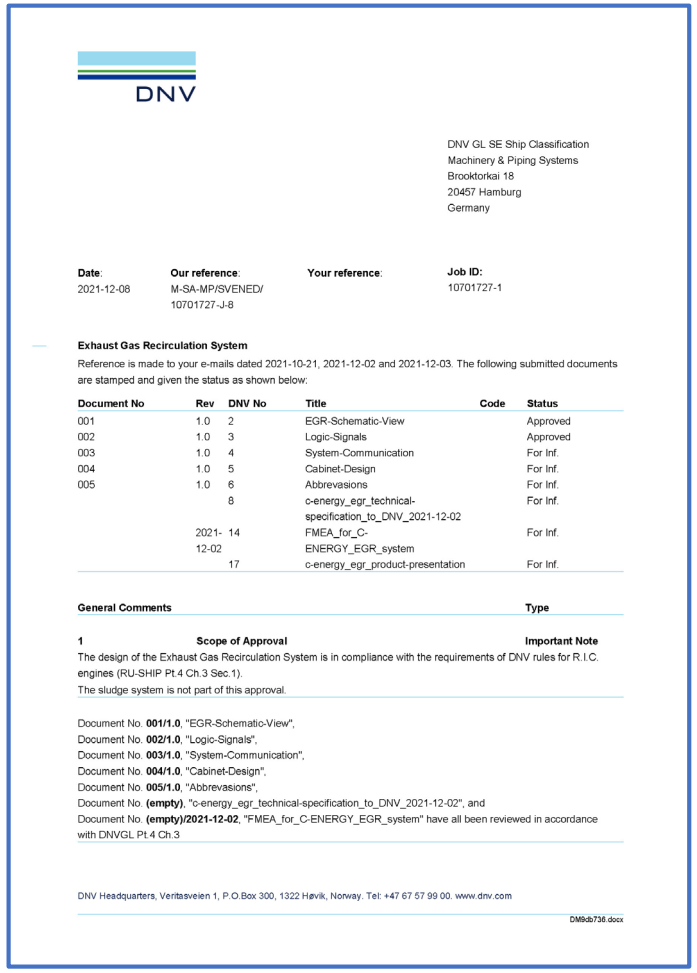
E.G.R. system – exhaust gas cycle



E.G.R. system – supply and return water cycle (closed loop example)



E.G.R. system – approved design



DNV

DNV GL SE Ship Classification
Machinery & Piping Systems
Brooktorkai 18
20457 Hamburg
Germany

Date:	Our reference:	Your reference:	Job ID:
2021-12-08	M-SA-MP/SVENED/ 10701727-J-8		10701727-1

Exhaust Gas Recirculation System

Reference is made to your e-mails dated 2021-10-21, 2021-12-02 and 2021-12-03. The following submitted documents are stamped and given the status as shown below:

Document No	Rev	DNV No	Title	Code	Status
001	1.0	2	EGR-Schematic-View		Approved
002	1.0	3	Logic-Signals		Approved
003	1.0	4	System-Communication		For Inf.
004	1.0	5	Cabinet-Design		For Inf.
005	1.0	6	Abbrevasions		For Inf.
		8	c-energy_egr_technical-specification_to_DNV_2021-12-02		For Inf.
	2021-12-02	14	FMEA_for_C-ENERGY_EGR_system		For Inf.
		17	c-energy_egr_product-presentation		For Inf.

General Comments	Type
1 Scope of Approval	Important Note

The design of the Exhaust Gas Recirculation System is in compliance with the requirements of DNV rules for R.I.C. engines (RU-SHIP Pt.4 Ch.3 Sec.1).
The sludge system is not part of this approval.

Document No. **001/1.0**, "EGR-Schematic-View",
Document No. **002/1.0**, "Logic-Signals",
Document No. **003/1.0**, "System-Communication",
Document No. **004/1.0**, "Cabinet-Design",
Document No. **005/1.0**, "Abbrevasions",
Document No. **(empty)**, "c-energy_egr_technical-specification_to_DNV_2021-12-02", and
Document No. **(empty)/2021-12-02**, "FMEA_for_C-ENERGY_EGR_system" have all been reviewed in accordance with DNVGL Pt.4 Ch.3

DNV Headquarters, Veritasveien 1, P.O.Box 300, 1322 Høvik, Norway. Tel: +47 67 57 99 00. www.dnv.com

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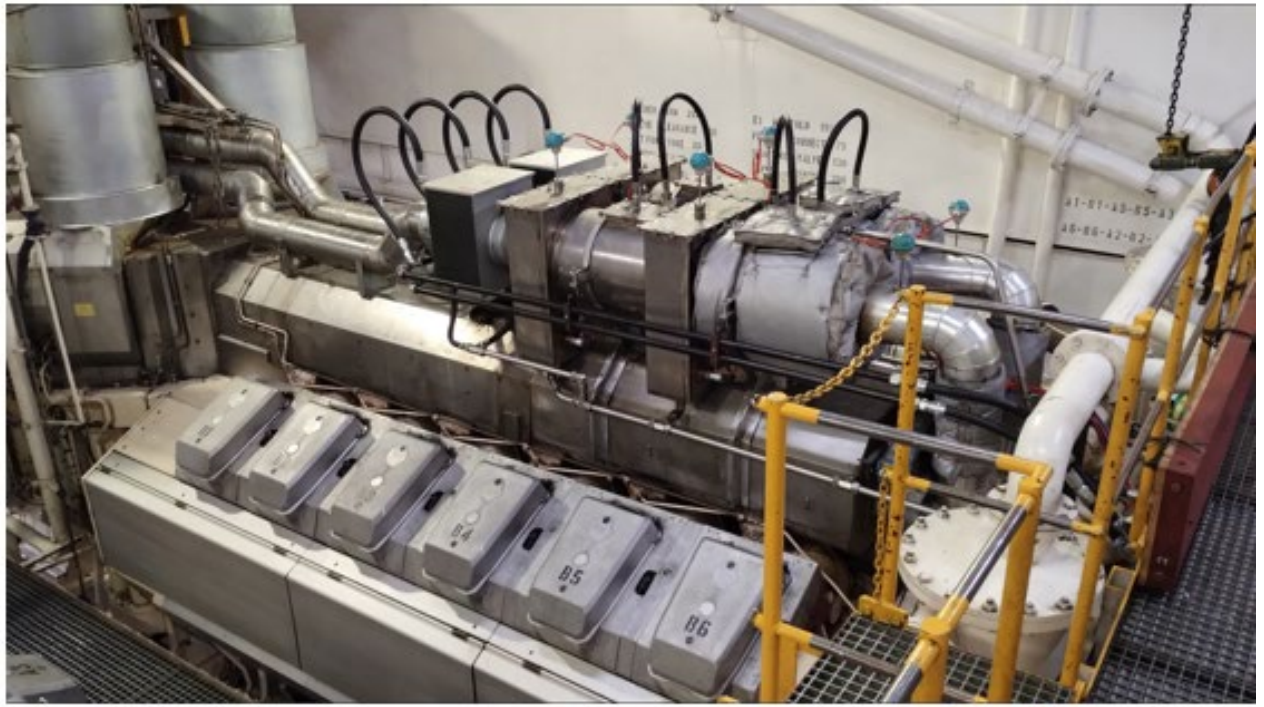
- DNV has issued a “Class Approval” in principle for our E.G.R. system on Diesel engines
- the design of the Exhaust Gas Recirculation (E.G.R.) system is in compliance with the requirements of DNV rules for R.I.C. engines (RU-SHIP Pt.4 Ch.3 Sec.1)
- our customers will always be supported is case of any Class questions

APPROVAL IN PRINCIPLE
DNV
DNV RULES / STANDARDS

E.G.R. system – typical installation on top the engine



Case Study (1/2)

- standard 1000 TEU container feeder ship
- one main engine, about 9 MW with IMO Tier II to achieve emission reductions IMO Tier III:

Case Study:	**Dual-Fuel conversion**	**SCR catalyst**	**AES E.G.R. system**	
1000 TEU Container ship	for Natural Gas	installation	E.G.R. installation	
			with fuel saving option	without fuel saving option
Engine update costs	2.600.000 €	50.000 €	960.000 €	915.000 €
LNG fuel gas & tank 500m³	2.400.000 €	n.a.	n.a.	n.a.
SCR cat / Mixing Unit / Comp. air	n.a.	350.000 €	n.a.	n.a.
Shipyard complete	4.550.000 €	1.020.000 €	160.000 €	95.000 €
Project Management	30.000 €	15.000 €	5.000 €	5.000 €
Sea Trial cost	75.000 €	40.000 €	20.000 €	10.000 €
Off-hire (10.000€/day)	560.000 €	280.000 €	140.000 €	70.000 €
total	**10.215.000 €**	**1.755.000 €**	**1.285.000 €**	**1.095.000 €**
Conversion time in Shipyard	6 weeks	2 weeks	1 week	0.25 week
Commissioning (cold / hot)	1 week	1 week	0.5 week	0.25 week
Sea trial	1 weeks	1 week	0.5 week	0.5 week
total	**8 weeks**	**4 weeks**	**2 weeks**	**1 week**
OPEX	👍	👎👎👎	👍👍👍	👍👍

Note: values and time frame are estimated and can variate depending on Shipyard, location and engine availability.

SSW Super 1000 type with approx. 13.000 dwt

Case Study (2/2)

Advantages of our E.G.R. system vs. SCR system

- DNV Class Approved system
- listed supplier for NOx-Reducing Technologies at the Norwegian NOx Fund
- no dry docking or shipyard is needed
- no additional Urea and Compressed Air are needed
- no extension of the funnel is needed, no loss of space e.g. for Cabins
- E.G.R. system is installed on exhaust pipe at top of the engine, no disturbance for engine maintenance
- engine is needed for approximately a few hours to make to connection to the E.G.R. system
- Fuel Saving Option (FSO) is available in special cases
- low CAPEX costs, very low OPEX costs

References (1/2)

Roll-On/Roll-Off ferry with 4x Sulzer 8L ZA40S Main Engines, each 5.7 MW
(510 rpm, Diesel-Mechanic application)

Performance of the E.G.R. on one engine:

- change of emission level from IMO Tier 0+ to Tier II level
- NO_x reduced by 78%

Additionally - Fuel Saving Option by setting back fuel injection timing (possible from IMO Tier 0+ to IMO Tier II)

- approx. 11% fuel saving
- 11% less CO_2 and PM emissions

References (2/2)

Cruise Liner MS ARTANIA for 1.200 passengers with
4x Wärtsilä 12V W32E Main Engines, each 7 MW (750 rpm, Diesel-Mechanic application)

Performance of the E.G.R. system:

- installed on all four engines during 2023
- upgrade of NOx emissions from IMO Tier II to III level
- new Technical File and EIAPP certificate have been issued by Lloyd's Register in July 2024
- NO_x reduced by approximately 80 %
- no chemicals, only water
- no backpressure or fuel consumption increase
- low OPEX costs

E.G.R. system – summary & benefits:

• **NOx emission reduction**	➔ to achieve a better IMO Tier level
• **Reduced installation effort & time**	➔ lower CAPEX costs
• **Only technical water is used**	➔ lower OPEX; no urea/chemical/ammonia slip
• **No backpressure increase**	➔ no fuel consumption increase
• **Small installation space**	➔ no loss of space for e.g. cabins

Disclaimer

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