The Retrofit Project

Retrofitting to reduce CO_2 emission – *a case study of three different vessels*

GREEN SHIP OF THE FUTURE

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The Retrofit Project

This report is a product of a Green Ship of the Future collaboration, supported by The Danish Maritime Fund. The objective of this project is to explore the potential of today's available and proven technologies to reduce emissions and energy consumption.

It is intended to inspire for a financial sustainable way to invest in green solutions that minimize the energy need and thereby our impact on the earth. Furthermore, it is meant as an inspiration for shipowners on where and how to look for fuel reduction potential, both on existing vessels and when planning future fleets.

Project partners

HAFNIA Member of BW Group
DFDS
MAERSK TANKERS
ALFA LAVAL
BES
C.C.JENSEN
Clorius CONTROLS
DANISH ENERGY CONSULTING
DEIF
DESMI
DNV·GL
GREENSTEAM
HEMPEL
KONGSBERG
MAN Energy Solutions
NORSEPOWER
OPTIMUM VOYAGE
orcan The Efficiency Company
Royston
WÄRTSILÄ
THE DANISH MARITIME FUND

→ Read more about the participating partners at the end of the report.

Executive Summary

The arguably most pressing environmental impact from shipping, is the emission of greenhouse gas (GHG) – especially the emission of CO_2. It is evident that implementation of a GHG neutral fuel is necessary, from both an environmental, climate and compliance perspective, but it is also evident that it will be years before we can rely purely on sustainable sources of energy. Therefore, we must constantly seek innovations in existing assets and ensure optimal energy efficiency, to keep the negative impact on environment as low as possible and reduce the overall energy cost.

"... we must constantly seek innovations in existing assets and ensure optimal energy efficiency"

This need is further stressed due to the long-lasting nature of the vessels, which represent large investments and a high percentage of the operating cost.

With the goal of exploring how much the energy consumption, and thereby CO_2 emission, can be reduced through retrofittable and proven technological solutions, 20 members of Green Ship of the Future launched a project series with a sample of high-volume vessels. Three different vessels, Hafnia Lise, Victoria Seaways, and Maersk Tianjin were explored and actual data and operation profile of the specific vessels were used in the individual cases.

The partners analyzed the data, identified areas with potential for energy optimization and calculated the expected cost in relation to its potential for fuel and CO_2 reductions. The findings are analyzed on their potential to deliver a 3-year full return on investment (ROI). While the goal of this project is not to provide an exhaustive overview of all available technologies, more than a dozen different areas, with significant potential of savings, were identified. The largest potential combined savings were 27.1%, equivalating to 5,208 tons CO_2 a year. The case with the least potential in terms of percentage saving, 11.1%, is on the other hand the case with the largest CO_2 reduction potential, equivalating to 7,350 less tons of CO_2 emitted per year. This is due to a different operational pattern. While, there are differences between the individual vessels and participating providers analyzing the cases, and it is therefore not possible to directly compare them, there were several general learnings that can be drawn. These are elaborated in the conclusion. It is vital to mention that there are significant additional potential savings if a ROI of 3 years is not required. Furthermore, because the actual fuel price for the sample period was used to calculate the ROI, the actual ROI is subject to changes depending on fluctuation in fuel prices the following years.

The exercise of optimizing the energy consumption is obviously important from an environmental perspective today and strategically it benefits from its correlations to financial savings from using fuel optimization. Though, even after a GHG neutral fuel is implemented, energy optimization remains vital. From an environmental perspective, because we will likely reach the zero emission vessels before the combined energy need of the world is covered by renewable sources, renewable renewable energy will still be a scarce resource that we must not waste on inefficiencies.

"... energy optimizing technology today, will most likely prove to be a source of competitive advantage in the future "

From a financial perspective it will be even more important than today, because all potential renewable alternatives are projected to be far more expensive than the fuel in use today. Therefore the future business case of optimizing the energy consumption will be superior to today. Hence, the investments in technologies today will not only benefit the environment, it is also possible to do it in a way that make short term financial sense. Finally, the learnings and knowhow that are drawn from investments made in energy optimizing technology today, will most likely prove to be a source of competitive advantage in the future and thereby increase likeliness of continuous profitability.

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Medium Range
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Introduction

For decades, reports and studies have hinted that we as a society are putting too much pressure on the earth. In recent years, new data and extreme weather cases in all parts of the world, have proved that the way we have organized and are exploiting our resources, is having a major impact on the climate. Therefore, political and private organizations are now facing major challenges in terms of minimizing the negative impact and, if possible, reverse some of the damages that have been done. The same also goes for the international shipping community. We are facing serious challenges in terms of CO_2 and other greenhouse gas (GHG) emission reduction. The main sinner in our industry is the fuel consumption of the vessels, and there is no doubt that the main focus is to live up to the 2030 and 2050 reduction targets, but that the end goal for the international maritime community is to come together to develop and implement pollution and GHG neutral fuels and, over time, rely 100% on renewable sources of energy.

Though full implementation of renewable energy propulsion lies many years in the future and due to the nature of our industry, with long lasting assets that represents major investments, it is vital that we look at the existing vessels and vessels being built today, as they will continue to operate many years into the future. Further stressing this need is the fact that a large part of the global fleet is not up for renewal anytime soon and their future compliance and energy efficiency is dependent on the shipowners retrofit choices. These choices are not easily made, and decisions are often based on the potential of the individual solutions, rather than a systematic approach.

To accommodate the difficult situation of the shipowners, and to explore the interdependencies of technology and causality in the engine room of a vessel, Green Ship of the Future and a group of members have co-developed a project exploring how far existing technology can take us on our mission to reduce emission from shipping in the short-term.

The objective

The objective of this project is to explore areas where retrofit can contribute significant energy savings of the selected vessel types and to present an overview of concrete examples that can be retrofitted today. To ensure maximum relevance, calculations are based on actual operational data, actual baseline fuel prices, and will be measured towards an estimated payback time of 3 years.

The partners in this project have explored three different high-volume vessels. An MR tanker from Hafnia, a RO-PAX from DFDS and an MR tanker from Maersk Tankers. As with the operational profile and fuel prices, the actual data and vessel profile of the specific vessels were used to ensure calculations on energy savings and business cases as close to reality as possible. In each case, the partners identify relevant technology with potential to significantly reduce the fuel consumption and again here, actual data from off-the-shelf technological solutions, that are ready to be retrofitted today, are used.

Each case and every vessel is different, and the fuel prices are highly volatile, therefore specific calculations are required to replicate this to other vessels. Yet, we hope to inspire shipowners, operators and financiers exploring energy optimization and CO2 reductions, to consider how presented areas and technologies can benefit their operational context.

"... we hope to inspire shipowners, operators and financiers exploring energy optimization and CO_2 reductions, to consider how presented areas and technologies can be used in their operational context "

Case Study 1.

– Hafnia Lise

Vessel description

Hafnia Lise was delivered in 2016 and was built according to standards with focus on hull performance, classification and ice classifications. The vessel was built as a well-thought-out technical solution that complies with current legislation. The yard offered some optimization options, but as the shipowner described it, it was not possible to see where and what the savings would affect, but more a list of options that together would save more than 100% of the fuel needed to run the vessel, so only a few options were chosen due to prior experience with the solutions.

INITIATION

M/T Hafnia Lise is an Oil and Chemical product tanker in the MR class (Medium Range), build at the Guangzhou International Shipyard, China in 2016. The vessel is ice classed +1A1.

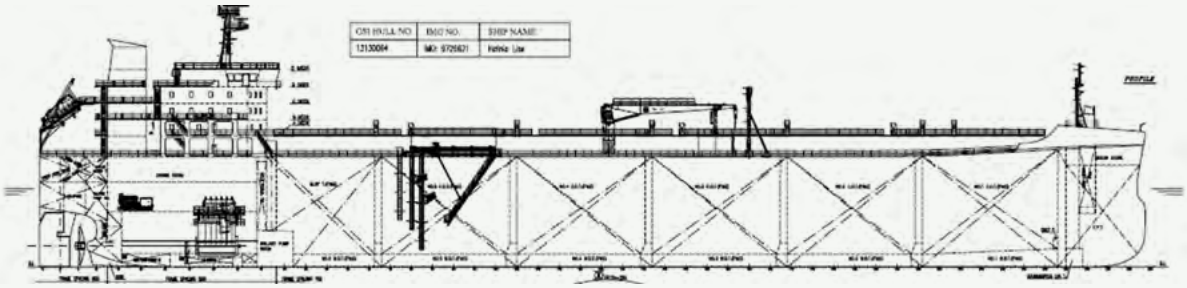
OPTIONS CHOSEN BY SHIPOWNER

- Frequency converters on seawater pumps
- Frequency converters on engine room ventilation
- Able to heat main engine with auxiliary cooling water during port stay
- Composite Boiler to minimize use of the larger auxiliary boiler when the steam demand is low

M7T Hafnia Lise manuvering in Saint Lawrence river, Canada

VESSEL DATA

Name	Hafnia Lise
Homeport Valletta (Malta)	Length 183 m
Width	32.26 m
Draft (max)	12.9 m
DWT	49,699 t
Hull type	Double hull
Cargo capacity	53,530 m^3
Cargo tanks	5 x 2 Cargo tanks + 2 Slop tanks + 1 ROT tank
Cargo pumps (electrical)	MarFlex deepwell
Pump capacity	550 m^3/h
Deck machinery is operational down to	- 25°C
Ballast water capacity	21,200 m^3



BASELINE FOR CALCULATIONS (AVG. HAFNIA MR FLEET)

Annual fuel consumption

RMG 380 3.5%	(ME) 4,085 ton + (Aux) 712 ton	4,797 ton/year (78%)
DMA 0.1 %	(ME) 1,165 ton + (Aux) 201 ton	1,366 ton/year (22%)
Aux fuel consumption is approx.		2.5 ton/day

AVERAGE BUNKER PRICES IN 2018 (AVG. HAFNIA MR FLEET)

RMG 380	3.5 %	418 $/ton
DMA	0.1 %	638 $/ton
Lube oil	ME/AUX	1.25 $/ltr.

LCV (Lower Calorific Value) ISO conditions

RMG 380 3,5 %	40,600 KJ/kg	(11.28 kW/kg)
Density at 15°C	990 kg/m3	CO_2 3,114 kg/ton fuel
DMA 0,1 %	42,700 KJ/kg	(11.86 kW/kg)
Density at 15°C	850 kg/m3	CO_2 3,206 kg/ton fuel

Trade Map Hafnia Lise

1st half 2018

2nd half 2018

TRADING PATTERN (AVG. HAFNIA MR FLEET)		
Laden days	131 days/year	36%
Ballast days	47 days/year	13%
Port days	172 days/year	47%
Idle days	15 days/year	4%

Hafina Lise outside Montreal

Areas suitable for optimization

Below is a list of areas selected for further optimization. In this project, focus is on short term decarbonisation and fuel reduction. While we are aware that there are other options available, some very innovative, the objective of this project is to explore the potential of today's best available and proven technology.

Listed in alphabetic order of company:

PAGE	SOLUTION	COMPANY
11	Boiler System	ALFA LAVAL
14	Ballast Water Management	BOS GLOBAL
15	Lube Oil treatment (CJC filter)	C. C. JENSEN
18	3-way valves for fresh cooling water for main engine	CLORIUS CONTROLS
20	Hull friction, Shore power, Lights	DANISH ENERGY CONSULTING
26	Pumps & engine room ventilation	DESMI
29	Data Platform	DNV GL
30	Hull fouling analysis, vessel speed and trim optimization	GREENSTEAM
30	Promas Lite (Rudder & Propeller)	KONGSBERG MARITIME
35	EcoBulb, Exhaust Gas By-pass matched for Low Load tuning, Power Take Off and new Kappel 2.0 Propeller	MAN ENERGY SOLUTION
47	Wind propulsion, Rotor Sail technology	NORSEPOWER
50	Route planning system	OPTIMUM VOYAGE
52	Organic Rankine Cycle (ORC)	ORCAN
55	Energy management	ROYSTON
56	Summary	

Boiler System

Installed base

Hafnia Lise use steam to heat fuel tanks, steam tracing of fuel pipes, cargo heating, lube oil separator, cargo cleaning and ice removal.

The installed base for Hafnia Lise is 1 x Combi-boiler type OC and 1 x Oil-fired boiler type OL. The OC boiler can utilize heat in exhaust gas (Waste heat Recovery) from main engine to produce steam and change to an oil-fired section when needed. The OC is designed for 500 kg/h of steam production on exhaust gas section, and 1,200 kg/h of steam production by oil combustion. The OL can produce 18,000 kg/h of steam by oil combustion and is used mainly for cargo discharge procedures.

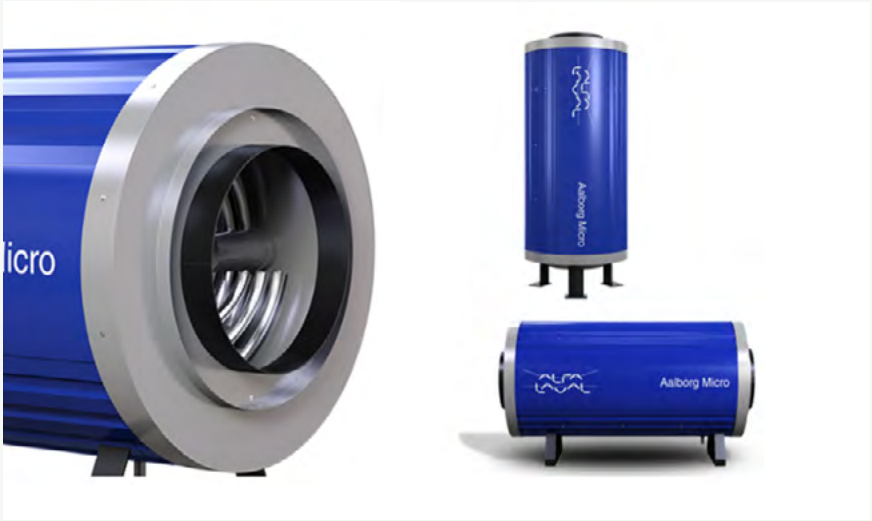
Operation pattern

On yearly basis Hafnia Lise, uses a total of 250t of oil in the boilers, with 75% on HFO and 25% on MGO. There is no data available on the operation pattern of the boilers informing which boiler is running, operation hours, stat/stop, and boiler load.

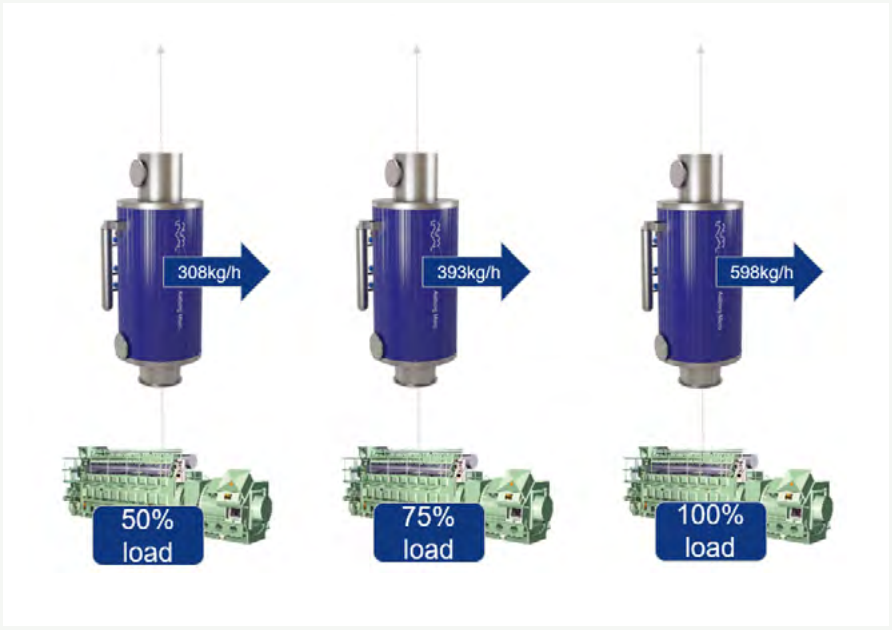
Micro exhaust gas Economizer on Hafnia Lise

The Alfa Laval Aalborg Micro is a WHR (waste heat recovery) heat exchanger unit which is designed for smaller sized diesel/gas engines as well as for gas turbines.

Onboard Hafnia Lise there is 3 x 900 kW auxiliary engines installed where heat in the exhaust gas is not utilized. Installing Micro economizers can reduce fuel consumption on the OL and OC boilers oil-fired section, by utilizing the heat to produce steam. It is recommended to install one Micro economizer on each Auxiliary engine, to have full flexibility and availability.



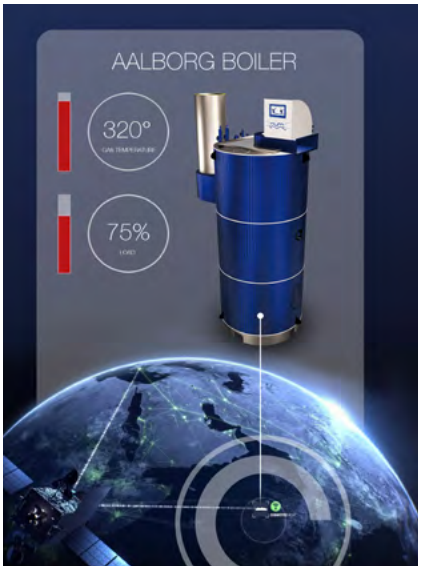
For Hafnia Lise 1 x Micro economizer can produce 393kg/h of steam at 75% engine load, as shown in below picture. This steam production that can reduced the OL and OC boilers oil fired operation with around ~30kg/h of fuel oil. If engine loads are higher or if 2 engines are in operation, more steam will be produced from the economizer and therewith an increased fuel saving.



Micro economizer steam output at different engine loads

Micro economizer has a good potential to help optimize fuel economy and reduce CO2. However, in this case more data on the existing boilers are needed to be accurate on ROI for Micro installation.

Installation of data-log on Hafnia Lise



During beginning of 2020 Alfa Laval have installed a data-log devise on Hafnia Lise boiler plant. After a period of operation, data can be extracted and analyzed by Alfa Laval boiler specialists, and with that information it is possible to find the ideal optimization solution with ROI calculation.

Moreover, the data log device can be used to continuously monitor the auxiliary boiler operation pattern. With access to the vessel's satellite connection, we make current boiler status, operating data and settings available online through a secure portal.

This portal can be accessed by the vessel's crew, the relevant onshore organization and Alfa Laval service specialists.

The Digital Services built on the portal are available in two different packages. The Silver package lets the vessel's crew – in collaboration with Alfa Laval's 24/7 Service Hotline – rapidly identify and rectify a problem, which saves time and potential cost. The Gold package further allows the system to be used for boiler health analysis, with Alfa Laval providing a monthly health report. This report includes suggestions for boiler optimization and reducing fuel consumption, as well as faults detected tanker. The technology is sold via subscription, so no upfront payment is necessary.

Learn more about digital steam service on:

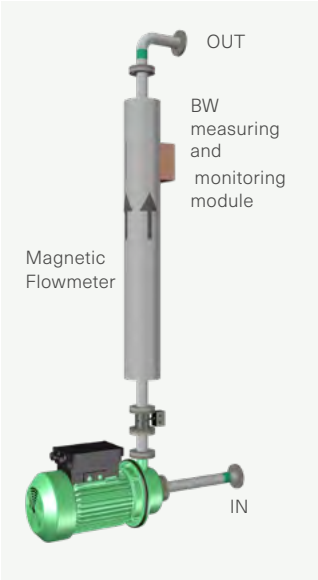
→ www.alfalaval.com/service-and-support/service-overview/improvement-services/boiler-digital-services/

Learn more about Aalborg Micro on:

→ www.alfalaval.com/products/heat-transfer/boilers/exhaust-gas-economizer/aalborg-micro/

Ballast Water Management System

Hafnia Lise is equipped with a ballast water management system (BWMS) from Headway Technology Co., Ltd. The BWMS complies to the IMO D-2 Regulation, California Requirement and USCG Standard. Current BWMS is based on an electro-catalyst process with an energy consumption specified as 17 kWh per 1,000 m^3, not including power for the ballast pumps during operation.



The mission of BOS is to create solutions that make better sense for the ecology and economy of ship owners. Truly green solutions come with low power requirements, near zero emissions and GHG, the best solutions and ideas are made to be simple. This is fundamental in BOS' research and product development.

Ballast Water Management System BOS Natural Ballast

BOS Natural Ballast measures and records all ballast water management parameters continuously. Typical ballast water treatment system assumes operational compliance once type approved. This may not be true since ships take ballast water from all corners of the oceans. The system verifies that the ballast water management system meets the ballast water discharge standard at all times.

The system can be for both retrofit and new built.

Savings and ROI

ITEM	OS NATURAL BALLAST	HAFNIA LISE EXISTING BWTS	SAVING
Power of BWTS	3 kW	17 kW	14 kW
Assumptions: - duration of each ballast operation = 20 hrs - no of ballast operation per year = 20			
Total Ballast Operation per year (hrs)	**400 h/year**	**400 h/year**	
Total kWh consumption per year	**1,200 kWh/year**	**6,800 kWh/year**	**5,600 kWh/year (82%)**

The standard price is 200.000 USD*.

Lube Oil Treatment and Oil Filtration

C.C.JENSEN

Lube Oil treatment

Hafnia Lise is equipped with separators for cleaning of the lube oil to the main engine and auxiliary engines. The lube oil is preheated in a steam heat exchanger before separation, with steam from the OC boiler (waste heat recovery boiler), main engine during sailing or from the OL steam boiler when the main engine is not running. Except for longer port stays, separators run continuously. Oil sludge from separators has a certain amount of water in it, which is used to clean the bowl. The oil sludge is to be either incinerated onboard or to be sent for treatment/disposal ashore.

Description of action and technology

The objective is to save energy by replacing existing technology used to clean lubricating oil on 2-stroke and 4-stroke engines.

By replacing the traditional purification system, where the oil needs to be heated to 90 to 95 degr. C, with a CJC off-line filter with the patented flow drive technology, the need for heating the lube oil is eliminated. The CJC filter reduces the overall power consumption with up to approx. 90%. Calculations are based on 8,000 running hours for both separators and filters per year and 2 tons of lube oil waste per year.

Heating that is normally for both separators and filters used for heating lube oil when the main engine is running is free to be used for other purposes such as an ORC plant that produces electricity.

Besides heat savings, a significant reduction in lube oil consumption and reduction of the lube oil waste is expected. Both reduce the total CO_2 footprint.

Reliable machinery performance starts with clean & dry oil

Energy savings based on baseline of calculations

MAIN ENGINE SUMMARY	L.O. CENTRIFUGE	CJC L.O. FILTER
Energy costs per year [kWh]	237,775	4,000
Energy savings with CJC per year [kWh]		**233,775**
Lube Oil waste [kg/year]	2,000	48
Lube Oil waste savings with CJC [kg/year]		**1,952**
CO_2 emission [kg CO_2/ year]	126,430	3,098
CO_2 emission savings with CJC [kg CO_2/ year]		**123,333**

AUX. ENGINE SUMMARY	L.O. CENTRIFUGE	CJC L.O. FILTER
Energy costs per year [kWh]	139,600	4,320
Energy savings with CJC per year [kWh]		**135,280**
Lube Oil waste [kg/year]	2,250	60
Lube Oil waste savings with CJC [kg/year]		**2,190**
CO_2 emission [kg CO_2/ year]	127,230	3,136
CO_2 emission savings with CJC [kg CO_2/ year]		**124,094**

Investments and Savings

Fuel saving	**70 ton/year**
Investment (ME + AUX)	**44,000 $**
Fuel cost savings	**36,750 $/year**
Lube oil waste saving	**18,900 $/year**
Total savings	**55,650 $/year**
CO_2 reduction	**239 ton/year**
Return on Investment (ROI)	**< 1 year**

Interdependencies with other technologies

The solutions do not, normally, affect other technologies besides reducing the energy consumption. In the case of Hafnia Lise, it will be possible to release excess steam from the composite boiler which can, for example, be used in an ORC plant for the production of electricity. Moreover, the amount of oil sludge will be reduced, hence also the cost of handling or disposing of the oil sludge.

The technology in a newbuilding situation

Installing a CJC filter unit in a newbuilding process will make savings in the initial capex and for the shipyard it will mean less installation cost as you do not need compressed air etc.

Does it make sense to implement in this particular case?

The technology makes sense to install on Hafnia Lise, as it will make a direct saving in energy and oil consumption, both of which save in CO_2 emission. Besides the saving in energy, it is also a less complicated piece of equipment to maintain compared to traditional purifiers.

Low leakage valves

When Hafnia Lise is in port or at anchor (idle mode) the main engine is shut down, but kept heated, ready for operation. Most 3-way valves in the fresh water-cooling system leak about 0.5% resulting in a heat loss to the sea cooler. The heat lost in port (idle mode) by leaking 3-way valves must be replaced by the boiler which increases fuel consumption on the boiler.

Description of action and technology

By replacing the 3-way control valve with a low leak valve it is possible to reduce the leak over the HT FW cooler and thereby save fuel used to reheat the HT water. The leak today is set to be 0.5%. Clorius Controls offer a low leakage valve with a reduction to 0.01%.

In general, the replacement is one to one and does not require docking or special competences.

Energy savings based on baseline of calculations

Our baseline considers running on MDO 0.1%S @638$/ton and a temperature of 55°C going into the engine. The cooler is cooling the leakage down to 36°C. We estimate to use 140g/eKWh on the boiler. The flow of HTFW is set to 93 m3/h

Interdependencies with other technologies

Replacing the 3-way valves does not affect other technologies other than reducing boiler load.

The technology in a newbuilding situation

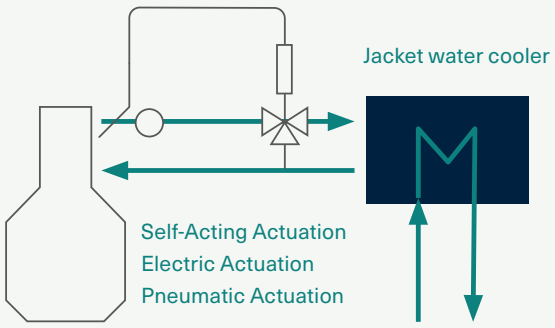
If low leakage valves are installed as newbuild, there will be cost savings to both the heat losses and replacement valves from the very beginning of operation.

Does it make sense to implement in this particular case?

Hafnia Lises' operation pattern for the main engine is about 50/50, which is about the same for most MR tankers. The business case is good and to be recommended.

Engine Jacket Cooling water system

In general, we recommend following the guidelines from MAN ES to make the LTFW as cold as possible (10°C). If followed, the result is expected to be a significantly bigger cool down, hence a much lower payback time.



Calculation example 1.

Flow m3/h	Leak %	Consumption Foul/year	Cost/year HFO	Cost/year LSFO 0,1% S	Cost/year MDO 0,1%
95	0.5%	12.9 ton	$ 5,385	$ 7,729	$ 8,219
95	0.01%	0.26 ton	$ 108	$ 155	$ 164
Savings/year $	12.62 ton	$ 5,277	$ 7,575		$ 8,054
ROI years	0.9	0.64			0.6

Note: Calculation made with 36°C FW cooling water

Calculation example 2.

Flow m3/h	Leak %	Consumption Foul/year	Cost/year HFO	Cost/year LSFO 0,1% S	Cost/year MDO 0,1%
95	0.5%	30.5 ton	$ 12,753	$ 18,306	$ 19,466
95	0.01%	0.61 ton	$ 255	$ 366	$ 389
Savings/year $		29.9 ton	$ 12,498	$ 17,940	$ 19,076
ROI years			0.4	0.27	0.25

Note: Calculation made with 10°C FW cooling water

Investments and Savings

Investment	**4,858 US$**
Fuel saving	**12.6 ton/year**
Fuel cost saving	**8,054 $/year**
CO_2 reduction	**40 ton/year**
Return on Investment (ROI)	**0.6 years**

Hull friction

DANISH ENERGY CONSULTING

Hafnia Lise is a relatively new vessel and is designed to have a low hull friction and is fitted with an ice classed bulbous bow. The vessel operates within the limits it has been designed to.

Slow steaming has in recent years been a way to save fuel for shipowners, but the savings often fail because the ship operates outside its design area. It is therefore important to look at hull optimization when considering slow-steaming. Still more vessels receive a “nose job” i.e. new designed bulbous bow, that matches the new service speed. Hafnia Lise is operating within design speed, thus there is no need for optimization at this point.

Hafnia Lise is coated with Hempadur antifouling. Due to sailing in icy waters and the relative short sailing time, we have not been able to locate areas with ROI below the requested target, so focus has been concentrated on other areas with larger effect.

The project group has also been looking into other methods to reduce hull friction as air lubrication etc. but these solutions have a relatively long ROI when compared to Hafnia Lise's trading pattern with approx. 50 % time in port. It has been stated that the sailing pattern in the project is very similar to most other MR tankers.

Hafnia Lise build at Guangzhou Shipyard International (GSI)

Shore Power

DANISH ENERGY CONSULTING

Most modern ships have a variety of electrical equipment requiring alternating current (AC) power for operation. While AC power is supplied by the ship's auxiliary engines and shaft generators at sea, it is desirable to connect to a dockside source of AC shore power when in port, to permit electrically disconnecting the auxiliary generators, deactivating the ships auxiliary engines. Doing so, will save fuel, running hours and maintenance on the ship's auxiliary generators and engines. This can be done without interrupting power to the various shipboard electrical components. For the port (and local community), all emissions during port stay are eliminated when using shore power.

Before connecting the ship's main distribution to AC shore power, the ship's main distribution must be disconnected from the ship's generator AC output which will cause a power interruption to the shipboard electrical components. This can, in some cases, cause breakdown of electrical components.

Furthermore, the characteristics of the shore power might differ from the characteristics of the ship's power. E.g. shore power might be a 50 Hz power supply, while the ship uses 60 Hz power.

Accordingly, it is necessary to convert shore power to shipboard use and also to transfer the ship's main power to AC shore power without interrupting power to shipboard electrical components. A converter placed onboard can be used for this in ports globally.

Not many ports offer shore power to tankers, due to the risk of fire. In addition, the cost of installation, which needs to be able to run in an EX environment, is a barrier. The Port of Long Beach (USA) is among the few ports in the world, offering shore power to berthing tankers, proving that it is possible to make shore power available in the environment of a tanker terminal.

Energy savings based on baseline of calculations

Looking at Hafnia Lise, the cost of shore power must be lower than $0.11 USD/kWh which is the average cost price for producing power on Hafnia Lise (looking only at fuel cost). Using shore power will reduce the cost for maintenance of the auxiliary engines, lower noise level aboard and reduce emissions in the harbour and surrounding areas.

Below are calculations for Hafnia Lise, were she to connect to shore power instead of using their own auxiliary engines "AUX". Calculations are made for US and Canadian ports according to trading pattern for 2018.

The calculations are made from the shipyards theoretical electric load needed for harbor stay and for unloading. The maintenance cost for running AUX is an estimate based on information from Hafnia. It is noted here that if the electrical load differs from the yard's electrical calculations, the fuel consumption will be lower, but maintenance cost / savings will remain the same.

Investment

The estimates cost for implementing shore power on a MR tanker the size of Hafnia Lise is in the range of $300,000 – $750,000 USD. This covers the cost of the converter and integration into the ship's power system.

PREREQUISITES	
Electric load "Harbor"	**491 kW**
Electric load "Unloading"	**2,373 kW**
Average price shore power US ports	**0.10 USD/kWh**
Average price shore power Canadian ports	**0.10 CAD/kWh**
DMA 0,1 % price	**638 USD/mt**
Maintenance cost pr. AUX	**0.26 USD/h**
AUX running during port stay	**1 pc.**
AUX running during unloading	**3 pcs.**

FINANCIAL SAVINGS	
US port	
Port stay, incl. maintenance savings	**≈ 350 USD/day**
Unloading, incl. maintenance savings	**≈ 1,500 USD/day**
Canadian port	
Port stay, incl. maintenance savings	**≈ 650 USD/day**
Unloading, incl. maintenance savings	**≈ 2,900 USD/day**

CO_2 SAVINGS	
Port stay	**≈ 7.5 ton/day**
Unloading	**≈ 36 ton/day**

Return on investment

Because the exact number of days in any specific port is not known, it has not been possible to calculate a return of investment.

Interdependencies with other technologies

Saves fuel and running hours on auxiliary engines. Does not affect other systems on board.

The technology in a newbuilding situation

The demand for lower emissions from shipping is increasing. Shore power can help to reduce the environmental impact of ships in port. Integrating a shore power system on newbuildings will be less complex and less costly than retrofit.

Technically it's feasible, but the question is whether the terminals have the willingness to invest in the shore power plants and whether the legislators will lower the taxes on shore power and thereby contribute to reducing shipping emissions.

Does it make sense to implement in this particular case?

At this point, a majority of the ports where Hafnia calls do not have the option of shore power. It will therefore not be profitable to invest in a shore power installation, for now.

Energy efficient lighting

DANISH ENERGY CONSULTING

The use of energy efficient lighting equipment such as low energy halogen lamps, fluorescent tubes and LED (light emitting diode) in combination with electronically controlled systems for dimming, automatic shut off, etc. is continuously developed as the focus on energy and environment has increased. The LED technology is to some extent "standard" when designing a new vessel today, but still some vessels are delivered without energy efficient lighting. LED has also been applied only to a limited extent to the shipping industry and standard normal design does often not include low energy lighting. Implementing an energy efficient light system will additionally reduce the maintenance hours and operating cost.

Hafnia Lise was delivered with standard fluorescent tubes and halogen lamps. Subsequent calculations are based on offers made to Hafnia Lise but will apply to most MR tankers. The calculations are based on baseline of calculations for Hafnia MR fleet.

Emergency lights is not included in calculations

LIGHTING ABOARD	
Fluorescent tubes ranged 18 / 36 W	**1,000 pieces**
Halogen floodlights ranged 40 / 400 / 500 / 800 W	**50 pieces**

FINANCIAL SAVINGS	
Converting to LED	**≈17,000 USD**
Converting to LED, RMG/DMA ≈30 ton/yearUSD	

CO_2 SAVINGS	
Converting to LED	**≈90 ton/year**

ROI	
Converting to LED	**≈2 years**

INVESTMENT	
Converting to LED	**≈34,000 USD**

Interdependencies with other technologies

Saves load on auxiliary engines and thereby saves fuel. Does not affect other systems on board.

The technology in a newbuilding situation

The LED technology is obvious in a newbuilding because the price difference in procuring ordinary lightning or Led is minimal.

Does it make sense to implement in this particular case?

Yes

Engine room light

Pumps and engine room ventilation

DESMI

In the design phase it was decided to optimize the engine room ventilation system with variable frequency drive (VFD), which was offered by the yard. It is, of course, possible to reduce the electrical power to the engine room fans, but it is important to consider if it is more relevant to reduce the engine room temperature, securing colder air to the main engine.

It is also important to choose the correct VFD regulation. The cheapest VFD regulators with manual settings are often regulated during sea trials and never touched again unless anything happens to it. Contrary, the most efficient VDF regulations are using multiple regulation factors as temperature, flow, pressure etc.

Hafnia Lise is equipped with both seawater and freshwater pumps for engine cooling etc. Pumps are normally designed to be able to operate in seawater temperature up to 32°C and running in one speed mode (start/stop). Accordingly, cooling pumps normally run at full speed to ensure sufficient cooling water. The installed VFD pack regulate pumps by water temperature or manual settings. Desmi experience shows that this (simple) VFD regulation is expected to reduce the electric consumption of the pumps with approx. 10-20%.

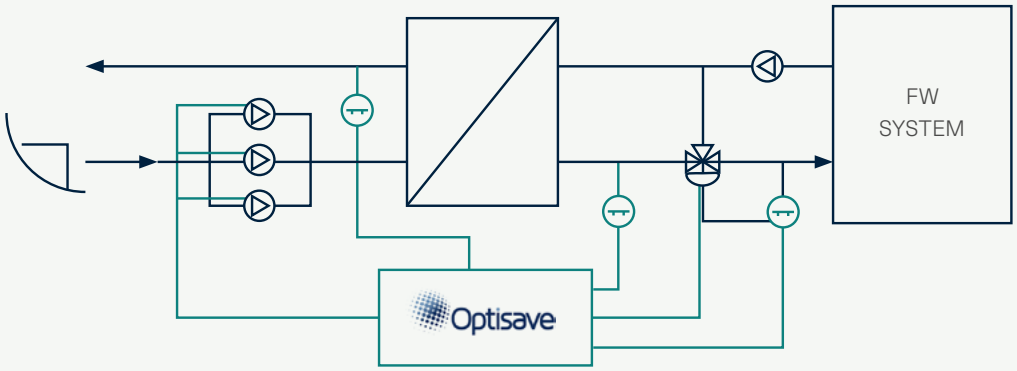
Description of action and technology

Desmi has designed an energy saving solution for both newbuildings and retrofit installations called “OptiSave”. OptiSave for pumps works on a combination of temperature and pressures to ensure lowest possible energy consumption and still providing sufficient flow/pressure. OptiSave for engine room fans works by a combination of temperature, overpressure and main engine load.

OptiSave frequency converters are programmed to operate all safety functions such as:

- *Standby control*
- *Black-out restart*
- *Priming control*
- *Over current protection*
- *Under voltage protection*
- *Internal temperature of electrical motor*

DESMI OptiSave solution for cooling pumps



Energy savings based on baseline of calculations

DESMI has calculated four different options for comparison on an OptiSave™ solution, replacing existing system.

Options 1*

	SAVINGS (HFO)	FUEL SAVINGS (Already installed VFD solution)	ROI
Seawater	5.5%	50 ton/year	4.6 years
Seawater + FW / LT Water	5.5%	50 ton/year	6.2 years
Seawater + engine room fans	6.0%	55 ton/year	5.4 years
Seawater + FW / LT Water + engine room fans	11.5%	105 ton/year	3.6 years

Electrical reduction	≈ 200,000 – 430,000 kWh/year
Fuel reduction	total 50 - 105 ton/year
Economical savings	≈ 20,000 – 43,000 $/year
Emissions reduction	135 - 283 t/CO_2 / 4.3 – 9.1 t/NOx / 2.6 - 5.5 t/SOx

** Calculations are based on AE consumption of 2.5 ton/day, compared to today's VFD solution.*

Options 2*

	SAVINGS (HFO)	FUEL SAVINGS (Newbuild)	ROI
Seawater	12.4%	113 ton/year	2.1 years
Seawater + FW / LT Water	21.0%	192 ton/year	1.6 years
Seawater + engine room fans	16.1%	147 ton/year	2.0 years
Seawater + FW / LT Water + engine room fans	24.8%	226 ton/year	1.7 years

Electrical reduction	≈ 450,000 – 1,000,000 kWh/year
Fuel reduction	total 113 - 226 ton/year
Economical savings	≈ 47,000 – 94,000 $/year
Emissions reduction	305 - 610 t/CO_2 / 9.8 – 19.6 t/NOx / 5.9 – 11.8 t/SOx

** Calculations are based on AE consumption of 2.5 ton/day.*

Investment

(estimated installation cost included) 97,000 $ - 157,000 $

Interdependencies with other technologies

Reduces the power consumption for auxiliary engines. Does not affect other systems if the requirements for cooling water and ventilation systems are met.

The technology in a newbuilding situation

If implementing the system in a newbuilding, correct functioning of pumps and ventilations systems are obtained from the very beginning and thus the fuel and emissions savings.

Does it make sense to implement in this particular case?

Because Hafnia Lise already has VFD on sea water pumps, calculations show a ROI target above the desired value. Calculation without prior VFD installation also argue, that an investment is advisable.

Data Platform

The maritime industry is undergoing a process of digital transformation and shipowners are collecting increasingly more data from their vessels. For a long time, the market for software to collect, process and network ship-specific data – including digital vessel fleet-management systems – has been developing to a lesser extent. Until recently the available systems had been isolated solutions for individual sub-sectors of shipping company operations. One reason for this had been the mere lack of technical possibilities to transfer and store the incoming data.

Analyze, control, and share data with Veracity by DNV GL.

The potential for smarter use of data in our industries is enormous. To facilitate frictionless connections between different industry players, domain experts and data scientists, DNV GL has built an open and secure platform facilitating exchange of datasets, APIs, applications and insights.

Named after one of the 4 Vs of Big Data: Volume, Velocity, Variety and Veracity – our platform is designed to help companies unlock, qualify, combine and prepare data for analytics and benchmarking. We are not looking to own data, but to help our customers and other stakeholders in our industries leverage the ever-increasing amount of data they own.

Secure sharing of data

The key to unlocking the potential that industrial data holds is trust, and the ability to operate across silos. That is why secure sharing mechanisms are at the core of our platform - to make it easy for you to manage access and control your own data sets. You can either perform your own analytics or invite others to perform analytics on your assured data. That is what we mean by an open platform. Security is of course carefully managed, and the infrastructure is based on Microsoft Azure.

For DNV GL, operating an open industry data platform, is first and foremost an additional way of fulfilling our purpose – to safeguard life, property and the environment. For more than 150 years DNV GL has been a trusted expert in the analogue world, connecting yards, designers, owners, operators, contractors and authorities. Now we are fulfilling this same role in the digital domain.

Creating value from data

→ *www.veracity.com/article/why-we-build-veracity*

Veracity will give you access to industrial applications and data analytics services that can help you make better use of your data to optimize your performance. Here you can combine your own data with other data sets available for purchase or subscription, to create new insights or solutions.

DNV GL and other providers will offer data quality management services upon request. These services will assist data managers in assessing, understanding and improving the quality of their data sets, and making them better suited for analytics.

Fouling, trim and speed analysis

GreenSteam recommend their Discover service to initially understand a vessel. GreenSteam Discover uses machine learning to create a vessel performance baseline from which fuel efficiency insights and actionable advice are provided, leading to measurable financial gains from maximizing the operational efficiency.

Using a range of voyage, fuel, and weather/sea-state data, Discover analyses the historical operational performance and advises on where the biggest inefficiencies are. Being data-driven, Discover can be applied to all vessel types, and it identifies a wide range of opportunities to improve efficiency. From vessel or voyage trim settings, to speed planning and optimization, hull/prop coatings performance, or to dry dock schedules, Discover identifies all the areas where fuel is wasted and where operational changes will deliver measurable savings. It is not unusual for Discover to identify fuel waste of over 10% in some areas.

Giving clear insights into where the biggest savings are going to be made, and requiring a low initial investment, Discover is a low-risk route to understanding where and how the operational performance of a vessel or entire fleet can increase.

Discover identifies fuel-saving opportunities. Machine learning technology accurately measures and identifies every inefficiency, however small, including those that are often overlooked by other models because they are perceived as immaterial or difficult to quantify.

When Vessel operators need to make a new technology investment decision that is based on proven benefits a machine learning approach is best placed to provide the necessary detail.

Discover delivers insights into your operations, identifying and reporting on your potential fuel savings before you invest further. Knowing where your savings are going to be made, you'll be able to prioritize decisions about which GreenSteam Advisor services to subscribe to. Either individually or together, they provide you with predictive advice on how to operate your vessels to maximize fuel savings and reduce the environmental footprint.

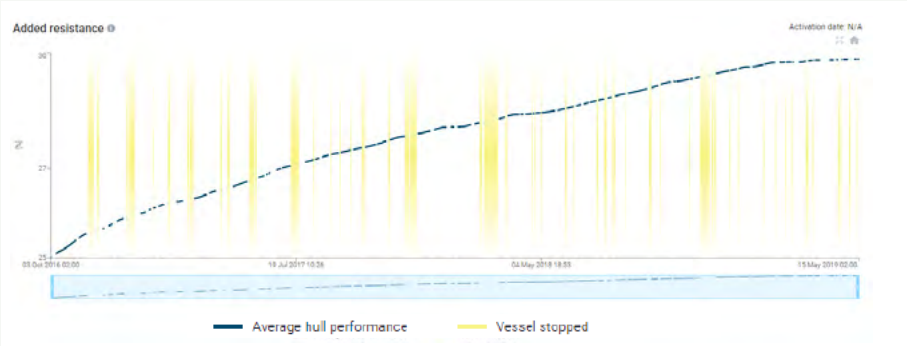
Energy savings identified on baseline

Discover identified that the total annual realizable savings amounts to $386,000, 763 ton of fuel, and 2,401 ton of CO_2 next 12 months if the full solution is implemented.

The waste levels identified by the Discover service are used together with the baseline profile created for the vessel to predict the waste for the next 12 months. If Hafnia Lise is operated as historically without any hull cleanings or changes to trim settings. A total of **$679,803** for the next 12 months will be wasted.

Fouling

Assuming a hull and propeller cleaning will improve performance by 8% (this has been identified by sister vessel Hafnia Henriette, which had same fouling level before the cleaning), the annual savings will be **$238,000**, limiting the fouling waste to $151,000.



Trim

Trim waste is based on data with little variation in trim meaning there is some uncertainty with regards to the predicted waste. Conservatively, let's assume 4% of the waste can be converted to savings, the annual savings will be **$119,000** annually. To realize these savings our Dynamic Trim Optimizer onboard solution is recommended, which delivers ownership of trim optimization to the crew onboard.

Speed

The fuel wasted on suboptimal speed is relatively low at 2.2%. Charter party speed and consumption are often a barrier to realizing this potential, however, with voyage optimization combined with speed optimization using our performance model will allow Hafnia to realize about 1% or **$30,000** annually.

The table below summarizes the current waste identified and using the baseline consumption figures, the waste over next 12 months is calculated.

Fouling, trim and speed analysis

Waste type	Waste level	Baseline RMG 380 3.5% consumption [mt/year]	Baseline DMA 0,1% consumption [mt/year]	RMG 380 3.5% waste [mt/year]	DMA 0.1% waste [mt/year]	Total waste [mt/year]	RMG 380 3.5% waste [$/year]	DMA 0.1% waste [$/year]	Total waste [$/year]
Fouling	**13.1%**	3,515	2,350	460	308	768	192,474	196,408	388,883
Trim	**7.6%**	3,515	2,350	267	179	446	111,665	113,947	225,611
Speed	**2.2%**	3,515	2,350	77	52	129	32,324	32,985	65,309
Total	**22.9%**					**1,343**			**679,803**

The calculations are based on the actual fuel consumption and trading pattern for Hafnia Lise in 2018, not average for Hafnia MR fleet.

The above savings of 804 mt/year RMG 380 and 539 mt/year DMA result is a CO_2 saving of ≈ 4,231 mt/year.

During the period of the trial, Discover will also be able to show any change to the figures as a result of implementing other new technologies and hardware.

Interdependencies with other technologies

Route optimization (from OptimumVoyage) can act as input to our Speed Optimizer.

Investment

A total investment of $70,000 is needed to realize the savings for the next 12 months of $387,000.

- All services incl Dynamic Trim, GreenSteam hardware, data collection, and advice: $25,000 annually.
- Installation of hardware for onboard solution: $20,000 (one-time fee)
- Hull cleaning is estimated at $25,000.

ROI (based on fuel savings)

1-year discounting – 6.75% discount rate
NPV **$303,613**
ROI **334%**

Does it make sense to implement in this particular case?

This technology examines the vessel and creates an accurate performance baseline. As well as providing insights on the vessels fouling, trim, and speed it will be able to clearly show the effect of implementing different technologies (or combination of technologies) on the vessel's performance.

Technology in a newbuilding situation

Analysis of a newbuild is difficult as there is no operational data to work with. However, by examining a large number of similar vessels, generic performance profiles can be created so performance optimization and specific vessel baselining can happen soon after a vessel is launched

Aft ship – Propeller and Rudder

KONGSBERG

Hafnia Lise is equipped with a cupped Fixed Pitch propeller, i.e. the edge and tip of the propeller blades are changed to increase the pitch of the propeller. This was done from newbuild due to the acceleration problems encountered on a sister vessel.

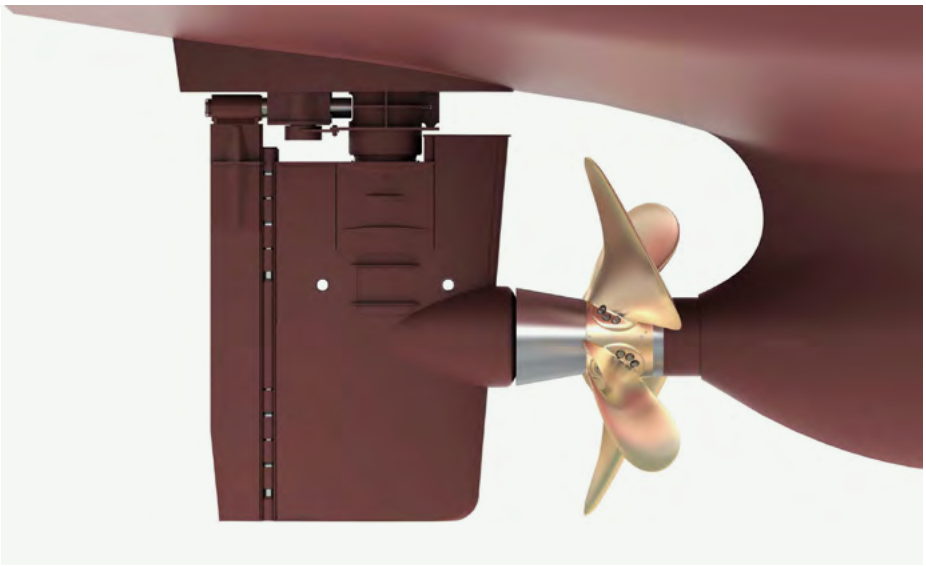
Subsequently it has shown that the acceleration problems originated from the main engine which has been corrected. Cupping of propellers are most often done to give the propeller more pitch and increased effectiveness. But because the cupping on Hafnia Lise was done to help a problem that originated from another source, it will be investigated if it is possible to increase the effectiveness of the whole aft ship, including propeller and rudder.

Description of action and technology

Promas Lite is a fuel saving system that utilizes the efficiency improvement potential in the interaction between rudder and propeller. Part of the improvement is given by the Costa Bulb that reduces the hub vortex and drag, reduces slipstream contraction and increases the wake fraction. The Hubcap will contribute by streamlining the transition of water. The contribution of the bulb and hubcap will enable an optimization of the propeller that would not be possible without the two former features. Therefore, a Promas Lite system always comprises all three features.

In retrofitting projects, there is usually also room for various extents of propeller efficiency improvement separated from the Promas Lite propeller effect described above but integrated in the retrofit as such – the Reblading effect. This has to do with the difference in present operation criteria compared to original design criteria and can involve multiple parameters that affect the propeller and ship performance.

Promas Lite, Kongsberg Maritime



Energy savings based on baseline of calculations

Typical savings contributed by the Promas Lite effect alone range between 2-6%, depending on vessel type and design. Savings contributed by the Re-blading effect can in some specific cases be as high as 20%.

The Propulsion efficiency improvement for Hafnia Lise is estimated to 3%. Hence the energy savings (Pd) is 195 kW at SMCR. Tonnes of fuel, CO_2, SOx, NOx is depending on Yearly Operation hours, SFOC at SMCR.

The reduction of Pd will slightly affect the SFOC for the engine at a given speed. This interdependency needs to be verified by the engine maker.

When looking into optimizing propeller and rudder on a MR tanker, each vessel must be evaluated separately to receive a correct evaluation.

The technology in a newbuilding situation

From a business perspective, to include the Promas concept in a newbuilding project is quite different from the retrofit situation. In the newbuilding case, the delta cost for installing the Promas concept compared to a conventional rudder and propeller is low, but the gain is high. This means that the ROI for the Promas features is fast and should always be considered when planning for a newbuild.

Investments and Savings

Fuel saving	**123 ton/year**
Investment cost (equipment)	**584,000 $**
Fuel cost	**60,000 $/year**
CO_2 reduction	**383 ton/year**
Return on Investment (ROI)	**8.5 years**

Calculations are made with actual consumption of RMG 380 3,5% and DMA 0,1%, changing into a low sulphur fuel in 2020 will affect the business case positively.

Does it make sense to implement in this particular case?

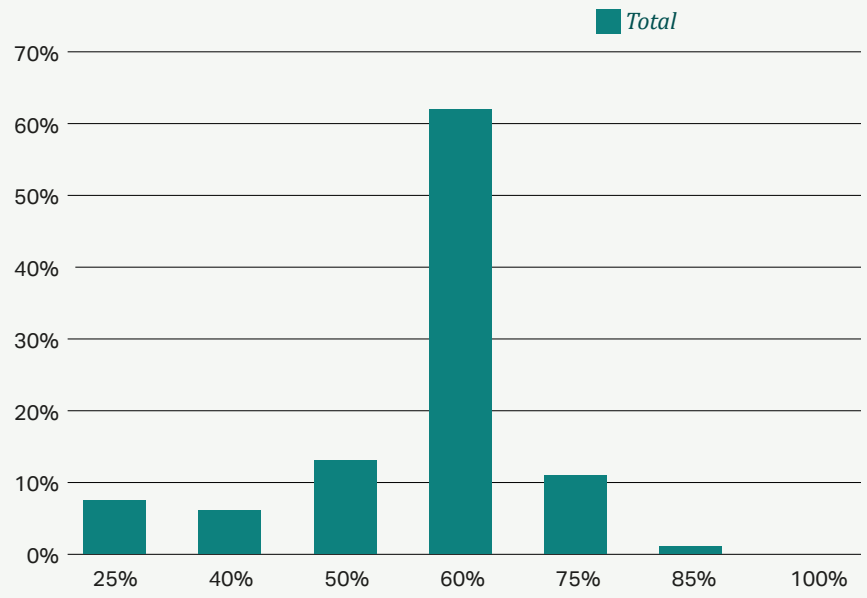
Hafnia Lise is not a suitable object for Promas Lite, from a ROI perspective, when looking at the existing fuel consumption of both RMG 3.5% and DMA 0.1%.

Existing propellers scrap value has not been included in the budget, which otherwise could improve the case ROI, but when looking into the existing data on Hafnia Lise, that the propeller already is cupped, and the fact that the space between propeller and rudder is relatively short, it cannot be recommended to optimize further in this case.

Main engine

Hafnia Lise is equipped with a 2-stroke DaLian Marine Diesel (license build MAN Diesel engine) Type: HHM MAN 6S50ME-B9.3-TII, Tier II MCR: 10,680 kW, SMCR: 7,628 kW, CSR: 6,684 kW.

Operational profile for Hafnia Lise



Based on the above operating profile the main focus will be on optimizing the vessel in the 60% load range (55.1% - 67.5%) as the large majority of the operating hours are in within this range.

Exhaust Gas By-Pass Matched for Low Load Tuning (EGB-LL)

Solution A investigates an Exhaust Gas By-pass matched for Low Load tuning (EGB-LL). It is expected that the existing turbocharger, with retained rotor, can accommodate the installation of an exhaust gas by-pass, with exchange of turbocharger matching components (nozzle & diffuser ring) only. If this solution is chosen final confirmation of the above must be obtained from the chosen turbocharger maker.

This solution will require an amendment to the technical file. Simplified onboard NOx measurements will be required.

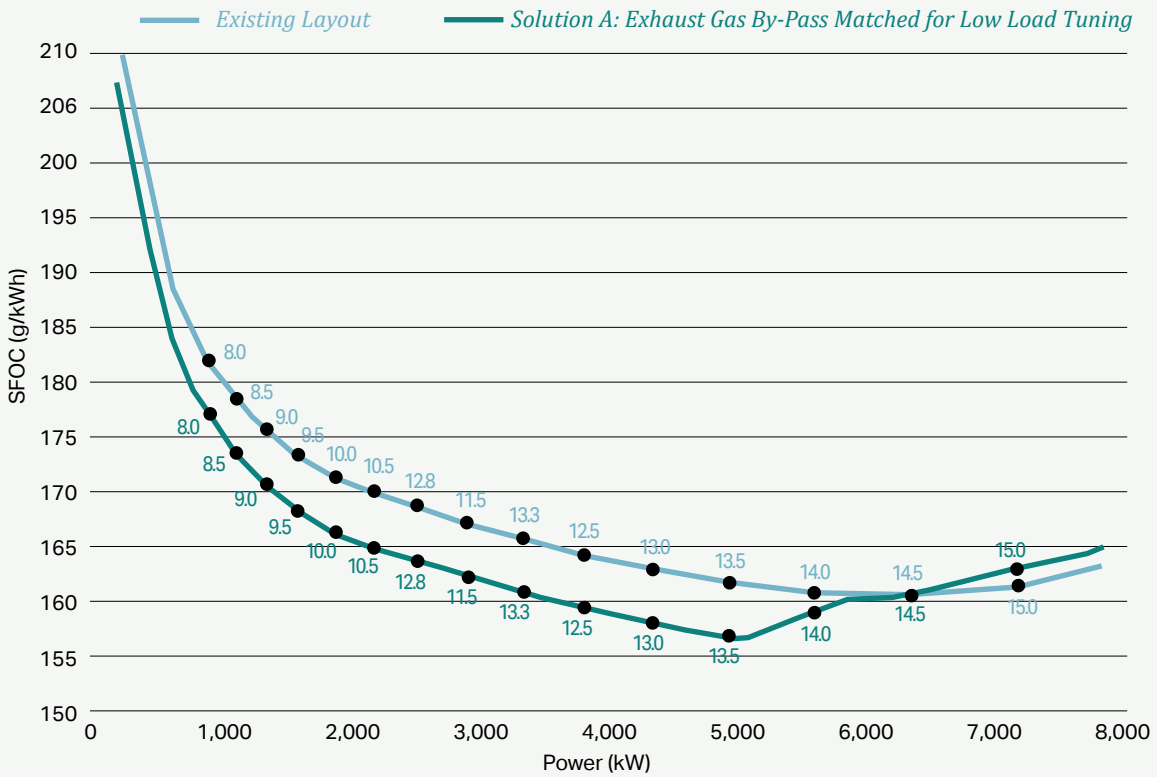
This solution has been investigated with regards to torsional vibrations. The investigations indicate no torsional vibration counter measure is required.

Potential Savings

The potential Specific Fuel Oil Consumption (SFOC) saving, which can be acquired when installing an Exhaust Gas By-Pass (EGB) matched for low load optimization is as follows:

- Effect from 75% load and below
- Full effect **5 g/kWh** from 65% and below
- Negative effect from 80% and up

Exhaust gas by-pass matched for low load turning



SFOC Saving For Solution A: Tuning - Design Draft

The calculated expected savings in Fuel Oil Consumption (FOC)

SAVINGS			
WITH EGB-LL	**FOC SAVINGS**		
	[ton/24h]	**[%]**	**[$/year]**
15.0 kn. design draft	**-0.252**	**-0.9**	**-21,003**
13.5 kn. design draft	**0.585**	**3.1**	**48,771**

Expected FOC saving for Solution A: Tuning

At a vessel speed of 13.5 kn. the CO_2 savings will be 1.8 ton/24h.

Scope of Supply for Exhaust Gas By-Pass (EGB-LL)

The following will be the scope of supply from MAN PrimeServ.

- Exhaust gas By-Pass valve
- Exhaust gas By-Pass control system
- By-pass orifice
- Exhaust gas piping from exhaust receiver to valve
- Insulation of exhaust gas piping from exhaust receiver to valve
- Installation of exhaust gas by-pass valve
- Turbocharger nozzle ring
- Turbocharger diffuser ring
- Installation of turbocharger nozzle ring and diffuser ring
- Commissioning
- Sea trial attendance (1 person)
- Simplified on-board NOx measurements
- Technical file amendment

Required Owner´s Supply / Yard Supply

The following items are not included in the quoted price as the exhaust gas piping arrangement is unknown to MAN PrimeServ at this point:

- Transport of all components from yard´s component reception area to inside the engine room.
- Exhaust gas by-pass piping required from exhaust gas by-pass valve to the exhaust gas pipe after the turbocharger
- Insulation of exhaust gas by-pass piping required from exhaust gas receiver to exhaust gas pipe.

ROI

The total price for a standalone solution including installation, modification of the turbocharger, installation & documentation: 187,695 resulting in an ROI of 3.8 years.

The price for components and installation of an exhaust gas by-pass matched for low load optimization is based on exchange of the turbocharger nozzle ring only.

Estimated Time for Installation

The Exhaust Gas By-Pass (EGB) matched for low load tuning installation including installation of new turbocharger matching components is estimated to require 5 days for installation.

MAN EcoBulb

Solution B consists of retrofitting the MAN EcoBulb solution to the propeller and rudder. The MAN EcoBulb is a custom designed solution consisting of a Faring Cone attached to propeller hub and Rudder Bulb attached to the Rudder.

The working principle for the MAN EcoBulb is that it eliminates the hub vortex generated behind the propeller hub. The hub vortex generates a drag and by eliminating it a saving in the required propulsion power is achieved.

The expected saving from applying the MAN EcoBulb is expected to be 1.5%.

The installation of the MAN EcoBulb will require a drydocking.

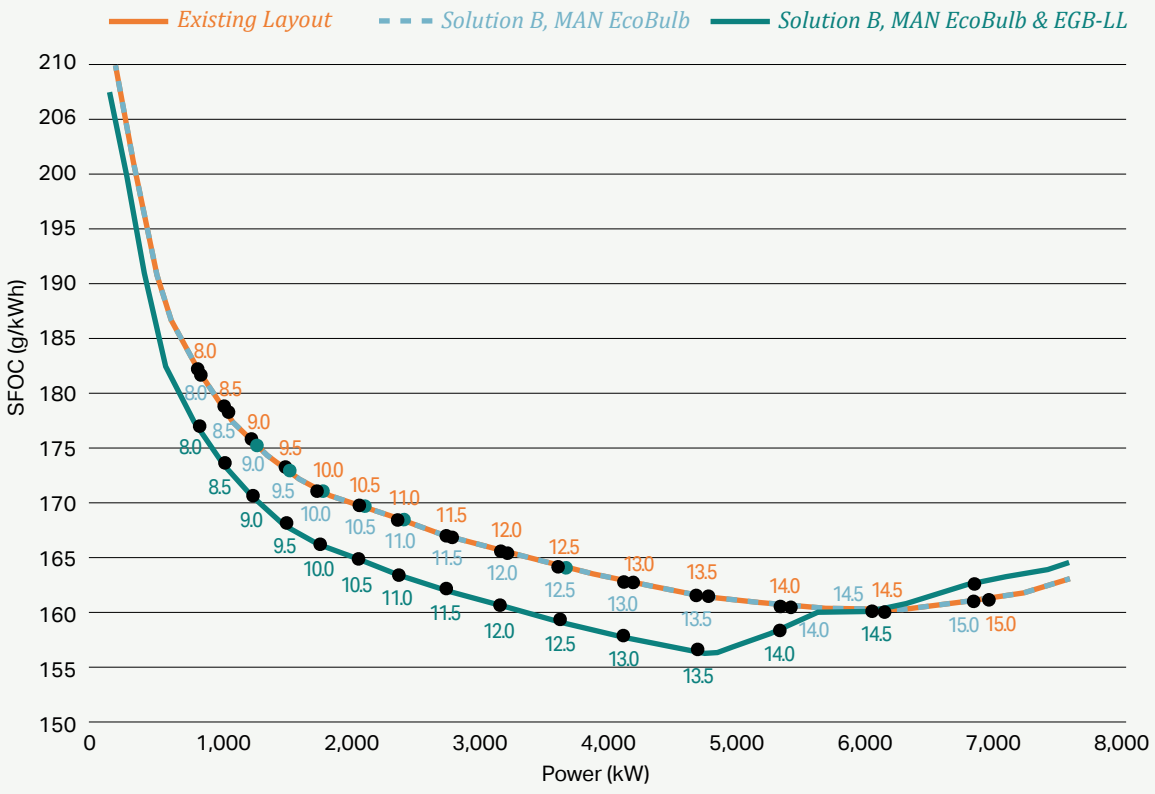
This solution has been investigated with regards to torsional vibrations. The investigations indicate that no torsional vibration counter measures are required.

This solution can be combined with **solution A: Exhaust Gas By-Pass Matched for Low Load Tuning (EGB-LL)**

Potential Savings

The potential Fuel Oil Consumption (FOC) saving is due to the increase in compression pressure at part load originating from the retrofit of the EcoCam. The reduction in FOC originates from one source. 1. Hub vortex elimination by MAN EcoBulb. The SFOC reduction for this solution is illustrated in figure below.

Solution B, man ecobulb



SFOC Saving Solution B

The SFOC reduction along with the reduced power requirement results in the total reduction in Fuel Oil Consumption (FOC).

The expected savings in FOC

HIGH LOAD	FOC savings		
	[ton/24h]	[%]	[$/year]
15.0 kn. design draft	0.440	1.6	36,679
13.5 kn. design draft	0.261	1.4	21,737

Expected FOC saving for Solution B

At a vessel speed of 13.5 kn. the CO_2 savings will be 0.8 ton/24h.

Scope of EcoBulb

The following will be the scope of supply from MAN PrimeServ, Project & Retrofit, Frederikshavn.

- Engineering Design based on the information given by customer
- Classification of required parts
- Fairing cone in stainless steel
- Bolts and nuts for fixing fairing cone to propeller hub
- Anode for propeller

Designed for installation in fairing cone

- Rudder bulb of steel similar to the existing rudder.
- Loose supply to yard
- Structure and shell plating to have up to 50mm over length for in-situ fitting by the installation team

Required Owner´s Supply / Yard Supply

The following items are not included in the quoted price from MAN PrimeServ:

- Installation is not a part of the scope of supply, as this is normally a yard task
- Transport of all components from yard/owner's component reception area to relevant installation positions inside the engine room
- Transport of used components away from engine room to owner's storage area
- Acceptable storage of components at yard/vessel
- Freight charges and customs duties, also for subsequent deliveries and special measurement equipment.
- Attendance of superintendent is not included, will be charged according to service letter conditions and rates
- Fees for special training courses / special certificates for MDT service personnel, which are mandatory to work on site
- Waiting time and delays

ROI

The budget price for a MAN EcoBulb including design & documentation: €116,265 resulting in a ROI of 6.1 years.

Estimated Time for Installation

Time consumption MAN EcoBulb retrofit is dependent on the shipyard but approximately 5 days has been achieved on previous projects.

Power Take Off and new Kappel 2.0 Propeller

This retrofit solution is a combined retrofit solution including both the installation of a new retrofit of a Power Take off in combination with a new retrofit custom designed Kappel 2.0 propeller and the installation of a MAN EcoBulb matching the propeller, hull and design speed.

The engine Specified Maximum Continuous Rating (SMCR) is not changed.

The savings presented originate from 3 parts:

1. Savings gained from the propeller retrofit required when installing a PTO. An optimized retrofit propeller reduces the power demand of the engine and thereby the fuel consumption
2. Fuel savings by utilizing the main engine with lower SFOC produce the required electrical power consumption during navigation
3. Reduced Maintenance cost as the activation of the PTO will reduce the amount of running hours necessary by the Auxiliary engines

Retrofitting a Power Take Off (PTO) will (if nothing else is done) result in the engine operation becoming heavy running and operate to the left side of the nominal engine operating propeller curve through SMCR.

A too heavy running engine will have increased Fuel Oil Consumption (FOC) and increased wear rate on combustion chamber components due to increased thermal load.

Therefore, when installing a PTO, MAN PrimeServ recommends to install a retrofit propeller which is designed with an increased light running margin in order to counter the heavy running effects of the PTO.

In this case a light running margin of 10% is chosen instead of the recommended standard of 5%. This is done not only to ensure correct light running when installing the PTO but also because the vessel series has had a history of low light running margin resulting in a requirement for cropping the propeller shortly after delivery.

Power Take Off – Design parameters

In order to investigate the different possibilities for retrofitting a Power Take Off (PTO) system, the design parameters have been investigated and decided upon as stated in the paragraphs below.

Existing Size & Type

The vessel has 3 gensets (auxiliary engines) of the same size and type and cylinder number installed.

Existing Auxiliary Engine Type Daihatsu DK-20e

- Units: 3 units
- Power: Approx. 960 kWm
- Output: 440 volt 60 Hz.

Electrical Power Consumption with PTO Engaged

The Power Take Off (PTO) will be engaged during “Normal Seagoing”. Therefore, for the commercial evaluation the power requirements stated in the Electrical Power Balance as required during “normal seagoing” is used.

The electrical consumption during “normal seagoing“ is stated to be ≈714kW

Power Take Off Layout

The layout of the Power Take Off (PTO) is based on the owner’s intention of substituting one genset (auxiliary engine) with the Power Take Off (PTO) and that the PTO can deliver all necessary electrical power during navigation in “Island Mode”.

The following design parameters has been used

PTO load during normal seagoing	**714 kW**
PTO Size:	**900 kWe**
	1,000 kWm

Power Take Off Position inside Engine Room

Based on the received documentation and the outline drawing from the Power Take Off alternator maker, it has been concluded that a position in front of the engine is possible. This is shown by the blue box on the figure below. As can be seen, there is space for the PTO between the forward bulkhead and the main engine.

This position will require that the seawater pipe between the sea chests is repositioned along with bilge and ballast water pumps and other equipment in the area.

Savings – FOC

The potential Fuel Oil Consumption (FOC) saving is due to the reduction of power at a given speed due to the increased efficiency of the Kappel 2.0 Propeller.

In addition, the saving from producing the electrical power with the PTO during normal seagoing is included.

Saving is due to the difference in SFOC between the main engine and the gensets.

The reduction in FOC originates from three sources:

1. Increased efficiency of the Kappel 2.0 propeller
2. Reduced SFOC for generating electrical power
3. Difference in SFOC for the genset and main engine

The engine SMCR is unchanged.

	Vessel speed		FOC savings	
	(kn)	[ton/24h]	[%]	[$/year]
Main Engine	15.0	-2,411	-8.9	-209,085
	13.5	-2,002	-11.6	-191,076
Gensets	15.0	3.77		335,534
	13.5	3.77		335,534
FOC saving	13.5			151,824

Expected FOC saving for Solution C: Power Take Off and new Kappel 2.0 Propeller

At a vessel speed of 13.5 kn. the CO_2 savings will be 5.5 ton/24h.

Potential Maintenance Saving on Gensets

The Power Take Off size is chosen so that the full electrical power production during navigation is delivered by the means of the Power Take Off (PTO). No gensets are expected to be in operation. As a result, the genset maintenance cost is reduced due to the reduced genset operating hours. The expected operating hours is 4,380 hours in navigation.

The reduction in maintenance cost originates from one source: reduced amount of operating hours on the gensets during navigation.

According to Hafnia, the average cost for maintenance is estimated to be 0.26 USD per operating hour per genset Based on this the expected saving on gensets operation is expected to be 1,138 USD.

MAN Alpha Kappel 2.0 Propeller

The below will be the scope of supply from MAN PrimeServ, Retrofit & Upgrade, Propeller & Aft ship, Frederikshavn.

- Kappel 2.0 propeller, 1 (one) piece per vessel. On exchange basis, existing propeller to be turned over to MAN PrimeServ
- Propeller shaft cone contact area calculation
- Propeller noise level evaluation
- Stern tube bearing load calculations
- Alternative shafting solutions (if needed)
- Class certificates
- The VibraSafe Concept
- Torsional vibration calculation (is there a barred PRM range)
- Axial vibration calculation
- Whirling vibration calculation (if needed)
- Shaft alignment calculations

Power Take Off System

The scope of supply for the Power Take off (PTO) system covers the components below:

- 1 Hybrid Multi Drive gearbox Type SHI
- The connecting parts for the highly elastic coupling and for mounting the gearbox on the main engine are included
- Lube oil supply system for PTO system connection to main engine lubrication oil system
- One (2) special permanent magnetic generator in extra short design for front end systems, 450 V 60 Hz, liquid cooled. Efficiency of the Generator 97%
- Frequency converter (FC) is air cooled. FC is equipped with an active front end for very low harmonic distortion and an insulation transformer for separation of the grid to the FC. FC can provide 2,5 times short circuit for 2 seconds for islanding operation. FC is suitable for island mode
- Instruments incl. wiring up to terminal box in accordance with the Classification Society DNV-GL
- Survey: DNV-GL or equivalent
- Cable between generator and FC up to 30 meter is included
- Cable between FC and main Switch Board up to 30 meter is included

Required Owner´s Supply / Yard Supply

The following items are not included in the quoted price from MAN PrimeServ, Retrofit & Upgrade, Propeller & Aft ship, Frederikshavn.

General

- Transport of all components from yard´s component reception area to inside the engine room
- Transport of used components from engine room to yard´s component reception area
- Freight charges and customs duties, also for subsequent deliveries and special measurement equipment, also return delivery of matching parts and measure equipment
- Fees for special training courses / special certificates for MDT service personnel, which are mandatory to work on site
- All engine tools to be available and in good working condition
- Engine room crane to be available and in good working order along with relevant lifting tools
- Engine condition to be within the limitations set in the MAN operational and maintenance manuals
- Waiting time and delays

MAN Alpha Kappel 2.0 Propeller

- Tank Test with wake field required for Kappel propeller design
- Changes required to the shaft alignment deemed necessary by the shaft alignment calculation report
- Changes and/or additional equipment required to the shaft and/or engine deemed necessary by the torsional vibration calculation report
- Installation
- Propeller Nut is not part of the scope of supply, as it is expected that it can be reused
- Propeller Cone is not part of the scope of supply, as it is expected that it can be reused
- Blue fitting between propeller shaft and propeller performed either in situ or in workshop

Power Take Off, the following items regarding the PTO installation is considered yard work:

- Installation of all components
- Design work necessary for installation
- The front end cover of the Main Engine has to be strengthened according MANs recommendations in order to carry the gearbox weight
- New encoder in case the existing cannot be reused
- Necessary steel work for frequency converter installation
- Necessary changes to piping etc. in order to make space for the PTO
- Necessary work required to bring the PTO into the engine room
- Necessary changes to electrical main switch board
- Necessary connections from junction box to safety system, including necessary changes to safety system
- Supervisor from MAN

Solution Cost and ROI

The table below shows the cost per vessel for this solution offered by MAN PrimeServ based on the scope of supply given above.

	PRICE
Engineering, Project Management etc.	**€ 211,825**
PTO including Frequency Converters FC	**€ 1,104,522**
Kappel propeller on exchange basis	**€ 198,943**
Total	**€ 1,515,290**
Additional Cost for Parent vessel	**€ 118,549**

Cost for Solution

The above calculations gives a ROI of 11.3 years

The additional cost per vessel covers the following

- Engineering covering all vessels
- Vibrasafe Concept

Wind propulsion, Rotor Sail technology

NORSEPOWER

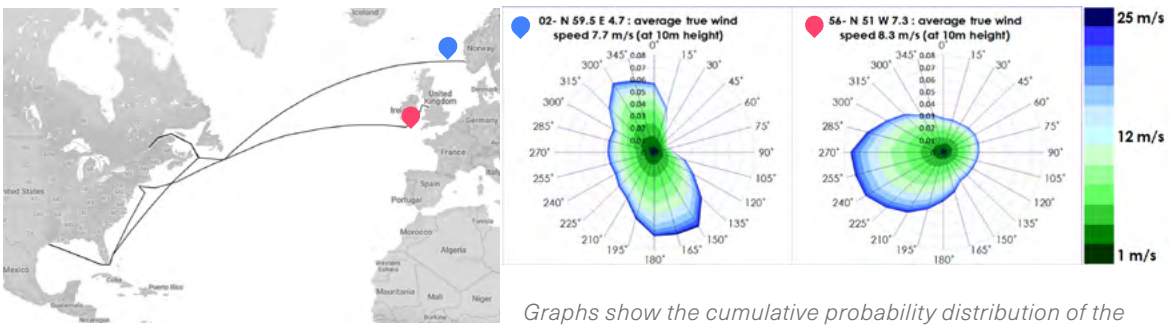
For this case, different types of wind propulsion have been considered, but concluded that Flettner Rotors have the largest impact on auxiliary wind propulsion for M/T Hafnia Lise. When installing a wind propulsion system, it naturally affects the propulsion system, including main engines and turbocharger, etc. When calculating the potential fuel savings utilizing auxiliary wind propulsion, the main ship parameters affecting the kilowatt savings are ship´s speed, total efficiency of the vessel, time-at-sea ratio and, naturally, the wind condition on the route. The installation height of the Rotor Sail correlates to the potential savings as well.

Overview and Magnus effect principle

Norsepower Rotor Sails are modernized version of Flettner Rotors. Rotor Sail technology is based on the Magnus effect. When wind meets the spinning Rotor Sail, the air flow accelerates on one side of the Rotor Sail and decelerates on the opposite side of the Rotor Sail. The change in the speed of air flow results in a pressure difference, which creates a lift force that is perpendicular to the wind flow direction.

The Norsepower Rotor Sail Solution is around ten times more efficient than a conventional sail, as more lift is produced with a much smaller sail area. Due to its simplicity and automated operation, it requires no reefing or crew attention when in operation. It is a "push button wind propulsion" from the bridge.

M/V Hafnia Lise, simulated route and examples of wind conditions



Graphs show the cumulative probability distribution of the wind speed at different wind directions. Colors represent the wind speed. Thickness of the line indicates the probability of certain wind speed from certain direction.

It allows the main engines to be throttled back, saving fuel and emissions while providing the power needed to maintain speed and voyage time.

The installation height of the Rotor Sail correlates to the potential savings as well. Therefore, two Rotor Sail models are proposed which are 24 and 30 meters high. Norsepower Rotor Sails are available in five models 18 x 3, 24 x 4, 28 x 4, 30 x 5 or 35 x 5 (rotor hight x diameter, meters). In case there is an air draft limitation, a tilting Rotor Sail model can be installed.

Potential energy savings

Norsepower made a simulation for M/V Hafnia Lise for the specified route in 2018. There is no information about air draft limitation on the route where M/V Hafnia Lise is trading.

TWO 24 x 4 ROTOR SAILS ON THE SPECIFIC ROUTE	
Average net savings	**7.3%**
Annual fuel savings	**417 ton**
Annual CO_2 reduction	**1,298 ton**
Average propulsion power	**474 kW**

TWO 30 x 5 ROTOR SAILS ON THE SPECIFIC ROUTE	
Average net savings	**11.7%**
Annual fuel savings	**670 ton**
Annual CO_2 reduction	**2,086 ton**
Average propulsion power	**761 kW**

Compatibility with other EE technologies

Rotor Sail solution is compatible with all other energy efficiency technologies available on the market which does not limit shipowners to Norsepower's sustainable technology only. It will be possible to reduce the load on the main engine maintaining the speed, saving fuel and thus reducing emissions

Rotor Sail Technology for newbuilding

A Rotor Sail retrofit installation requires a foundation and deck area reinforcement while for the newbuilding project it can be part of the vessel design and structure.

Investment

Two payment models are available for shipowners: traditional and pay-as-you-save model. The pay-as-you-save financing model was developed together with Norsepower's financing partners to enable a Rotor Sail system installation on-board a ship with a minimal investment by the shipowner at the start of Rotor Sail operation. This financing model is possible by sharing the estimated fuel savings, achievable with Rotor Sails, between the shipowner and Norsepower.

Evaluation of investment profitability

Rotor Sail solution profitability is effected by several factors such as fuel price, time-at-sea period and possible other emissions related costs. Since 2018, when the case study has been conducted, some of the factors have become more demanding.

Five Rotor Sails, which are in global operation today, gave us an opportunity to reduce manufacturing costs and the lead time. As maritime shipping is facing more stringent environmental regulations, Norsepower current payback period is in the range of three to nine years. For this particular case, if M/V Hafnia Lise increases the time-at-sea period, technology profitability will be closer to the payback period target indicated by Hafnia.

Route Planning Systems

OPTIMUM VOYAGE

Optimum Voyage delivers an algorithm driven route and speed optimization service directly applicable for all commercial vessels. A fuel consumption model is customized individually for each ship, and accounts for the influence of weather on voyages. In order to utilize the full voyage potential an optimization is run daily based on latest position and available weather forecast.

Description of action and technology

In order to uncover the savings potential for Hafnia Lise an extensive optimization study has been carried out. A fuel consumption model has been customized for the ship based on information made available by Hafnia. This energy model has continually been updated and improved based on noon reports to constantly have a clear picture of the state of the ship.

The optimization study has been carried out based on executed voyages for the past one and a half years, where Optimum Voyage has simulated advising the vessel. Upon departure an initial voyage suggestion has been given. Every 24 hours the suggestion has been updated based on the vessel position had it followed the previous suggested best route. Every optimization has been carried out using only the weather forecast available at that point in time. Upon arrival, the executed voyage has been compared with the optimized to show any potential fuel saving.

Of all the executed voyages disclosed by Hafnia a total of 32 have been optimized. Executed voyages have been discarded in cases where destination port has been altered mid-voyage, when there have been periods of very slow steaming, assumed awaiting external factors, or when there have been assumed ice restrictions not expressly specified.

Energy savings based on baseline of calculations

The total average fuel saving 14.1% for all optimized voyages. HFO consumption has been reduced by 26.7% and LSFO consumption has been increased by 14.5%.

The voyage optimization affects ME consumption for days en-route for both laden and ballast days, resulting in a yearly baseline consumption of 2,875 mt HFO and 1,234 mt LSMGO.

Applying average reduction and increase, the yearly reduction is:

768 mt HFO
-179 mt LSMGO
589 mt total fuel savings

The yearly fuel saving amounts to $206,000

The corresponding total CO_2 reduction, respecting difference in fuel types, is 1,815 mt.

Investment

The Optimum Voyage route optimization service works on a prorated subscription basis with a yearly fee for each vessel. The yearly cost is 6,500 USD.

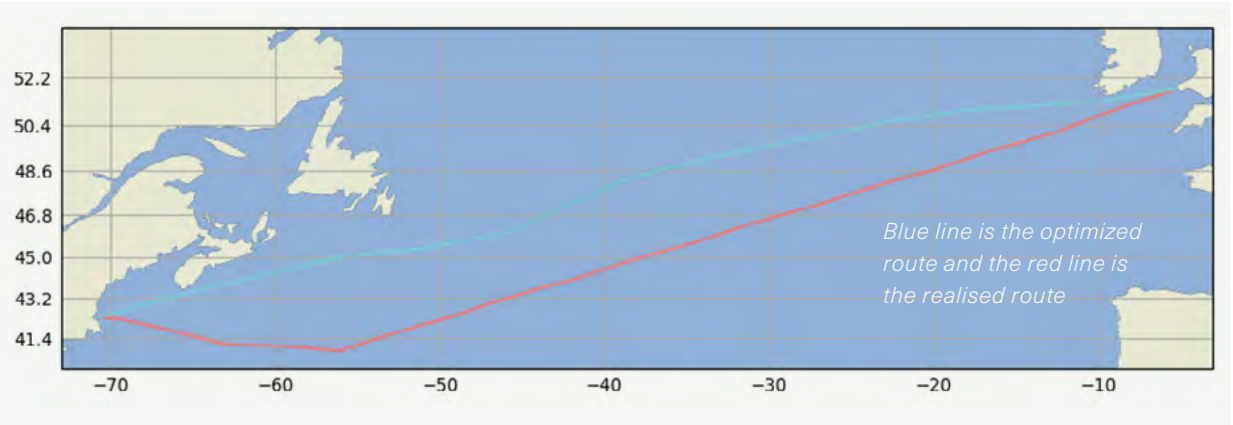
ROI

The yearly cost should therefore be covered within 12 days on average, thus disregarding whether the ship is idle, in port or enroute.

The study has been carried out assuming fixed arrival times for all voyages. Optimum Voyage also provides arrival time optimization in the yearly service fee and the payback period is therefore expected to be shorter.

Does it make sense to implement in this particular case?

Hafnia Lise is listed in Hafnia Management's MR Pool and operated from there. When receiving a charter, it is stated where and when the vessel has to be upon finalisation of the voyage. In the charterparty, the planned average speed the vessel has to sail is also specified. If the agreed arrival time is not met, the vessel receives a penalty. Optimum Voyage arrival time optimization is not applicable as a fuel saving means in this particular case. Given consent from the client for the vessel to comply with minimum average speed and specified arrival time, but at a variable speed for the single legs of the voyage the Optimum Voyages fixed ETA optimization is fully applicable and expected to deliver the savings seen in this study.



Further Comments:

The Optimum Voyage optimization service is one of the most directly applicable technologies for fuel consumption reduction as it does not require investments in either hard- nor software and is relevant for all ships in a fleet, no matter the age or state.

Organic Rankine Cycle (ORC)

An ORC plant is a modular system for generating power from waste heat. In general, various waste heat flows may be used, such as exhaust gas or cooling water heat from a combustion engine (HFO, diesel or gas) or similar sources of heat in marine applications.

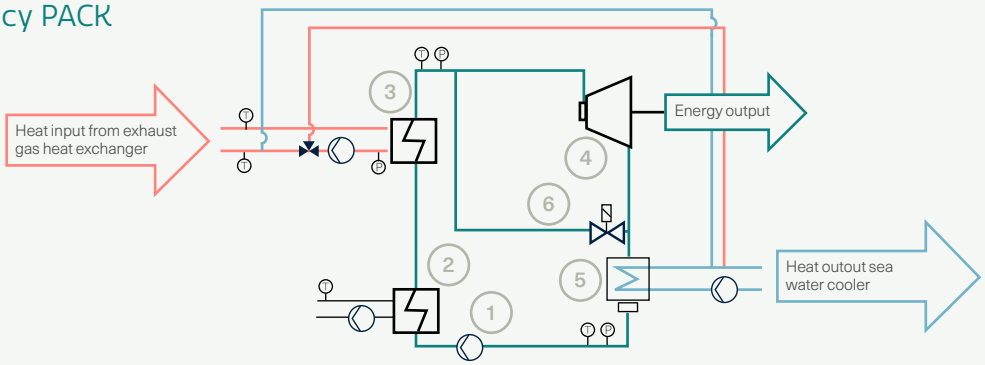
The energy output can either be used mechanically to support the propulsion of a ship or converted into electricity to supply the on-board grid or a battery pack without CO_2-emissions. The operation needs no human intervention except regular visual inspections and is mostly maintenance-free.

Orcan Energy has developed and introduced a State-of-the-Art and proven Waste Heat Recovery System for marine applications. In total more than 1,000,000 efficiency PACK fleet running hours have been collected, with already 48,000 running hours achieved on one Waste Heat Recovery plant. Currently an average availability rate in excess of 99.5% is achieved on a deployed fleet of > 200 installations worldwide in Orcan's key markets.

Description of action and technology

The efficiency PACK 's working principle is based upon the Organic Rankine Cycle (ORC). This is a closed steam cycle in which an organic working fluid (hydrocarbon) is used. The working fluid used in the efficiency PACK is non-toxic and non-flammable. Figure 1 shows a simplified model of the ORC system.

The efficiency PACK (Figure 1)



In the ORC system (efficiency PACK) a feed pump (1) transfers the liquid working fluid into a preheater (2) in which the fluid is heated to below boiling temperature.

The preheater is usually heated by an engine's hot jacket cooling water. After the preheater the fluid is evaporated and superheated in the evaporator (3).

The evaporator is heated by a pressurized hot water loop. The superheated steam then drives the expansion machine (4).

The expansion machine can be connected to a generator to produce electricity or connected to an engine's PTI (power take-in) via a transmission to supply mechanical power to the engine's crankshaft.

In the condenser (5) the steam at low pressure is liquefied again to close the steam cycle.

The condenser is cooled by a water cycle that is connected to a sea water cooler.

The cycle also includes a bypass valve (6) to pass the steam by the expansion machine for startup, shutdown and emergency purposes.

Energy savings based on baseline of calculations

Based under the assumption that increasing the steam capacity of the Aalborg OC boiler in exhaust gas mode would be technically feasible, the availability for sat steam input for the Orcan efficiency PACK is substantially higher. The waste heat recovery calculations are based upon the maximum steam production capabilities advertised by MAN Energy Solutions and based upon engine type MAN 6S50ME-B9.3-T2. As a matter of fact, the following set-up can be presented, offering a significant increased power output based on waste heat recovery:

Investments and Savings

Fuel savings 84.7 mt HFO / 77,4 mt MGO	**85,000 USD pr. year**
CO_2 savings	**511 ton/year**
Investment	**415,000 USD**
ROI	**4.9 years**
Totally produced by aux. in 2018	**4,680,163 kWh/year**
Theoretically production by ePacks (16.3% of total production)	**765,000 kWh/year**

Does it make sense to implement in this particular case?

Waste heat recovery on Hafnia Lise is in all cases technically possible. Generally, the Daihatsu auxiliary engines are running at a low average load factor, respectively 40% & 50%. Also, the steam production capacity of the Aalborg OC Composite boiler is limited, nevertheless the accumulated free cash flow achievements are in all set-up cases attractive.

The ROI on 4.9 years is outside the case target value, when looking strictly atthe calculation of Hafnia Lise, but assuming that due to the sulphur cap legislation effective from January 2020, the future operation will be either on MGO or on compliant fuels at a higher price and will surely be worth looking further into.

ENERGY SAVINGS BASED ON MGO AS ONLY FUEL AFTER 1. ST. JANUARY 2020.

(current MGO price, $618 ton)	
Savings	**163 mt MGO 119,000 USD pr. year**
CO_2 savings	**522 ton/year**
Investment	**415,000 $**
ROI	**3.5 years**

Interdependencies with other technologies

An ORC unit uses waste heat from main- and axillary engines and does not affect other technologies aboard.

The technology in a newbuilding situation

An ORC unit can reduce the load on auxiliary engines, which means that it will be possible to reduce genset size, so that it will be possible to run it in optimum operating range. Planning ORC into the auxiliary or propulsion system on a new-building project, will open opportunities for fuel and cost reductions from the very beginning.

Which benefits does the efficiency PACK offer?

- Significant fuel savings
- Attractive payback period and free accumulated cashflow during the operation of the efficiency PACK
- Significant emission reductions (savings) for CO_2, NOx, SOx and Particulate Matter (PM)
- Improvement of the Energy Efficiency Design Index (EEDI)
- Well selected and class approved rugged marine components that require minor scheduled maintenance
- Your ships contribute to a more sustainable future at sea by powering your ship with waste heat

Fuel monitoring system

Royston

enginei is a modular, solution-orientated fuel management product for the marine industry that incorporates a range of sophisticated tools, including an Electronic Fuel Monitoring System (EFMS). enginei monitors fuel flow for all consumers and bunkering operations, plus vessel speed, position, operational mode, engine running hours and more. enginei can use real time data to calculate the "Eco Speed" of a vessel, the most fuel-efficient speed of a vessel across all applicable operational modes, providing your crew with real-time advice on how to maintain optimal speed for maximum fuel efficiency.

Energy savings based on baseline information

enginei is a monitoring tool which provides detailed data-oriented analysis. Whilst energy saving is the main objective of the tools provided, it is not possible to calculate the savings based on information provided in this project. The savings are strongly dependent on the utilisation of the tools provided as part of the enginei monitoring system.

Return on investment (based on fuel savings)

The enginei system is a monitoring tool that allows the operator to have full visibility on their fuel usage and energy distribution. The system provides tools to analyse this usage and allows for operational changes to be identified to reduce consumption. Due to this, ROI is dependent on use case and cannot be calculated based on data provided in this project. Having said that, we achieved up to 30% fuel savings on various projects allowing for an ROI within 6 months.

Interdependencies with other technologies

The system is independent of all other systems.

The technology in a newbuilding situation

The system can be installed on newbuild or retrofit. The process does not change.

Does it make sense to implement in this particular case?

enginei allows for a holistic monitoring of fuel consumption and energy flow across the entire vessel. This provides the operator with a detailed energy distribution and therefore a benchmark of consumption. In addition, the analysis allows for operational changes which result in fuel consumption savings.

Summary

With the suggested solutions, it is possible to reduce fuel consumption with 17.5% on Hafnia Lise within the target ROI. Had the Hafnia fleet not been subject to limitations of operating in a pool and restrictive vessel instructions from charterer, it would be possible to reduce fuel consumption up to 27%. This figure should open for discussion on whether charterers could and should use route optimization as a tool in daily planning, thus contributing significantly to the decarbonization of the maritime industry.

Several of the suggested solutions are above the target value due to existing solutions on board. Retrofitting is therefore considered relatively expensive and less attractive if a ROI of < 3 years is upheld. In light of the current decarbonization challenge, planning and designing for a vessel driven solely by price, will, most likely, prove more expensive in the longer run.

Hafina Lise outside Montreal

Collective savings for Hafnia Lise

Emissions

CO_2 emissions (before)	18,480 mt CO_2/year	0.034 kg CO_2 pr. mt cargo

CO_2 reducing fuel consumption with 17,5% (excluding of route optimization)

CO_2 emissions (after, ROI below 3 year)	15,291 mt CO_2/ year	0.028 kg CO_2 pr. mt cargo

CO_2 reducing fuel consumption with 27 % (including route optimization)

CO_2 emissions (after, ROI below 3 year)	13,457 mt CO_2/ year	0.024 kg CO_2 pr. mt cargo

Effect of products

Company	Product	Savings on			Effects	ROI [years]	Fuel Saving [ton/years]	CO_2 reduction [ton/years]
		ME	AUX	Boiler				
Alfa Laval	Boiler optimisation			x	Reduce fuel consumption for boilers	N/A	N/A	
BOS	Ballast Water Managment system		x		Reduce the energy needed for Ballast Water Management system	N/A	N/A	
BOS	Emulsified fuel system	x	x		Better fuel efficiency	2.5	210	654
C. C. Jensen	LO filter system		x	x	Reduses energy needed for keeping the LO clean and heating the LO	< 1	70	221
Clorius Controls	Low Leak 3 way valve		x		Reduce the energy needed to heat the HT water	< 1	7	22
Danish Energi Consulting	Shore power		x		Reduce running time AUX	N/A	"Harbour" 2,4 ton/day "unloading" 11,25 ton/day	
Danish Energi Consulting	Light		x		Reduce load AUX	2	32	101
Desmi	OptiSave (frequency regulation of pumps)		x		Reduce the energy needed to run pumps	3.6	105	327
Greensteam	Hull fouling	x			Reduce load on ME	< 1	763	2,376
Kongsberg Maritime	Promas lite (Propeller blades, Hubcap, Rudderbulb)	x			Reduce load on ME	6.8	184	573
MAN	PTO (ME) + Kappel propel	x	x		Reduce running time of AUX and load on ME	11.3	316	984
MAN	Exhaust gas by-pass	x			Lower SFOC at low load	3.8	60	187
MAN	Rudder bulb "Ecobulb"	x			Reduce load on ME	6.1	47	146
Norsepower	Flettner Rotor	x	x		Reduce load on ME, but increase load on AUX	7	670	2,086
Orcan	ORC		x		Reduce load on AUX	4.9	162	504
Optimum Voyage	Rute optimisation	x			Reduce load om ME	< 1	589	1,834
Royston	Fuel measuring and flow monitoring					N/A	N/A	

Target value < 3 years Target value > 3 year

Target value <3 years	**1,671 ton/year**	**27.1%**	**CO_2 reductions**	**5,208 tons/year**
Target value > 3 year	**1,360 ton/year**	**22.1%**	**CO_2 reductions**	**4,234 tons/year**

Total fuel consumption (HFO + MGO) 6,163 ton/year

Case Study 2.

– Victoria Seaways

Vessel description

The vessel was delivered in 2009 and was build according to standards with focus on Lanemeter, hull performance and classification. The vessel was in 2014 retrofitted with scrubber on the main engines at Remontowa Shiprepair Yard in Gdansk.

INITIATION

M/F Victoria Seaways is a RO-PAX ferry, built at Nuovi Canterie Apuani Shipyard, Italy (#1241) in 2009.

The vessel is one in a series of 8 build in the period 2007 to 2010.

Sister vessels: Athena Seaways, Forza, Regina Seaways, Rizhao Orient, Superfast I, Superfast II, Tenacia

PRIOR ENERGY OPTIMIZATIONS ESTABLISHED BY SHIPOWNER SINCE NEWBUILD

- Greensteam, trim optimization
- Frequency drives on seawater pumps and engine room ventilation
- Partly conversion to LED lights

VESSEL DATA

Name	Victoria Seaways	Cars	600
Flag	Lithuania	Lanemeter	2,623 m
Homeport	Klaipeda	Main engines	2 x Wärtsilä 12V46C
Length	199.14 m	Rated power	12.600 kW per engine
Width	26.6 m	Scrubber	Alfa Laval – Pure SOx
Draft (max)	6.4 m	Propeller	Rolls-Royce 2 x Ø5,1m
DWT	8,500 ton	Axillary engines	3 x Wärtsilä 9L20
Hull type	Passenger / RO-RO cargo	Rated power	1,680 kW per engine
Passenger	600	Emergency generator	1x Caterpillar 3412
Number of beds	268		

GA Victoria Seaways

AVERAGE BUNKER PRICES IN 2018

HFO	3.5%	380 USD/ton
ULSFO	0.1%	534 USD/ton*
MGO	0.1%	570 USD/ton
Lube oil	ME/AUX	1.58 USD/ltr.

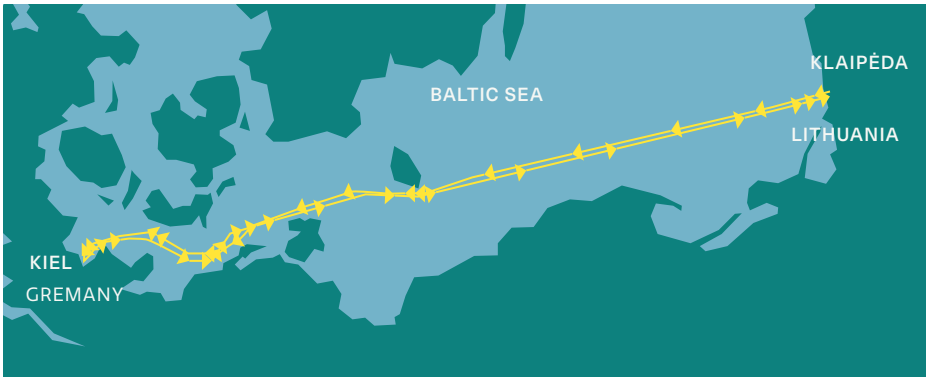
LCV (Lower Calorific Value) ISO conditions

RMG 380 3.5%	40,600 KJ/Kg	(11.28 kW/kg)
Density at 15°C	990 kg/m3	CO_2 3,114 kg/ton fuel
DMA 0.1%	42,700 KJ/Kg	(11.86 kW/kg)
Density at 15°C	850 kg/m3	CO_2 3,206 kg/ton fuel

*Calculated from the price difference between MGO and ULSFO of 36 USD/mt. The prices are taken from "Rotterdam bunker prices"

BASELINE FOR CALCULATIONS		
Annual fuel consumption		
HFO 3.5%	Main Engines	19,466 ton/year (91%)
ULSFO 0.1%	Auxiliary engines & boilers	1,836 ton/year (9%)
MGO 0.1%	Emergency generators	8.7 ton/year (100%)

Trade Map for Victoria Seaways



TRADING PATTERN		
Laden days	6,462 hours/year	74%
Harbour	1,436 hours/year	16%
Port days	144 hours/year	2%
Idle days	718 hours/year	8%

Port of Klaipeda

Areas suitable for optimization

Below is a list of areas selected for further optimization. In this project, focus is on short term decarbonisation and fuel reduction. While we are aware that there are other options available, some very innovative, the objective of this project is to explore the potential of today's best available and proven technology.

Listed in alphabetic order of company:

PAGE	SOLUTION	COMPANY
63	Boiler System	ALFA LAVAL
65	Lube Oil treatment (CJC filter)	C. C. JENSEN
68	3-way valves for fresh cooling water for main engine	CLORIUS CONTROLS
69	Fuel consumption monitoring / eco-driving	DEIF
71	Trim systems	GREENSTEAM
75	Antifouling	HEMPEL
78	Promas Lite (Rudder & Propeller)	KONGSBERG MARITIME
81	Wind propulsion, Rotor Sail technology	NORSEPOWER
83	Organic Rankine Cycle (ORC)	ORCAN
86	Lights	DANISH ENERGY CONSULTING
87	Main engines, Upgrade Turbo chargers	WÄRTSILÄ
90	Summary	

Boiler System

Installed base

DFDS Victoria Seaways RO-RO ferry use steam to accommodation and service, heat fuel tanks, steam tracing of fuel pipes, lube oil separator, freshwater generation and other.

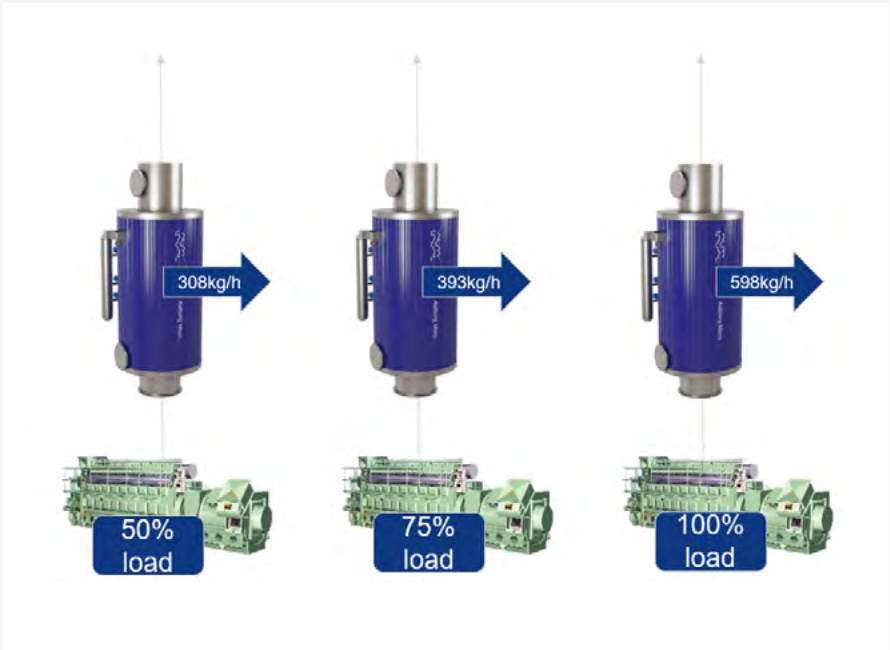
The installed base for Victoria Seaway is 1 x Oil-fired boiler type UNEX and 2 x XW economizers after the two main engines. The XW utilizes heat in the exhaust gas (waste heat recovery) from engines to produce steam and is done continuously during voyage. The UNEX is designed for 2,500 kg/h of steam production and is used when the XW is not providing sufficient steam.

Operation pattern

On Victoria Seaway seaways it is informed that the UNEX boiler is in operation 2,190 hours per year. The operation pattern for Victoria Seaways is stable and known and the same procedure every day. At open sea the XW economizers are producing sufficiency steam, but closer to port the vessel is decreasing speed, meaning lower engine load, and less steam production hence a need to operate the oil-fired boiler.

Micro exhaust gas Economizer on Victoria Seaways

In this case, with many operating hours on the oil-fired boiler and a continuously need for steam, installing Micro economizers after auxiliary engines can be an attractive solution. Below shows steam production at different engine loads.



Micro economizer steam output at different engine loads

The set-up with a Micro after each auxiliary engine has been suggested for best possible availability and flexibility and the installation has positive effect on fuel reduction and CO2 reduction

Return on investment

For this specific case a ROI has been made due to the well-known boiler operation hours and stable operation pattern of vessel.

1 x Engines running @ 50% load

Fuel saving	**≈ 85 tons/year**
CO_2 reduction	**≈ 264 tons/year**
Return on Investment (ROI)	**2,1 years**

Without transport and installation

For both cases it is important to highlight that the steam needs to be used when produced, and it needs to directly remove the oil consumption on the UNEX.

Learn more about Aalborg Micro on:

→ www.alfalaval.com/products/heat-transfer/boilers/exhaust-gas-economizer/aalborg-micro/

Lube Oil Treatment and Oil Filtration

C.C.JENSEN

Victoria Seaways is equipped with separators for cleaning of the lube oil to the main engine and auxiliary engines. The lube oil is preheated in a steam heat exchanger before separation, with steam from the UNEX boiler or (waste heat recovery boiler), main engine during sailing or from the OL steam boiler when the main engine is not running. Except for longer port stays, separators run continuously. Oil sludge from separators has a certain amount of water in it, which is used to clean the bowl. The oil sludge is to be either incinerated aboard or to be sent for treatment/disposal ashore.

Description of action and technology

The objective is to save energy by replacing existing technology used to clean lubricating oil on 2-stroke and 4-stroke engines.

By replacing the traditional purification system, where the oil needs to be heated to 90 to 95 degr. C, with a CJC off-line filter with the patented flow drive technology, the need for heating the lube oil is eliminated. The CJC filter reduces the overall power consumption with up to approx. 90 to 95%. Calculations are based on running 24 hours per day for the filter and the seperator.

Besides the saving in heating for the filter and separator, there will be a significant reduction in lube oil consumption and reduction of the lube oil waste, both reducing the total CO_2 footprint.

Seperator room Victoria Seaways

Energy savings based on baseline of calculations

Main engine summary	LO Centrifuge	CJC LO Filter
Energy costs per year [kWh]	366,684	12,900
Energy savings with CJC per year [kWh]		**353,784**
Lube Oil waste [ltr/year]	20,000	10,000
Lube Oil waste savings with CJC [ltr/year]		**10,000**
CO_2 emission [kg CO_2/ year]	232,694	8,183
CO_2 emission savings with CJC [kg CO_2/ year]		**224,511**

Aux engine summary	LO Centrifuge	CJC LO Filter
Energy costs per year [kWh]	59,718	5,418
Energy savings with CJC per year [kWh]		**54,300**
Lube Oil waste [ltr/year]	2,160	1,800
Lube Oil waste savings with CJC [ltr/year]		**360**
CO_2 emission [kg CO_2/ year]	37,896	3,439
CO_2 emission savings with CJC [kg CO_2/ year]		**34,457**

Investments and Savings

Fuel saving	**79 tons/year**
Investment (ME + AUX)	**62,830 USD**
Fuel cost savings	**42,186 USD/year**
Lube oil waste saving	**16,369 USD/year**
Total savings	**58,555 USD/year**
CO_2 reduction	**259 tons/year**
ROI	**< 1.1 year**

Interdependencies with other technologies

Does normally not affect other technologies besides reducing the energy consumption. In this case with Victoria Seaways, it will be possible to release excess steam from the composite boiler which can, for example, be used in an ORC plant to produce electricity. Moreover, the amount of oil sludge will be reduced and thereby the cost of handling or disposing of oil sludge.

The technology in a newbuilding situation

Installing a CJC filter unit in a newbuilding process will make savings in the initial capex and for the shipyard it will mean less installation cost as you do not need compressed air etc.

Does it make sense to implement in this particular case?

The technology make sense to install on Victoria Seaways, as it will make a direct saving in energy and oil consumption. Which both save CO_2 emission. Besides the saved energy it is also a less complicated equipment to maintain compared to traditional purifiers.

Low leakage valves

When Victoria Seaways is in port the main engine is shut down, but kept heated, ready for operation. Most 3-way valves in the FW-cooling system leak in the range of about 5-10% resulting in a heat loss to the cooler. The heat lost in port (idle mode) by leaking 3-way valves must be replaced by the electrical heater which will give an increased fuel consumption.

Description of action and technology

By replacing the 3-way control valve with a low leak valve it is possible to reduce the leak over the HT FW cooler and thereby save energy used to reheat the HT water. The leak is normally set to be +5% Clorius Controls offer a low leakage valve with a reduction to 0.5%.

In general, the replacement is one to one and does not require docking or special competences.

Energy savings based on baseline of calculations

The cooling water systems on Victoria Seaways are very complex, compared to cargo ships, and to locate possible energy savings, it will be necessary to involve a design consultant engineer to help Clorius Controls to understand the systems before they can calculate any possible savings.

Interdependencies with other technologies

Replacing the 3-way valves does not affect other technologies other than reducing electrical load.

The technology in a newbuilding situation

If low leakage valves are installed as newbuild, there will be cost savings to both the heat losses and replacement valves from the very beginning of operation.

Does it make sense to implement in this particular case?

The operation pattern for Victoria Seaways main engine in the current operation (Kiel - Klaipeda), is with about 17 % of the time in harbour and the main engines stopped. The business case is not to be recommended for this route in a retrofit situation without further investigating, due to the short period in harbour.

Comments from Clorius Controls

We are sure that heat load during port stay could be reduced in the range of 20-30%, but it comes more into “human factor”.

Thermostatic valves on the cooling water and lube oil systems should be replaced with Clorius electrical 3-way electrical control valves. All in order to avoid the spare part cost and yearly maintenance cost.

Leaking Thermostatic could also be avoided by replacement of the thermostatic valves to Clorius 3-way rotary valves.

Blueflow Energy Management System

Blueflow will enable the crew on Victoria Seaways to evaluate their navigation by giving instant feedback. The system offers numerous displays, specific lay-outs for the individual vessel, promoting eco-driving and monitoring energy consumers. It enables the crew to reduce fuel consumption by optimizing e.g. the harbor maneuvering and the ship speed.

The Blueflow System consists of:

- Blueflow Online, the secured cloud for storage vessels data. These data can be used to reduce energy consumption, make diagnostics, take comprehensive reports and increased knowledge of a vessel's performance.
- Blueflow Onboard integrates with various other onboard systems, flowmeters to monitor fuel, emissions sensors, GPS, weather data, energy consumption and other parameters in real-time.

Example of Blueflow ECO trip.

The graphical interface compares current trip with last trip on the same route and different maneuvering techniques are directly comparable.

ROI & Savings

Savings of up to 5-7% have been proven for ships like Victoria Seaways. The key factors to achieve fuel and energy savings are:

- motivation, awareness and mindset changes of the crew
- training of the key stakeholders

The calculation is based on 3% savings as a similar system is already installed. Victoria Seaways is equipped with only one fuel flowmeter for ME and one for AUX engines. But by implementing fuel flowmeters on all ME, AUX and Boilers there are more potential savings.

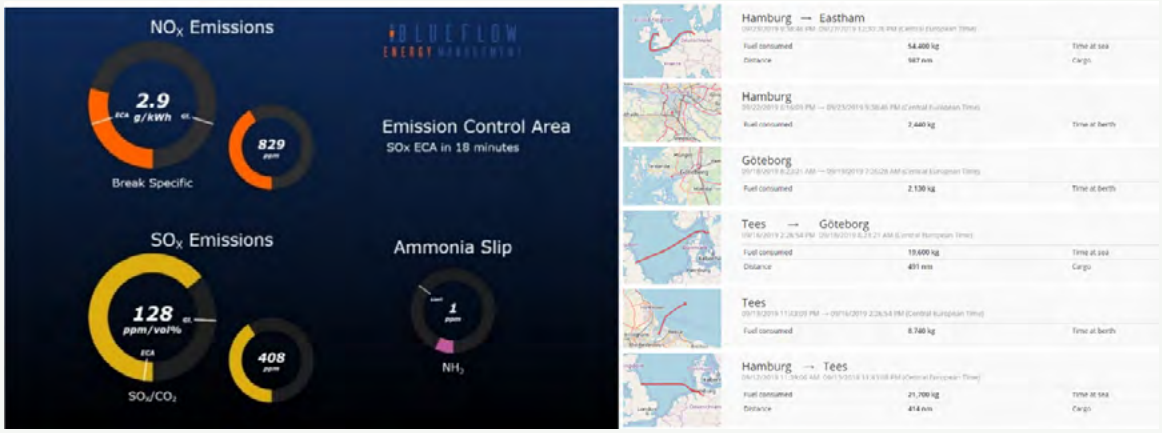
Fuel saving	**HFO 584 tons/year & ULSFO 55 tons/year**
Investment cost (ex. installation)	**44,000 USD + 5,650 USD (yearly subscription)**
Fuel cost	**251,874 USD/year**
CO_2 reduction	**1,989 tons/year**
ROI	**2-3 months**

Why install the Blueflow system onboard the ship/fleet

Due to the flexibility of the Blueflow system it easily integrates with both new and existing systems onboard – leaving no excuses to start taking advantages of:

- Fuel Savings lowering the OPEX for the specific ship/fleet
- Comparing performances of ships in the fleet
- Automatic generated MRV-reports, saving time for the crew and lowering the risk of penalties for in-correct reports
- Supervision of emissions including performance of e.g. Scrubbers and reporting

Example of Blueflow emission view and MRV reporting.



→ www.deif.com/marine-and-offshore/cases/fjord-line-saves-fuel-with-blueflow
→ www.deif.com/marine-and-offshore/cases/swedish-shipowner-cuts-fuel-consumption-by-20-percent-with-blueflow

Trim systems

GreenSteam analysis starts with its Discover service to initially understand the vessel. GreenSteam Discover uses machine learning to create a vessel performance baseline from which fuel efficiency insights and actionable advice are provided, leading to measurable financial gains from maximizing the operational efficiency.

The Discover service only needs data

Using just voyage, fuel, and weather/sea-state data, discover analyses the historical operational performance and advises on where the biggest inefficiencies are. Being data-driven, Discover can be applied to all vessel types, and it identifies a wide range of opportunities to improve efficiency. From vessel or voyage trim settings, to speed planning and optimization, hull/prop coatings performance, or to dry dock schedules, Discover identifies all the areas where fuel is wasted and where operational changes will deliver measurable savings.

It is not unusual for Discover to identify fuel waste of over 10% in some areas.

Insight first

Giving clear insights into where the biggest savings are going to be made, and requiring a low initial investment, Discover is a low-risk route to understanding where and how the operational performance of a vessel or entire fleet can be improved.

Discover identifies fuel-saving opportunities. Our machine learning technology accurately measures and identifies every inefficiency, however small, including those that are hard to see because they are perceived as immaterial or difficult to quantify.

Turning insights into savings

We know, however, that vessel operators need to make a new technology investment decision that is based on proven benefits. This is the power of Discover – it delivers insights into your operations, identifying and reporting on your potential fuel savings before you invest further.

Knowing where your savings are going to be made, you´ll be able to prioritize decisions about which GreenSteam Advisor services to subscribe to. Either individually or together, they provide you with predictive advice on how to operate your vessels to maximize fuel savings and reduce the environmental footprint.

Case study

Creating the optimal performance baseline for a vessel

As part of the Discover phase, GreenSteam creates a baseline that calculates when a vessel is performing as near as it can to optimal efficiency. It does this by analyzing up to 13 different variables, including sea depth, speed through water, draft, power, fuel usage, trim, fouling, etc. and calculates the level the vessel should operate in perfect sea conditions if operated optimally.

After accounting for the impact of external factors (e,g, wind, waves, currents etc.) any performance that reaches 99.9% efficiency against the vessel baseline is deemed to be operating optimally and any deviation from that is highlighted as sub-optimal, meaning manual intervention on factors such as speed and trim will have a material impact on performance.

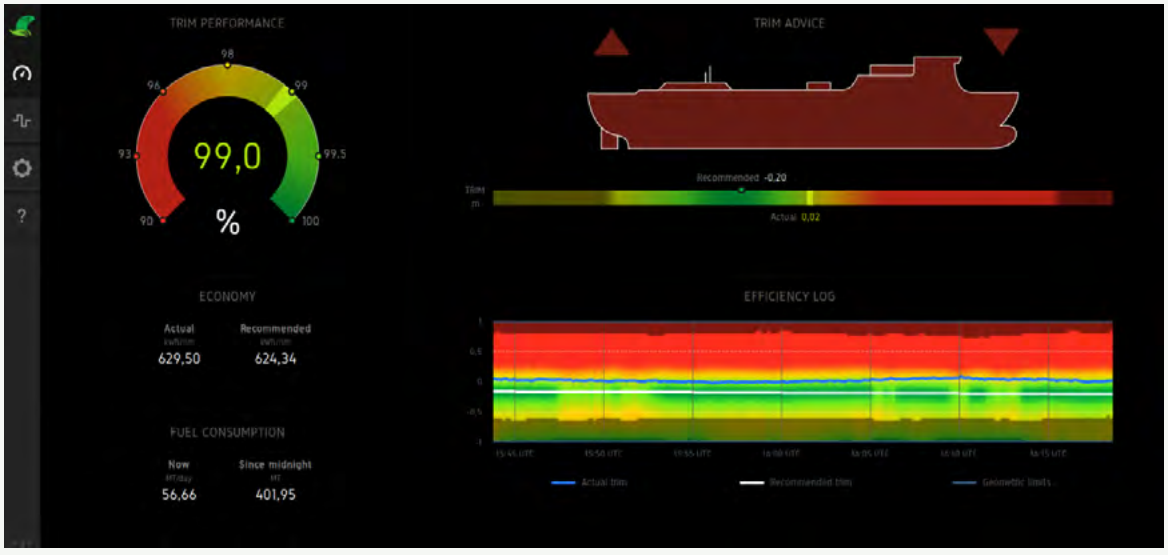
Focusing on where to make biggest energy savings

DFDS identified it could make a significant impact on reducing its fuel wastage by optimizing trim.

They wanted to go beyond the basic approach of setting trim at the start of a voyage, preferring to adjust it during the voyage to reflect the changing sea state and ensure the vessel operated at its optimum performance for the maximum length of time possible. This meant they would use GreenSteams Dynamic Trim optimizer module.

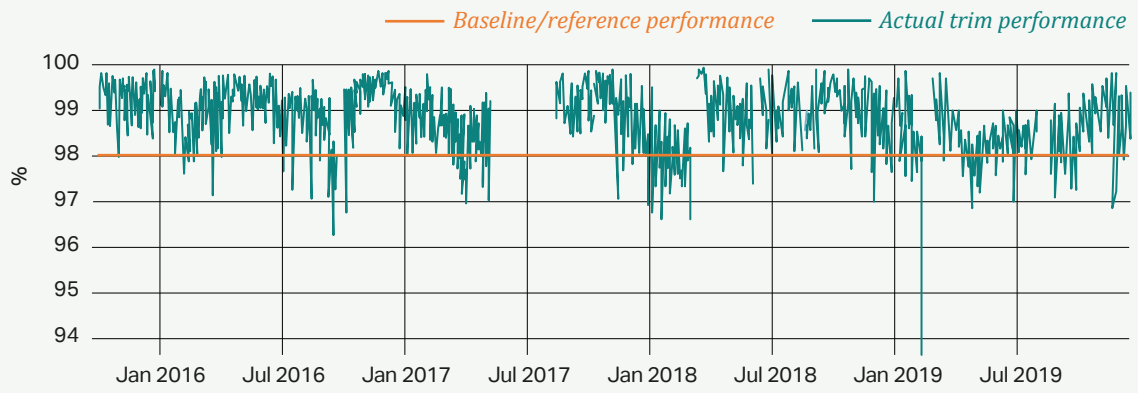
Adjusting trim in real-time to get closer to optimum performance

The graphic below shows the trim optimizer information for the crew to work with. The white line is the optimum trim and the blue is the actual trim – providing clear data on what action to take.



Over the four years that the trim analyzer has been on-board, the crews response has resulted in an improvement in trim performance, see charts below.

Dynamic trim performance

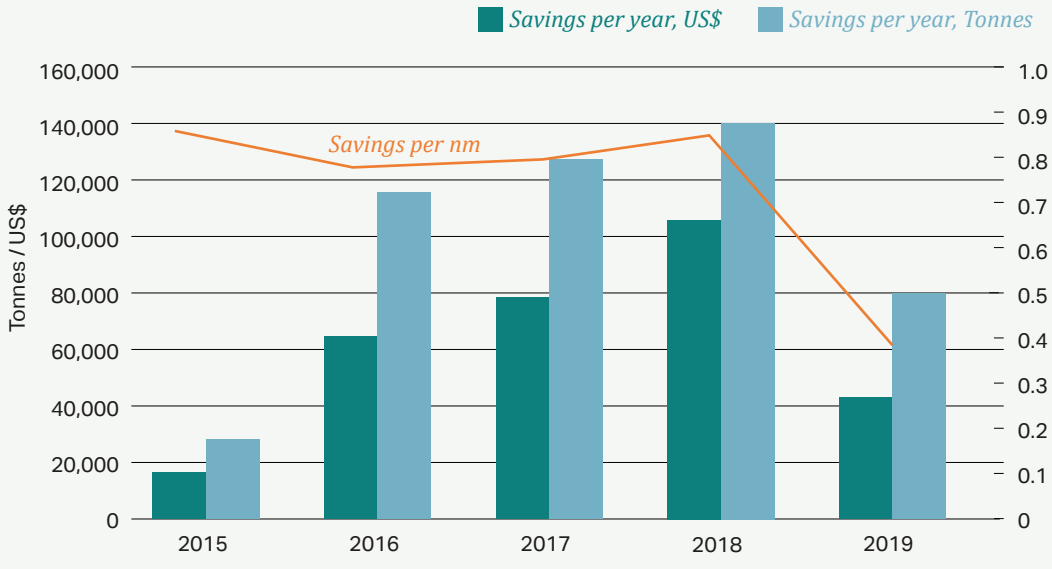


Quantifying the benefit

Once it was clear that the crew were responding to the advice of the Dynamic Trim optimizer tool, and performance was enhanced at a sustainable level over an extended period of time, it is possible to assess the benefit achieved.

The plot shows that Victoria Seaways is operated more efficiently compared to the period where the vessel did not have the system installed. The diagram below shows that savings normalized by distance are constantly high the first three years, but then dropping in 2019 suggesting that constant training and attention from both crew onboard and staff in the office is crucial to reap the benefits of optimization

Realized savings from GreenStream's Dynamic Trim Optimizer



Calculating the financial impact

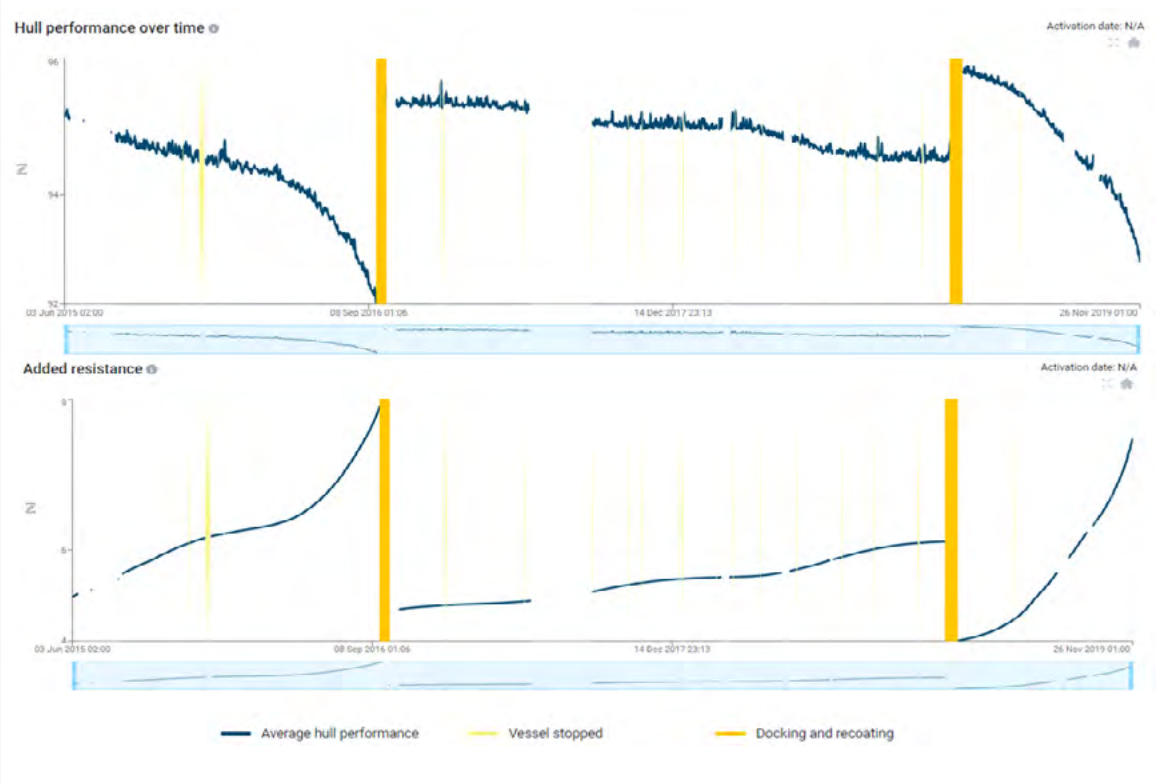
Based on the cost-benefit analysis to install and operate Dynamic Trim Optimizer, and the savings realized, DFDS was calculated that they achieved positive payback after 5 months with an NPV of $200k over the first 4 years of operation.

Summary

With fuel costs being a major expense in running costs, it is critical that operators use every tool available to keep wastage to a minimum and improve their bottom line. This also has a positive impact on reducing Greenhouse Gas emissions and helping move towards the IMO targets of reducing carbon emissions across the industry.

GreenSteams suite of services can help operators deliver more cost-effectively. The example shown in this case study shows that when crews respond to the advice they can trust, it has a significant impact on improving performance and the bottom line.

Dynamic trim performance



Antifouling fuel saving analysis

Description of action and technology

Hull performance is recognized as being critical in the efficient operation of vessels with respect to energy savings. Much focus is placed on the need for propeller and hull cleaning, slow steaming and efficient hull designs to achieve optimal operational parameters suited to the vessel type. Often the contribution that effective antifouling coatings can deliver in terms of maintaining hull performance is underestimated when evaluating hull performance. Whilst the financial, and time pressures associated with maintenance and repair or newbuilding priorities are key factors in product selection, it is frequently the case that the wider benefits of fuel saving and emission reduction associated with a specific antifouling product and appreciation of the return on investment relative to the financial savings in reduced fuel use are seldom factored into selection. This assessment lays out a series of scenarios defining the financial, efficiency and emission savings that can be achieved by utilizing state of the art antifouling technologies.

The fundamental principle of all antifoulings is to maintain a smooth hull. This is achieved in two ways firstly the inherent roughness of the coating itself and secondly by preventing fouling species from colonising the hull. Coating smoothness is achieved by utilising polymer resins to create a smooth surface. Fouling control is achieved by utilising non-stick technologies or incorporating biocides into the coatings system, or a combination of both approaches. These two aspects link to different benefits on fuel performance, the first being the absolute improvement in drag through the water, i.e. how smooth the coating is and the second being the deterioration of the coating smoothness with time as it becomes fouled. Depending on the product and technology chosen these figures vary, from approximately 6% for low performance products to as low as 1.2% for best in class products when considering speed loss with time at a given engine output. For example in the ISO19030 working group on hull performance measurement it was established that a typical A/F degrades by approximately 18% over 5 years (5.9% speed loss). The best products lose as little as 3.6% giving fuel savings of up to 15%..

Hempaguard products offered by Hempel A/S give you this best in class performance with Hempaguard X7 returning 1.4% speed loss values and the Hempaguard MaX system 1.2% for a 5 year scheme. This equates to 6 and 8% fuel savings on average compared with typical antifouling paints. These improvements are a result of developing technology that utilises silicone polymer resins with improved coating smoothness (compared with traditional antifoulings) and fouling release (non-stick) properties in combination with hydrogel and optimized biocide use to minimize fouling during service.

For an ageing fleet 'upgrading' the antifouling used can give immediate significant benefits to the total fuel consumption of the vessel. This evaluation compares Hempaguard X7 (best in class technology) with the best performing traditional antifouling coating (i.e. not utilising Hempaguard technologies) and a 'market average' coating typical on vessels of this type and age.

Energy savings based on baseline of calculations

The conclusion and recommendation of the study is to adopt Hempaguard for vessel refurbishment due to the significant reduction in fuel use and commensurate saving in emissions.

Product	Preparation	Coating Cost* (%)
Hempaguard X7	Full blast	100
	Spot blast	92
Globic 9000	Full blast	46
	Spot blast	31
Oceanic+	Full blast	19
	Spot blast	19

* Coating cost is expressed as the percentage of the maximum potential cost. I.e. Hempaguard X7

Comparison of Fuel and CO_2 savings plus Return on Investment (ROI) compared with the Market Average product (calculations are of 36 month)

Product	Fuel Saving ($)		Fuel Saving (Tonnes)		Reduction in CO_2 Emission (Tonnes)		ROI (Months)	
	Full Blast	Spot Blast	Full Blast	Spot Blast	Full Blast	Spot Blast	Full Blast	Spot Blast
Hempaguard X7	2,333,734	1,919,951	6,141	5,052	19,099	19,100	2.24	2.44
Globic 9000*	1,310,864	897,081	3,450	2,361	10,728	10,729	1.32	0.8
Oceanic+	119,170	-294,613	314	-775	975	975	0	-13.81

* It is assumed that shot blasting only removes 20% of the hull coating. Note also that general application costs are not included

The analysis shows that in all areas maximum savings in cost, fuel and emissions can be achieved when using Hempaguard X7. Significant improvements can be made by moving to higher tier traditional products such as Globic 9000. These paint schemes assume a 36month service period between drydockings and 75% vessel activity. Fuel savings will be substantially greater for periods greater than that (e.g. 5 years). Full blasting of the vessel prior to paint application also makes a significant difference in fuel consumption due to further improvements in hull smoothness (i.e. not overcoating irregular old paint) for a minor increase investment in terms of paint cost, and ROI. The increase in savings between traditional antifouling products and Hempaguard is also dramatic, almost 50% reduction for the high tier product (Globic) and 95% for the low tier product (Oceanic+) when considering the Full blast scenario.

The technology in a newbuilding situation

Hempaguard products (and silicones in general) can be applied at newbuild yards.

Does it make sense to implement in this particular case?

Antifouling coatings are arguably the simplest improvement that can be made to the underwater hull. They require no modification of the hull structure, or other engineering, use tried and tested application techniques that are standard in all docks globally and represent a cost-effective option to reduce the impact of the vessel. This is especially the case with older vessels that use old or low tier products where the margin of improvement in fuel saving relative to Hempaguard will be substantial

Investments and Savings

Fuel saving	**2,047 tons/year**
Fuel cost saving	**777,911 $/year**
CO_2 reduction	**6,366 tons/year**
Return on Investment (ROI)	**<1 year**

Aft ship – Propeller and Rudder

KONGSBERG

Promas Lite is a fuel saving system that utilizes the efficiency improvement potential in the interaction between rudder and propeller. Part of the improvement is given by the Costa Bulb that reduces the hub vortex and drag, reduces slipstream contraction and increases the wake fraction. The Hubcap will contribute by streamlining the transition of water. The contribution of the bulb and hubcap will enable an optimization of the propeller that would not be possible without the two former features. Therefore, a Promas Lite system always comprises all three features.

In retrofitting projects, there is usually also room for various extent of propeller efficiency improvement separated from the Promas Lite propeller effect described above but integrated in the retrofit as such – the Reblading effect. This has to do with the difference in present operation criteria compared to original design criteria and can involve multiple parameters that affect the propeller and ship performance.

Energy savings based on baseline of calculations

Typical savings contributed by the Promas Lite effect alone range between 2-6%, depending on vessel type and design. Savings contributed by the Reblading effect can in some specific cases be as high as 20%.

The Propulsion efficiency improvement for Victoria Seaways is estimated to 4%. Hence the energy savings (Pd) is approx. 950 kW at MCR. Tonnes of fuel, CO_2, SOx, NOx savings is depending on Yearly Operation hours, SFOC at MCR and engine specification.

The reduction of Pd will slightly affect the SFOC for the engine at a given speed. This interdependency needs to be verified by the engine maker.

The technology in a newbuilding situation

From a business perspective, to include the Promas concept in a newbuilding project is quite different from the retrofit situation. In the newbuilding case, the delta cost for installing the Promas concept compared to a conventional rudder and propeller is low, but the gain is high. This means that the ROI for the Promas features is fast and should always be considered when planning for a newbuild.

Investments and Savings

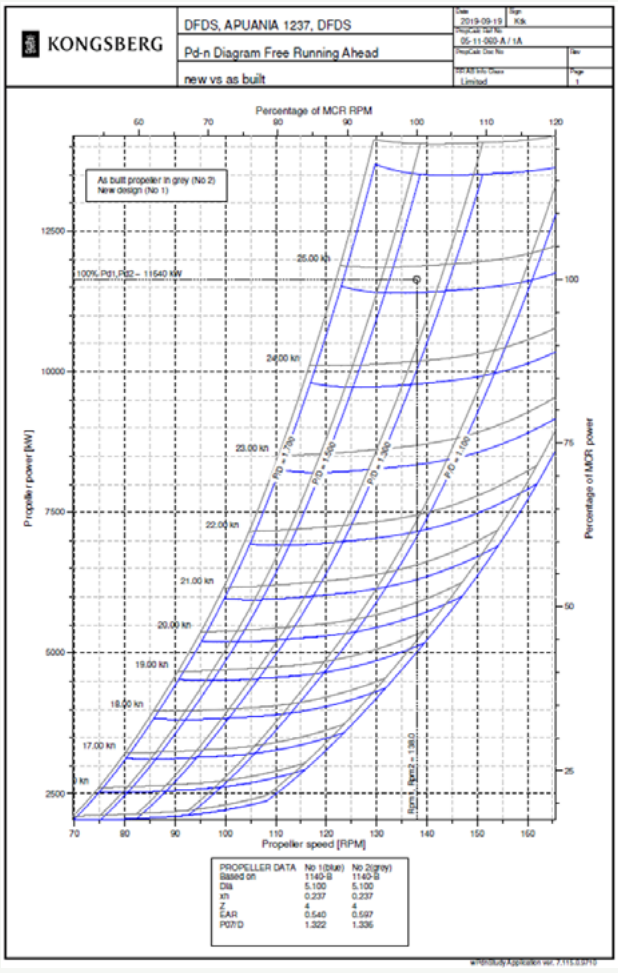
Fuel saving	**778 tons/year**
Investment cost (equipment only)	**660,000 USD**
Fuel cost	**295,000 USD/year**
CO_2 reduction	**2,400 tons/year**
ROI	**2.2 years**

Does it make sense to implement in this particular case?

We believe that in this case Victoria Seaways is a suitable object for Promas Lite, from a ROI perspective when looking at the existing fuel situation where the vessel is using HFO 3.5% with scrubber.

Existing propellers scrap value has not been included in the budget, which otherwise could improve the cases ROI, it can be recommended to optimize with Promas Lite in this case.

Propeller curve



Steering gear

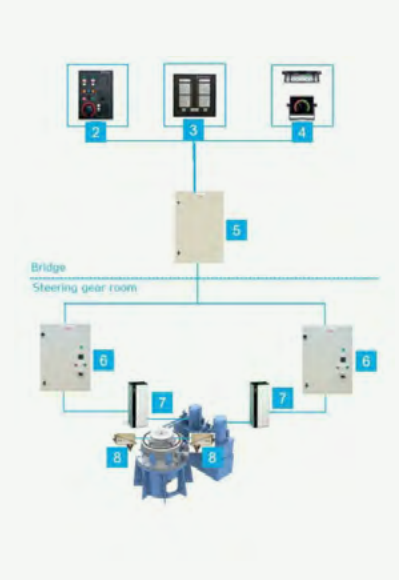
Fcon – steering gear upgrade

A frequency converter (one for each pump) is used to reduce the pump speed to the control valves idling pressure when there is no steering command signal.

When a steering command is given, the pump speed will increase to maximum again after approx. 1.5 seconds. This ramp up time will result in reduced pump speed on long voyages when the rudder is controlled by the autopilot and hence save power. The direction signals, (port/stbd) are carried out by conventional control valves.

Benefits with FCON:

- Power saving system for the RV type
- Reduced pump speed when no steering command
- Pump speed ramp up according to steering command saves power when in all steering modes
- Reduced hydraulic oil temperature



The steering gear on Victoria Seaways operate approximately 90% of the operational time in idling mode.

FCON will lower the idling frequency and reduce the power demand during idling and also during maneuvering with low rudder angles.

The technology in a newbuilding situation

From a business perspective, to include the Fcon concept in a newbuilding project you will have the fuel savings from the system from the start.

Investments and Savings

Fuel saving	**10 tons/year**
Investment cost (equipment only)	**53,591 USD**
Fuel cost	**5,340 USD/year**
CO_2 reduction	**31.1 tons/year**
ROI	**10 years**

Does it make sense to implement in this particular case?

We believe that in this case Victoria Seaways is not a suitable object for Fcon, from a ROI perspective when looking at the existing fuel situation where the vessel is using ULSFO 0.1% or MGO 0.1% without scrubber on the auxiliary engines.

Wind propulsion, Rotor Sail technology

NORSEPOWER

The project group has been looking into different types of wind propulsion solutions. It has been concluded that Flettner Rotors have the largest impact on auxiliary wind propulsion for M/F Victoria Seaways. When installing a wind propulsion system, it naturally affects the propulsion system, including main engines, turbocharger, etc. It is therefore important to see the influence they have on each other. When calculating the potential fuel savings utilizing auxiliary wind propulsion, the main ship parameters affecting the kilowatt savings are ship´s speed, total efficiency of the vessel, time-at-sea ratio and naturally the wind condition on the route. The installation height of the Rotor Sail correlates to the potential savings as well.

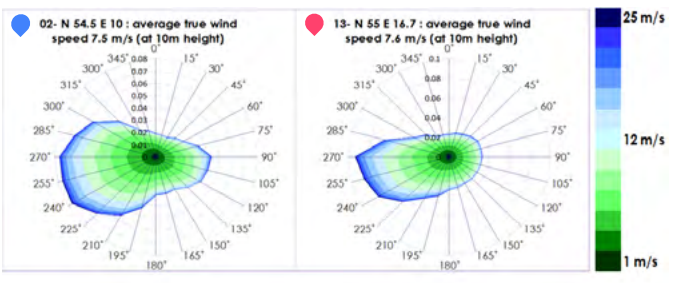
Overview and Magnus effect principle

Norsepower Rotor Sails are modernized version of Flettner Rotors. Rotor Sail technology is based on the Magnus effect. When wind meets the spinning Rotor Sail, the air flow accelerates on one side of the Rotor Sail and decelerates on the opposite side of the Rotor Sail. The change in the speed of air flow results in a pressure difference, which creates a lift force that is perpendicular to the wind flow direction.

The Norsepower Rotor Sail Solution is around ten times more efficient than a conventional sail, as more lift is produced with a much smaller sail area. Due to its simplicity and automated operation, it requires no reefing or crew attention when in operation. It is a "push button wind propulsion" from the bridge. It allows the main engines to be throttled back, saving fuel and emissions while providing the power needed to maintain speed and voyage time.

The installation height of the Rotor Sail correlates to the potential savings as well. Norsepower Rotor Sails are available in five models 18x3, 24x4, 28x4, 30x5 or 35x5 (rotor hight x diameter, meters). One Rotor Sail is proposed which is 30 meters high and located on deck 8. In case there is an air draft limitation, a tilting Rotor Sail model can be installed.

DFDS Victoria Seaways, Simulated route and examples of wind conditions



Graphs show the cumulative probability distribution of the wind speed at different wind directions. Colors represent the wind speed. Thickness of the line indicates the probability of certain wind speed from certain direction.

Potential energy savings

Norsepower run a simulation for Victoria Seaways for the round trip Kiel - Klaipeda. There is no air draft limitation on the route where Victoria Seaways is trading.

ONE 30x5 ROTOR SAIL ON THE ROUTE KIEL–KLAIPEDA	
Average net savings	**2,6%**
Annual fuel savings	**415 tons**
Annual CO_2 reduction	**1,292 tons**
Average propulsion power	**338 kW**

Compatibility with other EE technologies

Rotor Sail solution is compatible with all other energy efficiency technologies available on the market which do not limit shipowners to Norsepower's sustainable technology only. It will be possible to reduce the load on the main engine maintaining the speed, saving fuel and thus reducing emissions.

Rotor Sail Technology for newbuilding

A Rotor Sail retrofit installation requires a foundation and deck area reinforcement while in the newbuilding project it can be part of the vessel design and structure.

Investment

Two payment models are available for shipowners: traditional and pay-as-you-save model. The pay-as-you-save financing model was developed together with Norsepower's financial partners to enable a Rotor Sail system installation onboard a ship with a minimal investment by the shipowner at the start of Rotor Sail operation. This financing model is possible by sharing the estimated fuel savings, achievable with Rotor Sails, between the shipowner and Norsepower.

Evaluation of investment profitability

Rotor Sail solution profitability is effected by several factors such as fuel price, time-at-sea period and possible other emissions related costs. Since 2018, when the case study has been conducted, some of the factors have become more demanding.

Five Rotor Sails, which are in global operation today, gave us an opportunity to reduce manufacturing costs and the lead time. As maritime shipping is facing more stringent environmental regulations, Norsepower current payback period is in the range of three to nine years. For DFDS Victoria Seaways having current time-at-sea period, technology profitability is close to the payback period target when low sulfur fuel price is considered.

Organic Rankine Cycle (ORC)

An ORC plant is a modular system for generating power from waste heat. In general, various waste heat flows may be used, such as exhaust gas or cooling water heat from a combustion engine (HFO, diesel or gas) or similar sources of heat in marine applications.

The energy output can either be used mechanically to support the propulsion of a ship or converted into electricity to supply the on-board grid or a battery pack without CO_2- emissions. The operation needs no human intervention except regular visual inspections and is mostly maintenance-free.

Orcan Energy has developed and introduced a State-of-the-Art and proven Waste Heat Recovery System for marine applications. In total more than 1,000,000 efficiency PACK fleet running hours have been collected, with already 48,000 running hours achieved on one Waste Heat Recovery plant. Currently an average availability rate in excess of 99.5% is achieved on a deployed fleet of > 200 installations worldwide in Orcan's key markets.

Description of action and technology

The efficiency PACK 's working principle is based upon the ORC. This is a closed steam cycle in which an organic working fluid (hydrocarbon) is used. The working fluid used in the efficiency PACK is non-toxic and non-flammable. Figure 1 shows a simplified model of the ORC system.

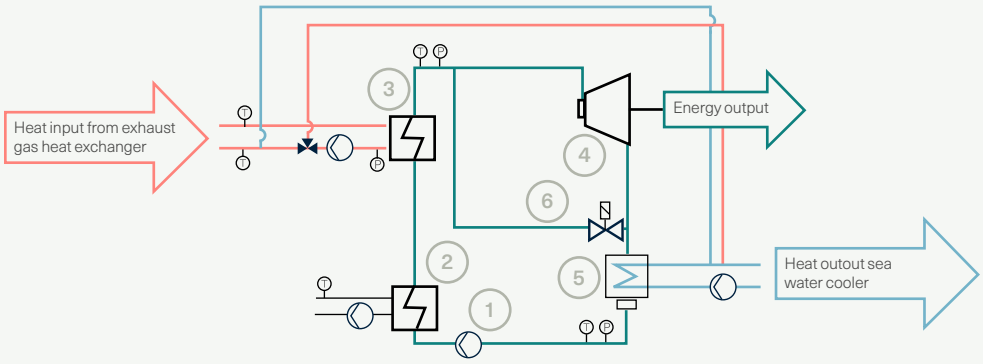
Energy savings based on baseline of calculations

Despite there is a lot of heat for recovery purposes, it is not possible to catch sufficiently with the current setup on Victoria Seaways.

Below explains why:

- The heat recovery boiler is limited in steam generation capacity, however if all the steam could be available in theory for heat recovery, it would be possible to generate 300 kW net electric power at 100% MCR
- Steam capacity at 85% load 1,200 kg/h, means that under normal sailing conditions this is reduced to 160 kW net electric power
- In wintertime all the steam from the boilers is needed, on top of that, the oil-fired boiler must come online, which means the eP's are out of service
- Additionally, to the above, it may be possible to retrieve 70-80 kW net electric power from the AUX's with the installation of heat recovery boilers

The efficiency PACK (Figure 1)



In the ORC system (efficiency PACK) a feed pump (1) transfers the liquid working fluid into a preheater (2) in which the fluid is heated to below boiling temperature.

The preheater is usually heated by an engine's hot jacket cooling water. After the preheater the fluid is evaporated and superheated in the evaporator (3).

The evaporator is heated by a pressurized hot water loop. The superheated steam then drives the expansion machine (4).

The expansion machine can be connected to a generator to produce electricity or connected to an engine's PTI (power take-in) via a transmission to supply mechanical power to the engine's crankshaft.

In the condenser (5) the steam at low pressure is liquefied again to close the steam cycle.

The condenser is cooled by a water cycle that is connected to a sea water cooler.

The cycle also includes a bypass valve (6) to pass the steam by the expansion machine for startup, shutdown and emergency purposes.

Does it make sense to implement in this particular case?

Since most of the steam that can be produced is already used for heating purpose on Victoria Seaways it will not be profitable in this case.

There will still be savings, but the expenses will be too much.

Energy savings

Because it is uncertain how much steam could be utilised in the eP's, it has not been possible to do any calculations on savings and ROI.

Interdependencies with other technologies

An ORC unit uses waste heat from main- and axillary engines and does not affect other technologies aboard.

The technology in a newbuilding situation

For a vessel similar to Victoria Seaways where ORC was part of the newbuild setup it would be possible to produce up to 700 kW net electric power at 85% MCR, which means that it will be possible to reduce genset size, so that it will be possible to run it in optimum operating range.

Planning ORC into the auxiliary or propulsion system on a newbuilding project, will open opportunities for fuel and cost reductions from the very beginning.

Which benefits does the efficiency PACK offer?

- Significant fuel savings
- Attractive payback period and free accumulated cashflow during the operation of the efficiency PACK
- Significant emission reductions (savings) for CO_2, NOx, SOx and PM
- Improvement of the EEDI
- Well selected and class approved rugged marine components that require minor scheduled maintenance
- Your ships contribute to a more sustainable future at sea by powering your ship with waste heat

Lights

DANISH ENERGY CONSULTING

Description of action and technology

The use of energy efficient lighting equipment such as low energy halogen lamps, fluorescent tubes and LED (light emitting diode) in combination with electronically controlled systems for dimming, automatic shut off, etc. is continuously developed as the focus on energy and environment has increased. The LED technology is to some extent "standard" when designing a new vessel today, but still some vessels are delivered without energy efficient lighting. LED has also been applied only to a limited extent to the shipping industry and standard normal design does often not include low energy lighting. Implementing an energy efficient light system will additionally reduce the maintenance hours and operating cost.

Victoria Seaways was delivered with standard fluorescent tubes and halogen lamps where some of the lightning is in EX-proof armatures. Subsequent calculations are based on offers made to Victoria Seaways. The calculations are based on baseline of calculations for DFDS Victoria Seaways.

Investments and Savings

Fuel saving	**48.4 tons/year**
Investment	**212,857 USD**
Fuel cost savings	**25,846 USD/year**
CO_2 reduction	**151 tons/year**
Return on Investment (ROI)	**8.2 year**

Interdependencies with other technologies

Saves load on auxiliary engines and there by saves fuel. Does not affect other systems on board.

The technology in a newbuilding situation

The LED technology is obvious in a newbuilding because the price difference in procuring ordinary lightning compared to LED is minimal.

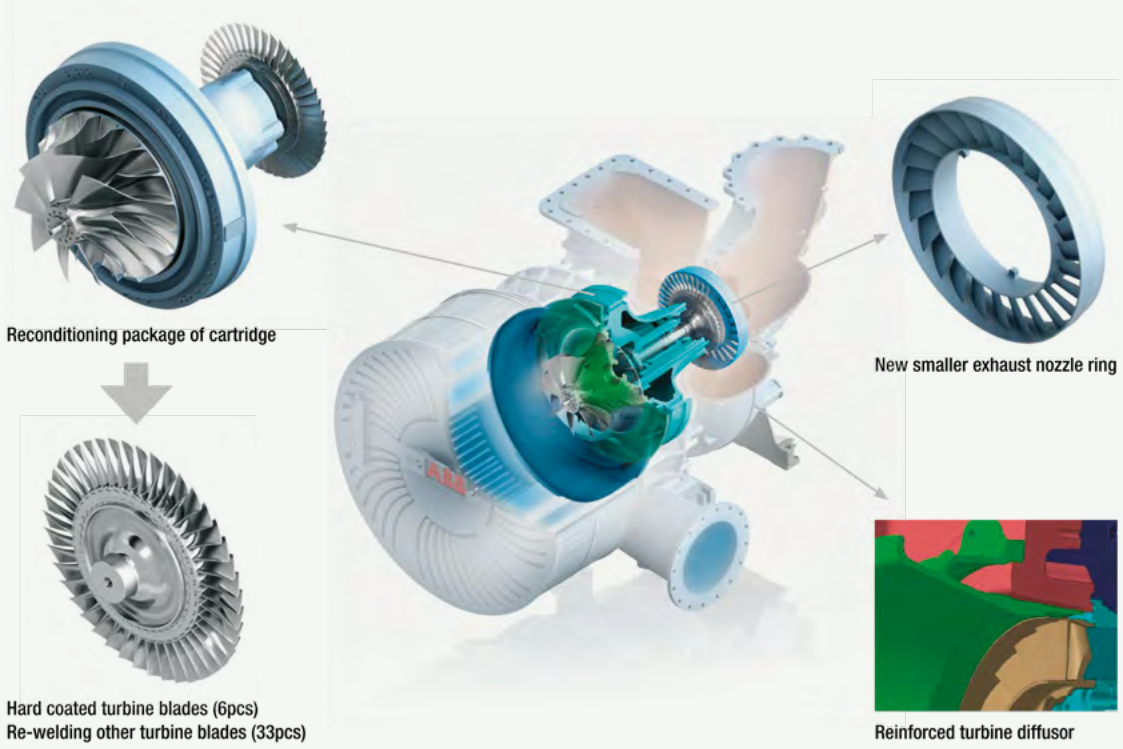
Does it make sense to implement in this particular case?

With a ROI of above 3 years it does not make sense in this case. Note that on Victoria Seaways they have already started with converting to LED lights and the "lowest hanging fruits" are picked, leaving the more expensive conversions left, which shows on the ROI. Normally calculations on LED conversions from traditionally fluorescent lighting, shows a ROI below 2 years.

Turbo charger upgrade on main engines

Upgrade kit utilizes the latest high efficiency compressor technology from TPL-C series turbochargers adapted for TPL-A family connected to optimum nozzle ring specification.

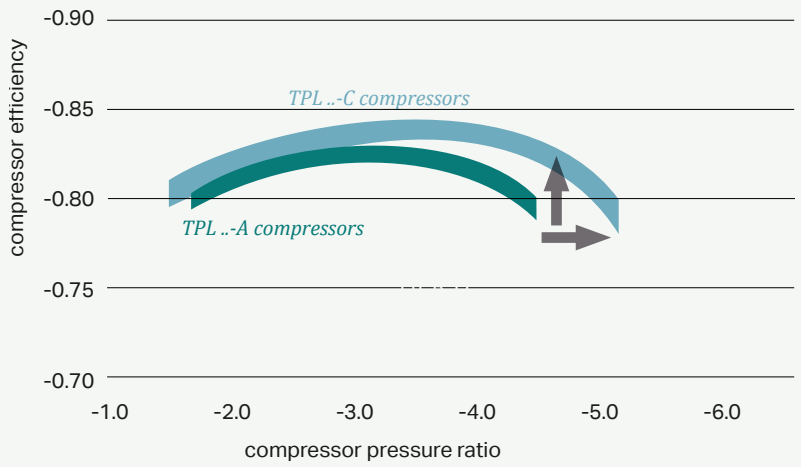
Turbo charger upgrade



Benifits

- Lower fuel consumption
- Lower thermal load
- Higher turbocharger speed, speed margin
- The improved efficiency and reduced thermal loading also results in reduced lifecycle maintenance costs

Product features compressor, higher compressor efficiency



Efficiencies shown for reference only

Optimum time for installation of turbocharger upgrade package is when existing turbochargers are reaching 50,000 operating hours SIKO, at this maintenance interval the turbocharger requires a complete overhaul. By upgrading the turbocharger to latest compressor technology is a profitable investment instead of carrying out the extensive SIKO maintenance of existing turbocharger.

Performance Package Benefits

The Performance Package brings several financial and technical benefits amongst others:

Upgrade benefits		Added value
Increased turbocharger efficiency	→	Fuel savings of 1.5 g/kWh, lower fuel treatment, less scrubber liquid, reduced emissions
Reduced engine exhaust gas temperatures	→	Lower thermal load → reduced maintenance costs → less downtime
Increased speed margin	→	Higher operational flexibility
Applicable for highly loaded HFO solutions	→	Applicable for highly loaded HFO solutions
"Drop-in" solution (replacement of components only)	→	Short downtime for upgrade installation
Wärtsilä will take the lead in the Re-certification process	→	Ensuring un-interrupted vessel operation
Up-to-date technology, latest experience available in the market	→	Future-proof installation

Investments and Savings

Fuel saving	181 tons/year
Investment	881,156 USD
Fuel cost savings	68,780 USD/year
CO_2 reduction	564 tons/year
Return on Investment (ROI)	8.4 year
Savings on SIKO maintenance 2 engines (information from DFDS)	300,000 USD

Interdependencies with other technologies

It improves the performance of the main engines.

The technology in a newbuilding situation

Unless it is an extra option it should be a standard delivery at newbuilding

Does it make sense to implement in this particular case?

With a ROI of above 3 years it does not make sense in this case.

Summary

With the solutions suggested above, it is possible to reduce the fuel consumption on Victoria Seaways with 11.1% within the target ROI below 3 years.

Several of the solutions suggested are above the target value and some are already installed onboard.

Victoria Seaways is, with her 9 years, the oldest vessel in the GSF retrofit project. Still it has been a challenge to locate fuel savings within the target ROI and one of the conclusions on this must be, a dedicated crew, a superintendent and a technical organization within DFDS that is highly focused on optimizing their fleet.

Collective savings for Victoria Seaways

Fuel savings	**2,331 tons/year**

Emissions

CO_2 reduction with a 11,1% fuel reduction	**7,259 ton/year**

Effect of products

Company	Product	Savings on			Effects	ROI [years]	Fuel Saving [ton/years]	CO_2 reduction [ton/years]
		ME	AUX	Boiler				
Alfa Laval	Boiler optimisation			x	Reduce fuel consumption for boilers	2.3	85	265
C. C. Jensen	LO filter system		x	x	Reduses energy needed for keeping the LO clean and heating the LO	1.1	79	246
DEIF	Energy Management System	x			Reduce load on ME	0.25	639	1,990
Greensteam	Already installed				Reduce load on ME	< 0.5		
Hempel	Sillicone antifouling				Reduce load on ME	<1.0	779	2,426
Kongsberg Maritime	Promas lite (Propeller blades, Hubcap, Rudderbulb)	x			Reduce load on ME	2.2	778	2,423
Kongsberg Maritime	Fcon	x			Reduce load on ME	10	10	31
Norsepower	Flettner Rotor	x			Reduce load on ME, but increase load on AUX	6 - 6.3	415	1,292
ORCAN	ORC		x		Reduce load on AUX	N/A	N/A	
Danish Energy Consulting	Lights		x		Reduce load on AUX	8.2	48,4	151
Wärtsila	TC upgrade	x			Reduce load om ME	8.4	564	1,756

Target value < 3 years Target value > 3 year

Target value < 3 years	**2,360 ton/year**	**11.1%**	**CO_2 reductions**	**7,350 tons/year**
Target value > 3 year	**1,037.4 ton/year**	**4.9%**	**CO_2 reductions**	**3,230 tons/year**

Total fuel consumption 21,311 ton/year

Case Study 3.

– Maersk Tianjin

MARITIME HAWAI'I

Vessel description

The vessel was delivered in 2016 and was built according to standards with focus on hull performance, classification and ice classifications. The vessel was built as a well-thought-out technical solution that complies with current legislation. The yard offered some optimization options, from which the following was chosen.

INITIATION

M/T Maersk Tianjin is an Oil and Chemical product tanker in the MR class (Medium Range), build at the Sungdong Shipbuilding and Marine Engineering, South Korea 2016. The vessel is ice classed +1A1. DNV-GL

OPTIONS CHOSEN BY SHIPOWNER

- Low leakage 3-wayvalves
- Able to heat main engine with auxiliary cooling water during port stay
- Composite Boiler to minimise use of the larger auxiliary boiler when the steam demand is low

GA Maersk Tianjin

VESSEL DATA

Name	M/T Maersk Tianjin
Homeport	Singapore
Length	183 m
Width	32.2 m
Draft (max)	12.9 m
DWT	49. t
Hull type	Double hull

BASELINE FOR CALCULATIONS

Annual fuel consumption

HFO 3.5%	(ME) 3,635 ton + (Aux) 711 ton	4,346 ton/year (87%)
MGO 0.1 %	(ME) 457 ton + (Aux) 178 ton	635 ton/year (13%)

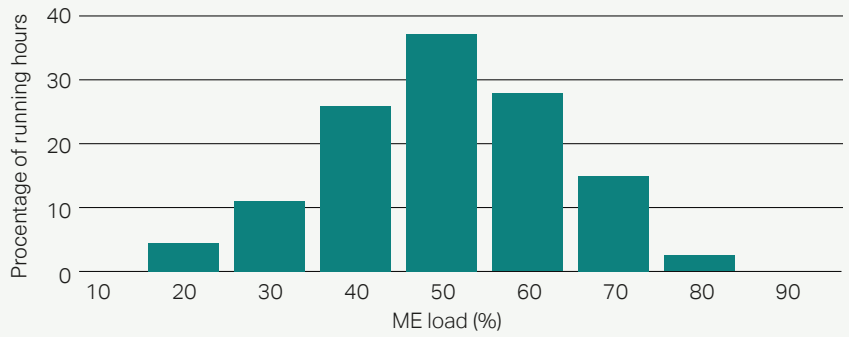
AVERAGE BUNKER PRICES IN 2018

HFO	3.5 %	400 $/ton
MGO	0.1 %	600 $/ton
ULSFO	0.1 %	550 4/ton
Lube oil	ME/AUX	1.00 $/ltr.

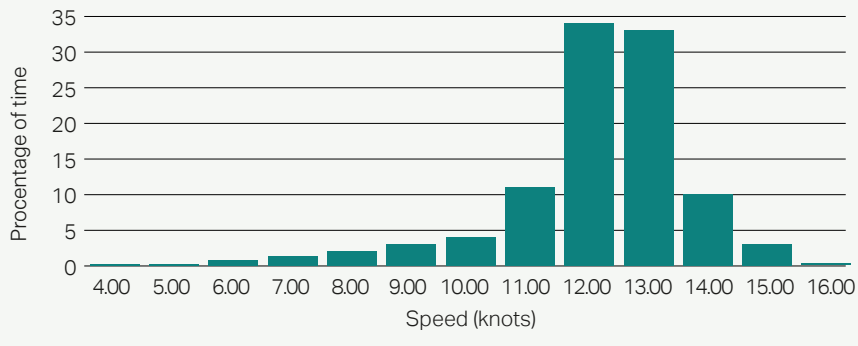
LCV (Lower Calorific Value) ISO conditions

HFO 3.5 %	40,600 KJ/kg	(11.28 kW/kg)
Density at 15°C	990 kg/m3	CO_2 3,114 kg/ton fuel
MGO 0.1 %	42,700 KJ/kg	(11.86 kW/kg)
Density at 15°C	850 kg/m3	CO_2 3,206 kg/ton fuel

Main engine load



Vessel speed



Areas suitable for optimization

Below is a list of areas selected for further optimization. In this project, focus is on short term decarbonisation and fuel reduction. While we are aware that there are other options available, some very innovative, the objective of this project is to explore the potential of today's best available and proven technology.

Listed in alphabetic order of company:

PAGE	SOLUTION	COMPANY
96	Boiler System	ALFA LAVAL
99	Ballast Water Management System L	BOS GLOBAL
100	Lube Oil treatment (CJC filter)	C. C. JENSEN
103	3-way valves for fresh cooling water for main engine	CLORIUS CONTROLS
104	Pumps & engine room ventilation	DESMI
107	Antifouling fuel saving analysis	HEMPEL
112	Promas Lite (Rudder & Propeller)	KONGSBERG MARITIME
114	Wind propulsion, Rotor Sail technology	NORSEPOWER
117	Organic Rankine Cycle (ORC)	ORCAN
120	Summary	

Boiler System

Installed Base

Maersk Tianjin uses steam to heat fuel tanks, steam tracing of fuel pipes, cargo heating, lube oil separator, cargo cleaning and ice removal, etc.

The installed base for Maersk Tianjin is 1 x Combi boiler type AQ10 and 1 x Oil-fired boiler type OL. The AQ10 boiler can utilize heat in exhaust gas (waste Heat Recovery) from main engine to produce steam and change to an oil-fired section when needed. The AQ is designed for 1,000kg/h of steam production on Waste heat recovery section, and 2,200 kg/h of steam production by oil combustion. The OL can produce 18,000 kg/h of steam by oil combustion and is used mainly for cargo discharge procedures.

Operation pattern

Fuel consumption and steam production is not measured onboard. However, it has been informed that the OL has 1,542 yearly operation hours which can function as a basis.

Section below describes technologies that can be applied on OL boiler to increase efficiency.

OL performance improvement

It is possible to increase the OL boiler efficient with up to 9% and thereby reduce fuel oil consumption, by installing a Micro economizer as a feedwater preheater. For Mærsk Tianjin this can be an attractive installation with yearly saving up to 80t of fuel oil equal to 32,000 USD.

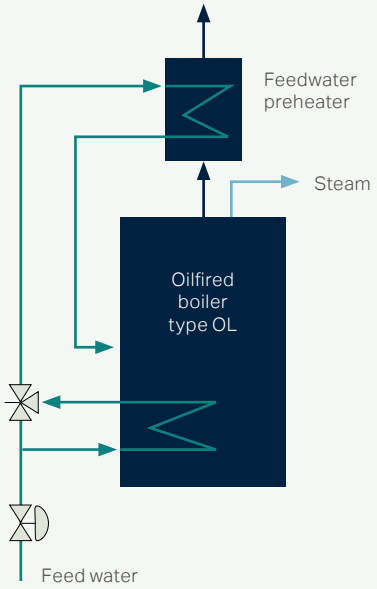
Feedwater preheater on OL boiler

A feedwater preheater is an exhaust gas boiler installed after OL boiler, with the purpose of utilizing heat in exhaust gas coming from oil combustion.

The exhaust gas boiler will preheat the OL boiler feedwater from 60-80degC to temperatures close to boils point at the rated boiler pressure.

This solution can be attractive when the OL is running frequently and with a fairly stable load pattern.

Saving potential in the range of 5-9% fuel oil saving.



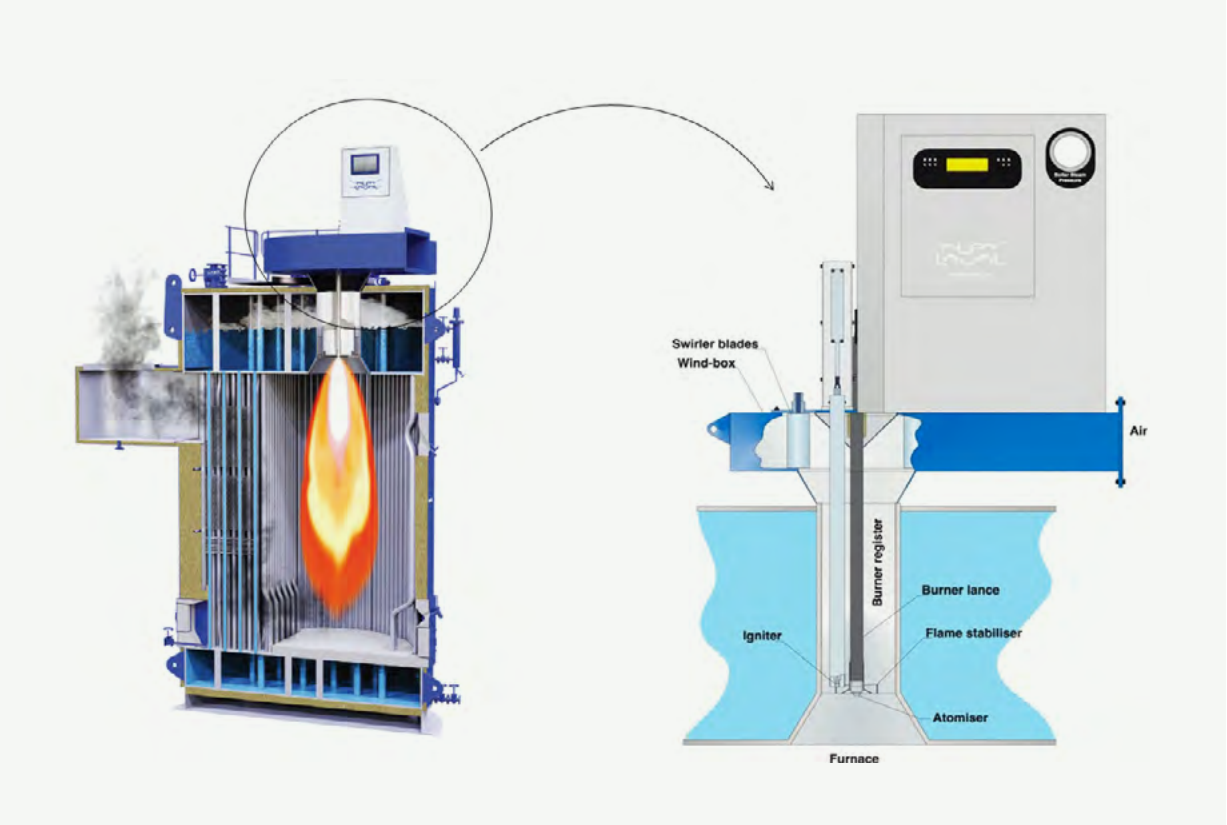
Low load Burner

When operating a large oil-fired boiler there is a limitation in terms of turndown ratio, meaning the minimum capacity of the boiler steam production is limited to around 20% load. But with an upgrading kit the low load operation of the boiler system it is possible to go to ≈5%.

The upgrade consists of mechanical upgrade of the burner, hardware and software upgrades. The upgrade can be done by your Alfa Laval service engineers and is expected to take 5 days and can be done while Vessel is in operation.

There are different scenarios that makes the application relevant, but common for all is the need to operate the OL lower than 20% load. Advantage of a low load burner is optimized boiler operation which lead to fuel saving, and also less start/stop on the boiler system. And thereby also less wear and tear on the boiler system.

For Maersk Tianjin, this is considered relevant if the vessel steam demand is more than the maximum limit of the AQ10 boiler and below the minimum capacity of the OL. Another example is slow steaming vessels where the engine loads are reduced which leads to less steam production on the exhaust gas economizers, forcing increased operation on the oil-fired boilers. In cases where an OL boiler will be forced in operation as a consequence of slow steaming, its minimum design point at 20% can be higher than the actual steam demand. To cope with that, the boiler will operate with many starts and stops which is not recommendable as it increases wear and tear on the burner and negatively affects the efficiency of the boiler and fuel oil consumption.

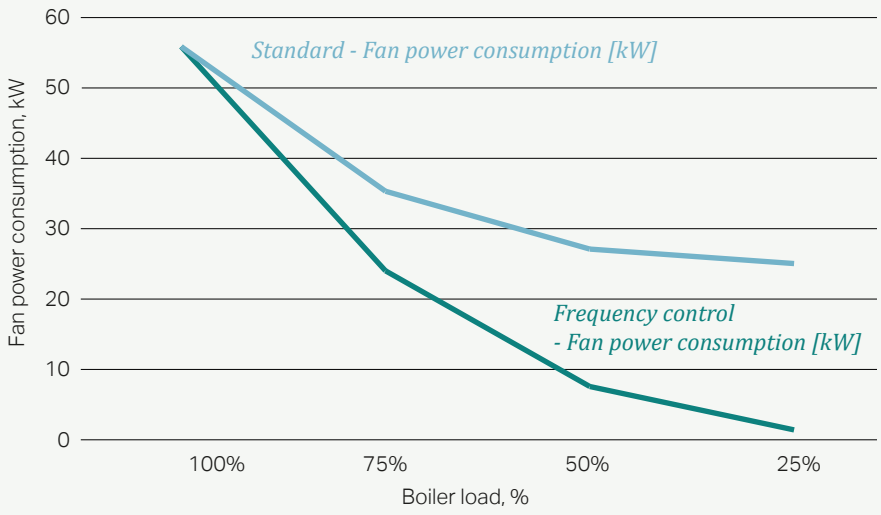


Variable frequency drive on combustion air fans

For OL boiler the Forced Draught air supply fans can be of large size and require significant power consumption, and under the right circumstances it can be an attractive solution to install a variable frequency drive. Today when running at boiler at 50% steam production the fan will be running full load and adjust airflow with a damper. By installing a variable frequency drive on the forced draught fan motor, it will be possible to reduce the airflow to steam production which results in a direct fuel saving on the auxiliary engines.

An additional benefit is that the number of running auxiliary engines can be reduced, as no heavy starts will be required after installation of a frequency drive.

20T OL fan power savings (kWh)



Above curve shows example of the power saving with a frequency drive and below table summarize in actual saving.

18 OL FAN POWER SAVINGS (KWH) EXAMPLE FOR MÆRSK TIANJIN				
Load (Steam production)	**100%**	**75%**	**50%**	**25%**
Total boiler operation hours per year	200	500	500	342
Total power saving per year (kWh)	**0**	**5,500**	**9,500**	**7,866**
Total power saving per year, accumulated				**22,866 kWh**

Contact your local boiler specialist for more help. 24/7 local support:

marine.service@alfalaval.com

PHONE: +46 4336 7700

Ballast Water Management System BOS Natural Ballast

BOS Natural Ballast measures and records all ballast water management parameters continuously. Typical ballast water treatment system assumes operational compliance once type approved. This may not be true since ships take ballast water from all corners of the oceans. The system verifies that the ballast water management system meets the ballast water discharge standard at all times.

The system can be for both retrofit and newbuild.

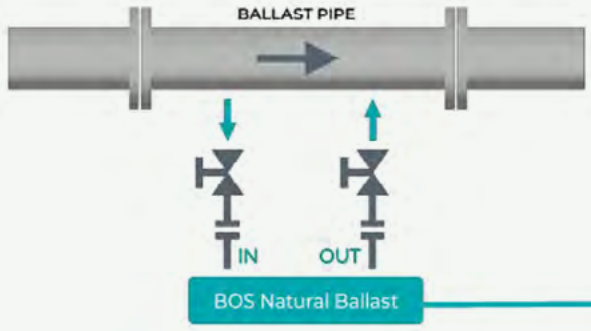
Ballast Water Management System

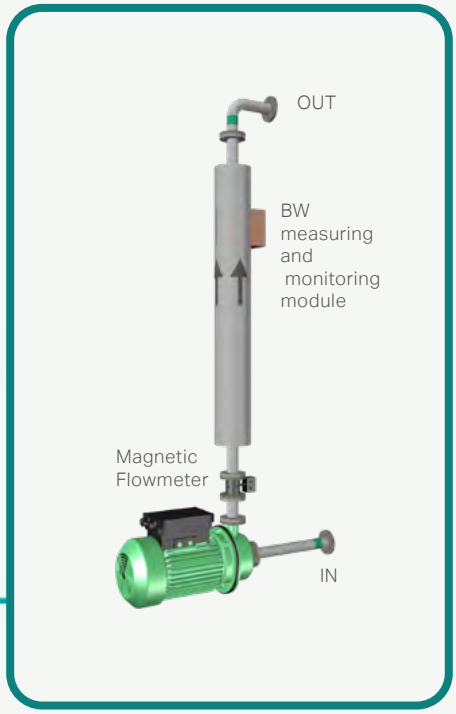
Power: 3kW

Space: Smallest footprint, one size fits all

Time: Quick instillation (3-5 days without dry docking

Automation: Automated operation





Lube Oil Treatment and Oil Filtration

C.C.JENSEN

Lube Oil treatment

Maersk Tianjin is equipped with separators for cleaning of the lube oil to the main engine and auxiliary engines. The lube oil is preheated in a steam heat exchanger before separation, with steam from the AQ boiler (waste heat recovery boiler), main engine during sailing or from the OL steam boiler when the main engine is not running.

Oil sludge from separators has a certain amount of water in it, which is used to clean the bowl. The oil sludge is to be either incinerated aboard or to be sent for treatment/disposal ashore.

Description of action and technology

The objective is to save energy by replacing existing technology used to clean lubricating oil on 2-stroke and 4-stroke engines.

By replacing the traditional purification system, where the oil needs to be heated to 90 to 95 degr. C, with a CJC off-line filter with the patented flow drive technology, the need for heating the lube oil is eliminated. The CJC filter reduces the overall power consumption with up to approx. 90%. Calculations are based on running hours supplied by Maersk Tianjin.

A filter is replacing one separator for the M/E. The G/E separator used for 3 G/E's and is replaced with a dedicated filter per G/E. Both separators have 5,800 running hours/year and 24 hours a day for the filter.

Besides the saving in heating, there will be a significant reduction in lube oil consumption and reduction of the lube oil waste, both reducing the total CO_2 footprint. A filter is replacing one separator for the M/E. The G/E separator used for 3 G/E's and is replaced with a dedicated filter per G/E. Both separators have 5.800 running hours/year and 24 hours a day for the filter.

Energy savings based on baseline of calculations

MAIN ENGINE SUMMARY	L.O. CENTRIFUGE	CJC L.O. FILTER
Energy costs per year [kWh]	54,380	2,580
Energy savings with CJC per year [kWh]		**51,800**
Lube Oil waste [kg/year]	747	96
Lube Oil waste savings with CJC [kg/year]		**651**
CO_2 emission [kg CO_2/ year]	30,740	1,830
CO_2 emission savings with CJC [kg CO_2/ year]		**28,910**

Aux engines:

SUMMARY	L.O. CENTRIFUGE	CJC L.O. FILTER
Energy costs per year [kWh]	37,490	5,420
Energy savings with CJC per year [kWh]		32,070
Lube Oil waste [kg/year]	2,484	96
Lube Oil waste savings with CJC [kg/year]		**2,388**
CO_2 emission [kg CO_2/ year]	23,350	3,840
CO_2 emission savings with CJC [kg CO_2 / year]		**19,510**

Interdependencies with other technologies

Does not normally not affect other technologies besides reducing the energy consumption to boilers. In this case with Maersk Tianjin, it will be possible to release excess steam from the composite boiler which can be used in e.g. an ORC plant to produce electricity. Moreover, the amount of oil sludge will be reduced and thereby the cost of handling or disposing of oil sludge.

The technology in a newbuilding situation

Installing a CJC filter unit in a newbuilding process will make savings in the initial capex and for the shipyard it will mean less installation cost as you do not need compressed air etc.

Investments and Savings

Fuel saving	**22 tons/year**
Investment (ME + AUX)	**50,000 $**
Fuel cost savings	**9,200 $/year**
Lube oil waste saving	**3,200 $/year**
Sludge saving	**7,900 $/year**
Spare parts saving	**750 $/year**
Total savings	**21,050 $/year**
CO_2 reduction	**68 tons/year**
Return on Investment (ROI)	**< 2.4 year**

Note: If separators are operating according to procedure Return on Investment (ROI) is <1.4 years

Does it make sense to implement in this particular case?

The technology make sense to install on Maersk Tianjin, as it will make a direct saving in energy and oil consumption, both of which save CO_2 emission. Besides the saved energy it is also a less complicated piece of equipment to maintain compared to traditional purifiers.

Reliable machinery performance starts with clean & dry oil

Low leakage valves

Maersk Tianjin has already installed low leakage 3-way valves on the main engine cooling system.

Description of action and technology

With the 3-way control valve with a low leak valve, it is possible to reduce the leak over the HT FW cooler and thereby save fuel used to reheat the HT water. The leak today is set to be 0.01% and no further optimizing is possible.

Energy savings based on baseline of calculations

None

Interdependencies with other technologies

Replacing the 3-way valves does not affect other technologies other than reducing boiler load.

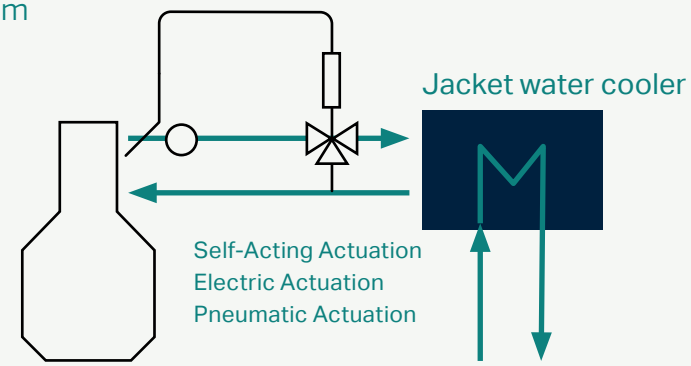
The technology in a newbuilding situation

If low leakage valves are installed as newbuild, there will be cost savings to both the heat losses and replacement valves from the very beginning of operation.

In general, we recommend following the guidelines from MAN ES to make the LTFW as cold as possible (10°C). If followed, the result is expected to be significantly bigger cool down, hence a much lower payback time.

Engine Jacket Cooling water system

In general, we recommend following the guidelines from MAN ES to make the LTFW as cold as possible (10°C). If followed, the result is expected to be significantly bigger cool down, hence a much lower payback time.



Pumps and engine room ventilation

DESMI

In the design phase it was decided to optimize the engine room ventilation system with variable frequency drive (VFD), which was offered by the yard. It is, of course, possible to reduce the electrical power to the engine room fans, but it is important to consider if it is more relevant to reduce the engine room temperature, securing colder air to the main engine.

It is also important to choose the correct VFD regulation. The cheapest VFD regulators with manually settings are often regulated during sea trials and never touched again unless anything happens to it. Contrary, the most efficient VDF regulations are using multiple regulation factors as temperature, flow, pressure etc.

Maersk Tianjin is equipped with both seawater and freshwater pumps for engine cooling etc. Pumps are normally designed to be able to operate in seawater temperature up to 32°C and running in one speed mode (start/stop). Accordingly, cooling pumps normally run at full speed to ensure sufficient cooling water. The installed VFD pack regulate pumps by water temperature or manual settings. Desmi experience shows that this (simple) VFD regulation is expected to reduce the electric consumption of the pumps with approx. 10 - 20 %.

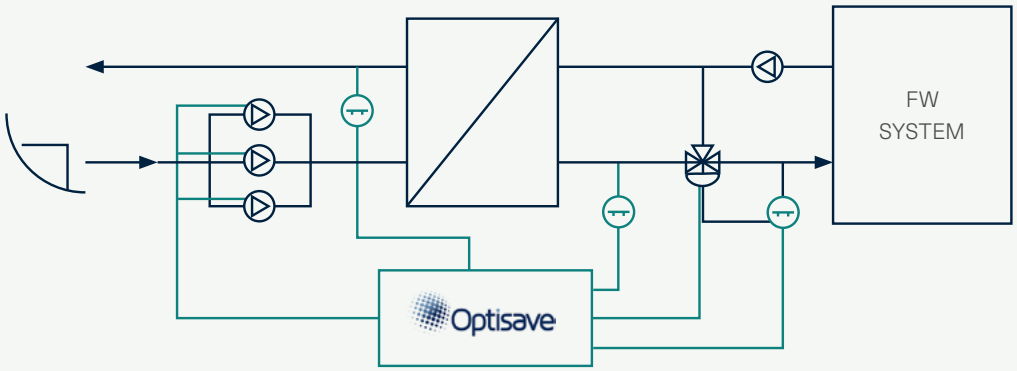
Description of action and technology

Desmi has designed an energy saving solution for both newbuildings and retrofit installations called “OptiSave”. OptiSave for pumps works on a combination of temperature and pressures to ensure lowest possible energy consumption and still providing sufficient flow/pressure. OptiSave for engine room fans works by a combination of temperature, overpressure and main engine load.

OptiSave frequency converters are programmed to operate all safety functions such as:

- *Standby control*
- *Black-out restart*
- *Priming control*
- *Over current protection*
- *Under voltage protection*
- *Internal temperature of electrical motor*

DESMI OptiSave solution for cooling pumps



Energy savings based on baseline of calculations

DESMI has calculated 2 options, one for the cooling water system and one for then engine room fans, on the OptiSaveTM solution, replacing existing system.

Option 1, cooling water system

Fuel saving	116 tons/year
Investment (incl. installation)	70,000 $
Fuel cost savings	46,360 $/year
CO_2 reduction	359 tons/year
NOx reduction	10 tons/year
SOx reduction	6 tons/year
Return on Investment (ROI)	1.5 year

Option 2, engine room fans

Fuel saving	32.4 tons/year
Investment (incl. installation)	60,000 $
Fuel cost savings	22,600 $/year
CO_2 reduction	175 tons/year
NOx reduction	5 tons/year
SOx reduction	3 tons/year
Return on Investment (ROI)	4.6 year

Interdependencies with other technologies

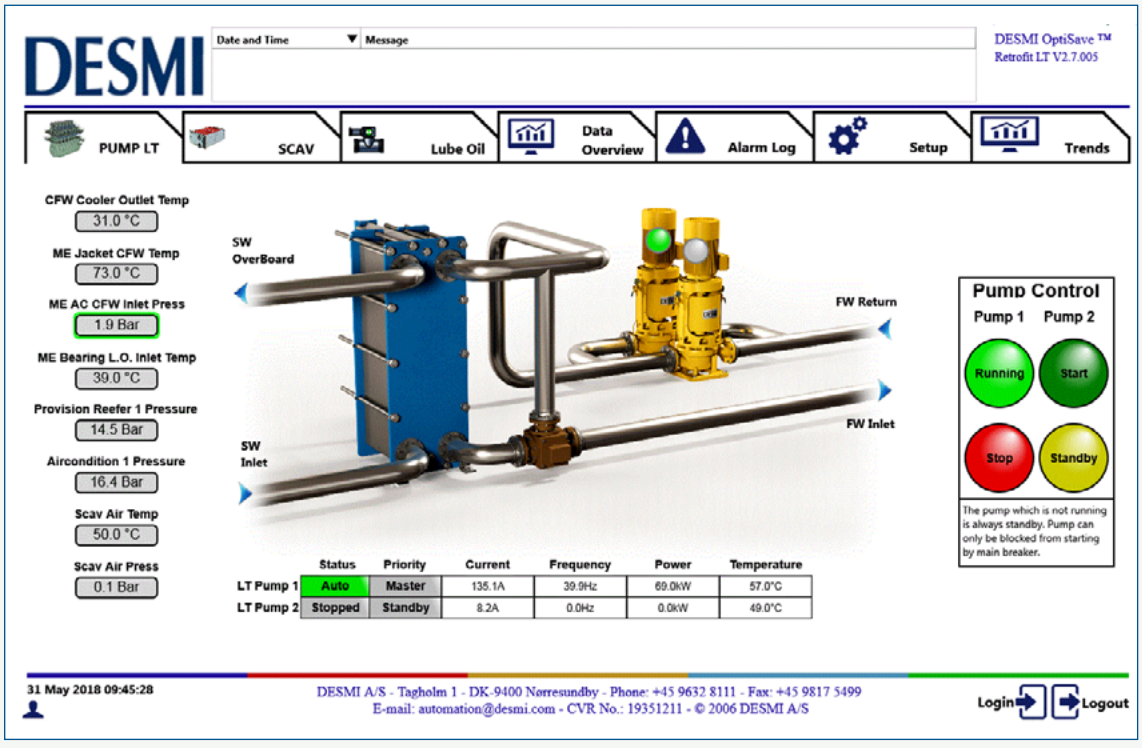
Reduces the power consumption for auxiliary engines. Does not affect other systems if the requirements for cooling water and ventilation systems are met.

The technology in a newbuilding situation

If implementing the system in a newbuilding, correct functioning of pumps and ventilations systems are obtained from the very beginning and thus the fuel and emissions savings.

Does it make sense to implement in this particular case?

Since the ROI for both options are below the 3 years it makes sense to implement both options on Maersk Tianjin.



Antifouling fuel saving analysis

Hull performance is recognized as being critical in the efficient operation of vessels with respect to energy savings. Much focus is placed on the need for propeller and hull cleaning, slow steaming and efficient hull designs to achieve optimal operational parameters suited to the vessel type. Often the contribution that effective antifouling coatings can deliver in terms of maintaining hull performance is underestimated when evaluating hull performance. Whilst the financial, and time pressures associated with maintenance and repair or newbuilding priorities are key factors in product selection, it is frequently the case that the wider benefits of fuel saving and emission reduction associated with a specific antifouling product and appreciation of the return on investment relative to the financial savings in reduced fuel use are seldom factored into selection. This assessment lays out a series of scenarios defining the financial, efficiency and emission savings that can be achieved by utilizing state of the art antifouling technologies.

The fundamental principle of all antifoulings is to maintain a smooth hull. This is achieved in two ways firstly the inherent roughness of the coating itself and secondly by preventing fouling species from colonising the hull. Coating smoothness is achieved by utilising polymer resins to create a smooth surface. Fouling control is achieved by utilising non-stick technologies or incorporating biocides into the coatings system, or a combination of both approaches. These two aspects link to different benefits on fuel performance, the first being the absolute improvement in drag through the water, i.e. how smooth the coating is and the second being the deterioration of the coating smoothness with time as it becomes fouled. Depending on the product and technology chosen these figures vary, from approximately 6% for low performance products to as low as 1.2% for best in class products when considering speed loss with time at a given engine output. For example in the ISO19030 working group on hull performance measurement it was established that a typical A/F degrades by approximately 18% over 5 years (5.9% speed loss). The best products lose as little as 3.6% giving fuel savings of up to 15%..

Hempaguard products offered by Hempel A/S give you this best in class performance with Hempaguard X7 returning 1.4% speed loss values and the Hempaguard MaX system 1.2% for a 5 year scheme. This equates to 6 and 8% fuel savings on average compared with typical antifouling paints. These improvements are a result of developing technology that utilises silicone polymer resins with improved coating smoothness (compared with traditional antifoulings) and fouling release (non-stick) properties in combination with hydrogel and optimized biocide use to minimize fouling during service.

For an ageing fleet ‘upgrading’ the antifouling used can give immediate, significant benefits to the total fuel consumption of the vessel. This evaluation compares Hempaguard X7 (best in class technology) with the best performing traditional antifouling coating (i.e. not utilising Hempaguard technologies) and a ‘market average’ coating typical on vessels of this type and age. Projected fuel savings and return on investments were made for each product by comparing

the expected fuel use with the current reported fuel consumption of the vessel to date. To do this it was assumed that the coating currently on the vessel is equivalent to Globic 8000 in terms of expected speed loss and absolute performance savings out of dock.

The conclusion and recommendation of the study is to adopt Hempaguard for vessel refurbishment due to the significant reduction in fuel use and commensurate saving in emissions.

Briefly put, there are 3 main types of technology available to the market. Below is a brief summary of those types and corresponding Hempel products that are discussed in this evaluation later in the document:

Antifouling:

The traditional approach to fouling control. The majority of the products in the market today fit into this category. The products use sparing soluble polymers to control the release of biocides so that they are active at the surface of the paint to control fouling. By 'tuning' the polymer technology different rates of release can be achieved to match the operational profile of the vessel to provide the right protection for the required trading pattern and interdock period. Technologies vary widely within and between companies, as does performance. Products referred to in this document which fit in this category are Globic 9000, Globic 8000 and Oceanic+. The 'market average' product will be a traditional Antifouling.

Fouling Release:

These are biocide free products which use 'non-stick' polymers to make it difficult for fouling organisms to adhere to the surface of the vessel, and 'self-clean' once the vessel is underway to remove organisms that may have managed to attach. These coatings are typically much smoother than traditional antifoulings reducing drag immediately after launch. Products from this category have not been used in this review but include Hempasil X3+.

Fouling Defence:

Next generation products that combine the coating technology from Fouling Release with the biocide technology of traditional products. These products offer the best out of dock performance with the smoothest profile available and greatest fouling control performance available. Non-stick characteristics minimizes fouling adhesion and controlled biocide release ensures maximum idle periods possible in all water types and trading routes. Biocide loading in the product is on average 90% lower than traditional antifouling. Hempaguard X7 is an example of a Fouling Defence product which has been used in this review.

Product Overview

Hempaguard X7 – Fouling Defence:

Hempaguard products integrate silicone hydrogel and full biocide diffusion control in a unique system that creates a hydrogel microlayer between the coating surface and the organism. Ideal for vessels on flexible trading patterns or looking for maximum fuel and CO_2 savings. Offers 90-month sustained fouling defence and 6% 'out of dock' fuel savings and less degradation with 1.4% speed loss over 5 years compared to best fuel savings compared to best in-class antifoulings over the entire service interval. Guarantee: up to 120 idle days.

Globic 9000 / 8000 – Antifouling:

Hydrolysing, low friction polymer technology using patented acrylate technology. Water activated capsules are used to control polishing to ensure efficient controlled release of best-in-class biocides. Works immediately upon entering the water, polishing effect requires no frictional force across the paint surface to control release.

Globic 9000: Premium hydrolysing nano acrylate antifouling for up to 90 months service intervals. Highest performing traditional antifouling with a maximum speed loss of 3%.

Globic 8000: top tier hydrolysing nano acrylate antifouling for up to 90 months service intervals with a maximum speed loss of 4%.

Oceanic+ – Antifouling:

Combined synthetic rosin and insoluble co-binder provides predictable polishing and biocide release working on contact with water. Polishing effect requires frictional force across the paint surface during sailing to maintain performance. Effective antifouling with strong biocide package suitable for service intervals up to 60 months with a maximum speed loss of 5.9%.

Energy savings based on baseline of calculations

The evaluation used the Maersk Tianjin as a reference vessel using data provided to the GSF project to define the paint scheme needed, the operational profile and fuel costs for the vessel.

Investment costs, energy savings and the return on investment period for each coating option are presented in the following tables.

Product	Preparation	Coating Cost* (%)
Hempaguard X7	Full blast	100
	Spot blast	90
Globic 9000	Full blast	46
	Spot blast	30
Oceanic+	Full blast	20
	Spot blast	20

* Coating cost is expressed as the percentage of the maximum potential cost. I.e. Hempaguard X7

Best improvement: Hempaguard X7, Premium Antifouling, full blast vs Current

HEMPAGUARD X7		GLOBIC 9000		CURRENT SYSTEM		MARKET AVERAGE	
Speed loss % (3 year)	0.8	Speed loss % (3 year)	0.9	Speed loss % (3 year)	3.5	Speed loss % (3 year)	3.5
Fuel consumption decrease in USD	615,222	Fuel consumption decrease in USD	345,572	Fuel consumption decrease in USD	31,416	Fuel consumption decrease in USD	0
Tonnes	1,538	Tonnes	864	Tonnes	78	Tonnes	0

Unit	Product	Speed Loss	Total Fuel consumption	CO_2 Emis-sion	Fuel savings vs Market average	Total Savings	Reduc-tion in CO_2 Emision	ROI (Month)
USD	Hempaguard X7	0.8	3,748,055	NA	615,222	14	NA	
Tonnes	Hempaguard X7	0.8	9,370	29,141	1,538		4,783	11.7
USD	Globic 9000	0.9	4,017,705	NA	345,572	8	NA	
Tonnes	Globic 9000	0.9	10,044	31,238	864		2,686	6.77
USD	Oceanic+	3.3	4,331,861	NA	31,416	1	NA	0
Tonnes	Oceanic+	3.3	10,830	33,608	78		244	0
USD	Market Average*	3.5	4,363,277	NA	NA	NA	NA	NA
Tonnes	Market Average	3.5	10,908	33,924	NA		0	NA

*Additional operational costs such as cleaning have been excluding - cleaning can cost circa $25,000 per clean. These can be avoided with higher tier products such as Hempaguard X7

Comparison of Fuel and CO_2 savings plus Return on Investment (ROI) compared with the Market Average product

PRODUCT	FUEL SAVING ($)		FUEL SAVING (TONNES)		REDUCTION IN CO_2 EMISSION (TONNES)		ROI (MONTHS)	
	Full Blast	Spot Blast	Full Blast	Spot Blast	Full Blast	Spot Blast	Full Blast	Spot Blast
Hempaguard X7	615,222	506,141	1,538	1,265	4,783	3,935	11.7	14.23
Globic / Hempaguard X7	553,860	444,778	1,384	1,112	4,306	3,458	12.02	14.97
Globic 9000	345,572	236,490	864	591	2,686	1,838	6.77	3.81
Oceanic+ (Equiv current scheme)	31,416	-77,666	78	-194	244	-604	0	0

Does it make sense to implement in this particular case?

Antifouling coatings are arguably the simplest improvement that can be made to the underwater hull. They require no modification of the hull structure, or other engineering, use tried and tested application techniques that are standard in all docks globally and represent a cost-effective option to reduce the impact of the vessel. This is especially the case with older vessels that use old or low tier products where the margin of improvement in fuel saving relative to Hempaguard will be substantial.

With an ROI of less than 1 year it will make sense to implement in this case.

The technology in a newbuilding situation

Hempaguard products (and silicones in general) can be applied at newbuild yards. Applying the solution from newbuild will give the fuel saving from the start of the vessels service.

With MR tankers that do not have that much sailing time and due to a low fuel consumption, it will be necessary to evaluate the individual case to find out if it makes sense to invest the extra funds into the fuel saving from the bottom paint.

PRODUCT	SPEED LOSS	TOTAL SAVINGS %
Hempaguard X7	0.8	14
Globic 9000	0.9	8
Oceanic+	3.3	1
Marked Average	3.5	N/A

Aft ship – Propeller and Rudder

KONGSBERG

Maersk Tianjin is equipped with a Silla Metal 4 blade fixed pitch propeller with a diameter at 6.7 meter.

Promas Lite is a fuel saving system that utilizes the efficiency improvement potential in the interaction between rudder and propeller. Part of the improvement is given by the Costa Bulb that reduces the hub vortex and drag, reduces slipstream contraction and increases the wake fraction. The Hubcap will contribute by streamlining the transition of water. The contribution of the bulb and hubcap will enable an optimization of the propeller that would not be possible without the two former features. Therefore, a Promas Lite system always comprises all three features.

In retrofitting projects, there is usually also room for various extents of propeller efficiency improvement separated from the Promas Lite propeller effect described above but integrated in the retrofit as such – the Reblading effect. This has to do with the difference in present operation criteria compared to original design criteria and can involve multiple parameters that affect the propeller and ship performance.

Energy savings based on baseline of calculations

Typical savings contributed by the Promas Lite effect alone range between 2-6%, depending on vessel type and design. Savings contributed by the Reblading effect can in some specific cases be as high as 20%.

The Propulsion efficiency improvement for Maersk Tianjin is estimated to 4%. This includes a “static” saving by Promas lite concept of 3% and a propeller design effect of 1% (new design point).

When looking into optimizing propeller and rudder on a MR tanker, each vessel must be evaluated separately to receive a correct evaluation.

The technology in a newbuilding situation

From a business perspective, to include the Promas concept in a newbuilding project is quite different from the retrofit situation. In the newbuilding case, the delta cost for installing the Promas concept compared to a conventional rudder and propeller is low, but the gain is high. This means that the ROI for the Promas features is fast and should always be considered when planning for a newbuild.

Investments and Savings

Fuel saving	145 ton HFO + 18 ton MGO a year
Investment cost (equipment)	600,000 $
Fuel cost	68,900 $/year
CO_2 reduction	509 ton/year
Return on Investment (ROI)	8.7 years

Note. Calculations are made with actual consumption of HFO 3,5% and MGO 0.1%, changing into a low sulphur fuel in 2020 will affect the business case.

Does it make sense to implement in this particular case?

Maersk Tianjin is not a suitable object for Promas Lite, from a ROI perspective, when looking at the existing fuel consumption of both HFO 3.5% and MGO 0.1%.

Existing propellers scrap value has not been included in the budget, which otherwise could improve the case ROI.

Wind propulsion, Rotor Sail technology

NORSEPOWER

Wind propulsion

The project group has been looking into deferent types of wind propulsion solutions. It has been concluded that Flettner Rotors have the largest impact on auxiliary wind propulsion for Maersk Tianjin. When installing a wind propulsion system, it naturally affects the propulsion system, including main engines, turbocharger, etc. It is therefore important to see the influence they have on each other. When calculating the potential fuel savings utilizing auxiliary wind propulsion, the main ship parameters affecting the kilowatt savings are ship´s speed, total efficiency of the vessel, time-at-sea ratio and naturally the wind condition on the route. The installation height of the Rotor Sail correlates to the potential savings as well.

Overview and Magnus effect principle

Norsepower Rotor Sails are modernized version of Flettner Rotors. Rotor Sail technology is based on the magnus effect. When wind meets the spinning Rotor Sail, the air flow accelerates on one side of the Rotor Sail and decelerates on the opposite side of the Rotor Sail. The change in the speed of air flow results in a pressure difference, which creates a lift force that is perpendicular to the wind flow direction.

The Norsepower Rotor Sail Solution is around ten times more efficient than a conventional sail, as more lift is produced with a much smaller sail area. Due to its simplicity and automated operation, it requires no reefing or crew attention when in operation. It is a "push button wind propulsion" from the bridge. It allows the main engines to be throttled back, saving fuel and emissions while providing the power needed to maintain speed and voyage time.

Two 30x5 Norsepower Rotor Sails on Maersk Pelican

The installation height of the Rotor Sail correlates to the potential savings as well. Therefore, two Rotor Sail models are proposed which are 24 and 30 meters high. In case there is an air draft limitation, a tilting Rotor Sail model can be installed. Norsepower Rotor Sails are available in five models 18 x 3, 24 x 4, 28 x 4, 30 x 5 or 35 x 5 (rotor hight x diameter, meters) Due to size of vessel and area of operation, a solution with two Rotor Sails was considered to be the most feasible option for Maersk Tianjin.

Potential energy savings

Norsepower made a simulation for Maersk Tianjin for the global shipping routes.

TWO 24x4 ROTOR SAILS ON THE GLOBAL ROUTES	
Annual fuel savings	**275 tons**
Annual CO_2 reduction	**855 tons**
Average propulsion power	**300 kW**

TWO 30x5 ROTOR SAILS ON THE GLOBAL ROUTES	
Annual fuel savings	**470 tons**
Annual CO_2 reduction	**1,462 tons**
Average propulsion power	**511 kW**

Compatibility with other EE technologies

Rotor Sail solution is compatible with all other energy efficiency technologies available on the market which does not limit shipowners to Norsepower's sustainable technology only. It will be possible to reduce the load on the main engine maintaining the speed, saving fuel and thus reducing emissions.

Rotor Sail Technology for newbuilding

A Rotor Sail retrofit installation requires a foundation and deck area reinforcement while in the newbuilding project it can be part of the vessel design and structure.

Investment

Two payment models are available for shipowners: traditional and pay-as-you-save model. The pay-as-you-save financing model was developed together with Norsepower's financing partners to enable a Rotor Sail system installation onboard a ship with a minimal investment by the shipowner at the start of Rotor Sail operation. This financing model is possible by sharing the estimated fuel savings, achievable with Rotor Sails, between the shipowner and Norsepower.

Evaluation of investment profitability

Rotor Sail solution profitability is effected by several factors such as fuel price, time-at-sea period and possible other emissions related costs. Since 2018, when the case study has been conducted, some of the factors have become more demanding.

Five Rotor Sails, which are in global operation today, gave us an opportunity to reduce manufacturing costs and the lead time. As maritime shipping is facing more stringent environmental regulations, Norsepower current payback period is in the range of three to nine years. For this particular case by increasing Maersk Tianjin time-at-sea period together with route optimization, Rotor Sail technology profitability will get closer to the payback period target.

Two Rotor Sails 30x5 were installed onboard Maersk Pelican in August 2018. Independent measurements conducted by Lloyd's Register confirmed savings of 8.2% during the first year of operation. Two Rotor Sails 30×5 are expected to reduce average fuel consumption on typical global shipping routes by 7-10%.

Two 30×5 Norsepower Rotor Sails on Maersk Pelican

Organic Rankine Cycle (ORC)

An ORC plant is a modular system for generating power from waste heat. In general, various waste heat flows may be used, such as exhaust gas or cooling water heat from a combustion engine (HFO, diesel or gas) or similar sources of heat in marine applications.

The energy output can either be used mechanically to support the propulsion of a ship or converted into electricity to supply the on-board grid or a battery pack without CO_2- emissions. The operation needs no human intervention except regular visual inspections and is mostly maintenance-free.

Orcan Energy has developed and introduced a State-of-the-Art and proven Waste Heat Recovery System for marine applications. In total more than 1,000,000 efficiency PACK fleet running hours have been collected, with already 48,000 running hours achieved on one Waste Heat Recovery plant. Currently an average availability rate in excess of 99.5 % is achieved on a deployed fleet of > 200 installations worldwide in Orcan's key markets.

Description of action and technology

The efficiency PACK 's working principle is based upon the Organic Rankine Cycle (ORC). This is a closed steam cycle in which an organic working fluid (hydrocarbon) is used. The working fluid used in the efficiency PACK is non-toxic and non-flammable. Figure 1 shows a simplified model of the ORC system.

Energy savings based on baseline of calculations

Looking at the information received regarding the vessel shows that we have an average load on the AUX engines of 353 kW and that is 41%.

But using the fuel consumption, running hours and produced kW we get an SFOC of 228 g/kWh that according to the load tests equals a load of 25%.

Above say shows that the AUX engines run most of the time at low load.

To sum up the above, installing an ORC will only make the SFOC worse than it already is and then most of the savings will be lost on that account.

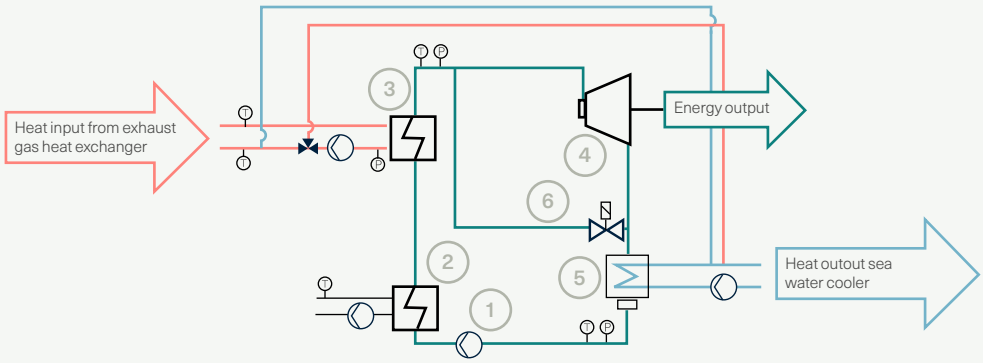
Does it make sense to implement in this particular case?

In this case it does not make sense since it will only make the AUX-engines more expensive to run with looking at the SFOC.

There will still be savings to be found but they are very expensive.

Description of action and technology

The efficiency PACK



In the ORC system (efficiency PACK) a feed pump (1) transfers the liquid working fluid into a preheater (2) in which the fluid is heated to below boiling temperature.

The preheater is usually heated by an engine's hot jacket cooling water. After the preheater the fluid is evaporated and superheated in the evaporator (3).

The evaporator is heated by a pressurized hot water loop. The superheated steam then drives the expansion machine (4).

The expansion machine can be connected to a generator to produce electricity or connected to an engine's PTI (power take-in) via a transmission to supply mechanical power to the engine's crankshaft.

In the condenser (5) the steam at low pressure is liquefied again to close the steam cycle.

The condenser is cooled by a water cycle that is connected to a sea water cooler.

The cycle also includes a bypass valve (6) to pass the steam by the expansion machine for startup, shutdown and emergency purposes.

Interdependencies with other technologies

An ORC unit uses waste heat from main- and axillary engines and does not affect other technologies aboard.

The technology in a newbuilding situation

An ORC unit can reduce the load on auxiliary engines, which means that it will be possible to reduce genset size, so that it will be possible to run it in optimum operating range. Planning ORC into the auxiliary or propulsion system on a newbuilding project, will open opportunities for fuel and cost reductions from the very beginning.

Which benefits does the efficiency PACK offer?

- Significant fuel savings
- Attractive payback period and free accumulated cashflow during the operation of the efficiency PACK
- Significant emission reductions (savings) for CO_2, NOx, SOx and Particulate Matter (PM)
- Improvement of the Energy Efficiency Design Index (EEDI)
- Well selected and class approved rugged marine components that require minor scheduled maintenance
- Your ships contribute to a more sustainable future at sea by powering your ship with waste heat

Summary

With the solutions suggested above, it is possible to reduce the fuel consumption on Maersk Tianjin with 15.6% within the target ROI below 3 years. Several of the suggested solutions are above the target value and some are already installed onboard.

During the project there was a change in participants, meaning that some areas can be seen in case 1 and others in case 3.

Collective savings for Maersk Tianjin

Fuel savings	**779 tons/year**

Emissions

CO_2 reduction with a 11,1% fuel reduction	**2,425 ton/year**

Effect of products

Company	Product	Savings on			Effects	ROI [years]	Fuel Saving [ton/years]	CO_2 reduction [ton/years]
		ME	AUX	Boiler				
Alfa Laval	Boiler optimization			x	Reduce fuel consumption for boilers		23	72
BOS	Ballast Water Managment system		x		Reduce the energy needed for Ballast Water Management system		N/A	N/A
C. C. Jensen	Lube Oil filtration	x	x		Reduces steam to lubeoil heaters for L.O. centrifuges and L.O. comsumption	2.7	48	149
Clorius Controls	Low Leak 3 way valve		x		Reduce the energy needed to heat the HT water	0	Already installed	
DESMI	OptiSave (frequency regulation of pumps)		x		Reduce the energy needed to run pumps	1.5	116	361
DESMI	OptiSave (frequency regulation of ventilation)		x		Reduce the energy needed to run engine room fans	4.6	32	100
Kongsberg Maritime	Promas lite (Propeller blades, Hubcap, Rudderbulb)	x			Maritime Reduce load on ME	8.7	163	508
Hempel	Hull paint / antifouling	x			Reduces hull friction	1	615	1,915
Norsepower	Flettner Rotor	x			Reduce load on ME, but increase load on AUX	10	470	1,464
Orcan	ORC		x		Reduce load on AUX	N/A	N/A	N/A

Target value < 3 years Target value > 3 year

Target value < 3 years	**779 ton/year**	**15.6%**	**CO_2 reductions**	**2,425 ton/year**
Target value > 3 year	**688 ton/year**	**13.8%**	**CO_2 reductions**	**2,144 tons/year**

Total fuel consumption (HFO + MGO) 4,981 ton/year

Conclusions

The goal of this project was to explore opportunities for energy optimization and inspire on potential retrofit solutions, including stand-alone efficiency upgrades and combined solutions. Another important aspect of this report is to show the potential of making green investment in a manner that minimizes operational cost and improve the potential of profitability. Therefore, the results have been filtered for the potential of a ROI in 3 years. Without limiting the ROI to 3 years, there are a substantial additional potential for optimization. This potential is accounted for in the summaries at the end of each case.

When calculating the ROI, the actual fuel prices in the operational period were used and the potential ROI reflects the fuel prices, hence the real ROI is subject to changes following the development of the fuel prices.

"... In terms of potential savings, the partners identified a combined potential saving of between 11.1 and 27.1 percent with an ROI of less than 3 years. "

We acknowledge that this is not an exhaustive collection of all available technologies for energy optimization. This report provides an extensive list of areas in which there is potential for optimization, but we realize that there are more areas that could present opportunities as there are additional innovative solutions and providers out there that can deliver promising energy optimization. Though, we believe we have managed to gather a well-rounded group covering the most promising areas suitable for optimization.

In terms of potential savings, the partners identified a combined potential saving of between 11.1 and 27.1 percent with an ROI of less than 3 years. This equivalate to a saving of between 2,425 and 7,350 tons of CO_2. To put this in perspective, in 2017, the average person emitted 4.8 tons of CO_2 - meaning that the potential savings in the best case equivalates the total emission of more than 1,500 people every year. While there is a difference in both the vessels and within the participants of each case, and the cases therefore cannot be directly compared, there are some general learnings that can be drawn from the cases that we encourage all shipowners and operators to further investigate;

- We found that in general, there is a lack of available data from the vessels and in some cases an overload of data that could not be used. Logging the right data is crucial to understand optimizing potential, therefore we encourage all shipowners and operators to prioritize collecting data and to be strategic about it, so only relevant data is collected, as data has no value till it is analyzed and used.
- We found steam to be a good example of lack of data. None of the vessels had any data on their steam consumption. They were clocking the hours on their boiler and had rough estimates on fuel consumption, but the steam consumption was not logged, despite being used for multiple applications on the vessels.
- We found that electricity production contributed to a relatively large share of the consumed energy and that the gensets were often running in a bad fuel spot. This led to an unnecessary waste and could be solved with a shaft generator. Furthermore, we found that a lot of energy was also wasted on inefficient lighting and overpowering fans and pumps. This can be solved by installing LED lighting and a frequency driver.
- We also found significant potential savings in areas such as lube oil cleaning, propellers, rudderbulbs, hull paints and anti-fouling, which are all often overlooked for their potential or disregarded as to expensive compared to the benefits.
- Finally, we identified a large potential within the application of digital technologies, where areas such as route, trim, speed and operation planning can be optimized for major potential savings - specially machine learning and AI shows potential as a reduction driver.

[1]https://ourworldindata.org/grapher/co-emissions-per-capita?tab=chart&country=AUS+CAN+USA+OWID_WRL

Notes from the project manager

By Senior project manager: Ole Jakobsen – Danish Energy Consulting

The Green Ship of the Future, 2020 Retrofit project, has only been possible due to a dedicated networking group and participant from maritime suppliers, makers and not the least shipowners and their technical departments that have kindly answered all questions and allowed us to take a look at their vessels.

Working with energy optimization

In designing the retrofit project, it was meant that we should have a MR series tanker and a LR series tanker, due to the difference in voyages compared to the two vessels. Due to changes in Maersk Tankers fleet, it was not possible to require the necessary data on a LR tanker and it was decided to continue with the MR tanker Maersk Tianjin. It gave the project to compare two MR tankers who are sailing in almost similar trading patterns but are operating in two different ways and built/designed in different countries. Changes in project participants in the project period, also shows changes in the results, but the variety of possibilities is still shown, where and how to optimise merchant vessels.

In the project is also a RO-PAX from DFDS who from the participants have been looked through to locate possible ways to reduce the fuel consumption. Victoria Seaways is, with her 9 years, the oldest vessel in the project, and should (theoretically) have the most possibilities for optimization. But a very dedicated crew, superintendent and technical project department in DFDS made it difficult for the project group to find larger fuel savings aboard, but a few areas were found and shown in the report.

One area of interest we heard in the project, was the lack of cooperation between the purchasing department and operation/maintenance department.

When designing a newbuilding, there is often a strong focus on the price of the vessel, but not so much on the following operational cost, where many times, small investments would pay back rather fast, compared to later installing a retrofit solution. It is not always possible to foresee how the vessel is operated, but it is our opinion that there is a lot to gain for shipowners making their departments cooperate closer and not only look at their own budget. It all comes from the same box after all.

In the project period from January 2019 to April 2020, there has been a large change in the fuel prices. Firstly, the changes with the 2020 sulphur limitation where the fuel prices rose and lately, the near shut down of the world and fuel prices falling due to the Covid-19 virus. In the project, known fuel prices and operational patterns from 2018 were used, making the different calculations comparable. All calculations are made on same data and should be comparable, readers must update investment prices and recalculate to current fuel prices to find areas of interest for own vessels.

"... When designing a newbuilding, there is often a strong focus on the price of the vessel, but not so much on the following operational cost, where many times, small investments would pay back rather fast, compared to later installing a retrofit solution."

Project partners

GREEN SHIP OF THE FUTURE

Green Ship of the Future (GSF) is a public-private collaboration seeking to reduce the negative environmental impact from shipping, by innovating towards a sustainable emission free maritime industry. Together, we explore short- and long-term solutions and all the necessary stepping stones between today, 2030, 2050 and beyond.

We believe that collaboration across the entire maritime ecosystem, and with those connected to it, is necessary to reach solutions at the quality and pace which is needed. We wish to bring the right stakeholders together, we wish to inspire, and we wish to facilitate green innovation through collaboration.

THE DANISH MARITIME FUND

The Danish Maritime Fund is a private, commercial fund. The purpose of the Fund is to provide financial support for initiatives that can help promote the positive development of Danish shipping and / or the Danish shipbuilding industry, including equipment manufacturers, so that new jobs are created and the industry is strengthened internationally.

We want to strengthen and contribute to shaping the future of Blue Denmark through the support of:

- Recruitment, development and training of the necessary and future-oriented maritime labor
- Market and practice close to maritime research, product and service development and the development of new business models
- Activities in the future of how to streamline, optimize, automate and digitize in the maritime sector
- Activities in the maritime sector that support the UN's 17 World Goals, for example (but not limited to) climate, environment, circularity, innovation, education, equal opportunities
- Activities that promote knowledge of Blue Denmark in general, including support for political initiatives

Hafnia are a leading international shipping company providing seaborne transportation of petroleum products worldwide and is owner and operator of the world's largest fleet consisting of 102 product tankers, four newbuildings and three product tanker pools; Hafnia Handy pool, Hafnia MR pool, and Hafnia LR pool.

We have a solid history in chartering, operations and technical management and strive to always offer customers the best solution for their transportation needs. This solution-focused approach has given us a strong reputation and we remain firmly committed to be a responsible member of the industry and operating according to the highest ethical standards.

Hafnia is a global company with offices in Singapore, Copenhagen and Houston and presence in Mumbai. We are part of BW Group, an international shipping group that has worked in oil and gas transportation, floating gas infrastructure, environmental technologies and deep-water production for over 80 years.

DFDS' core business is to move freight and passengers on ferry routes in and around Europe, and to provide transport and logistics solutions for a wide range of businesses. We have a strong focus on customer solutions and digitization, and our ambition is to continue to grow our network and range of services.

Today, DFDS has 8,000 employees operating in +20 countries. We serve 5.4 mio. passengers and more than 10,000 freight customers. In 2018, DFDS carried +40,000,000 lane meters, done with our 68 vessels on 24 routes, 8 terminals and more than 600 trucks to do the job.

DFDS transports everything from families on holiday to goods on road, rail and sea.

We fully recognize that our main impact on the climate and the environment comes from our business of moving freight and passengers on our ferry routes and from providing transport and logistics solutions for a wide range of businesses. We work to reduce the Environmental Footprint of our operations through sound practices and seek innovative and intelligent ways to develop DFDS in a greener direction.

This is one of the key drivers for participating in this and other projects under Green Ship of the Future.

Maersk Tankers facilitates the global trade of energy to meet the world's energy needs. The company is a leading player in the product tanker industry, operating one of the largest fleets of vessels and employs 3,000 employees worldwide. Established in 1928, Maersk Tankers has nine decades of experience and expertise in commercial and technical vessel management, providing customers and partners safe, efficient and flexible services that benefit their businesses.

The seaborne transportation of energy will remain of fundamental importance over the decades to come. We are here to facilitate its trade, contributing to meeting societies' energy needs.

Maersk Tankers transports oil products globally, moving, for example, gasoline and diesel for the transportation sector, jet fuel for the aerospace industry, naphtha for consumer goods, crude and fuel oil for refining and power generation and edible oils for the food and biofuel industries.

Maersk Tankers operates more than 160 product tanker vessels across five segments: Intermediate, Handy, MR, LR2 and Aframax.

Alfa Laval Aalborg is a branch under Alfa Laval Marine division that develops, produces, supplies and services boilers, burners, shell/tube heat exchangers, gas combustion units, inert gas systems and exhaust gas cleaning systems (scrubbers) for ships and industries worldwide. Alfa Laval Aalborg has a site in the north of Jutland, Denmark, where the world's largest test centre for marine equipment is established.

Alfa Laval Aalborg has been working with steam boilers for the marine market for more than 100 years and provides high-end, specialized boiler systems to the global market for both new and retrofit applications.

The mission of BOS is to create solutions that make better sense for the ecology and economy of ship owners. Truly green solutions come with low power requirements, near zero emissions and GHG, the best solutions and ideas are made to be simple. This is fundamental in BOS' research and product development.

The family owned C.C. JENSEN was established by Carl Christian Jensen in 1953 and design, manufacture and market CJC™ offline oil filtration systems. The company was founded on the idea of making it possible to filter oil continuously, so that it would maintain its lubricating characteristics over time. With their products, C.C. Jensen contributes to a greener maritime industry by reducing energy consumption and reducing the oil consumption of both main engines and auxiliary engines.

Clorius Controls is a leading manufacturer of valves, actuators, and comprehensive control solutions supporting various marine and industrial applications. Aside from our exhaustive assortment of control valves and actuators, we provide tailored solutions, including electric, pneumatic, self-acting and internally sensed control systems to meet the specific requirements set by the customers.

Clorius' products are designed to meet the tasking requirements of our clients. Our products, constructed with premium materials ensure longer life cycle, minimal maintenance and lower cost of ownership.

Clorius Controls caters to the specific needs of the maritime and offshore industry by supplying premium and highly efficient flow management solutions, comprising of top-quality control valves, actuators and positioners. Our products and services are continually ensuring safe, reliable and efficient usage while preventing any potential downtime.

Danish Energy Consulting is a private, impartial consultancy company and is one of the leading energy consultancy companies in Denmark. We guide businesses in how to utilise energy in the best possible way by providing holistic and quality-assured energy consulting that contributes to optimal work processes, a better operating economy and a more sustainable future. Our consultancy services are based on more than 13 years of experience with energy optimization in a broad range of businesses and processes. In recent years, we have been involved in completing more than 20% of Denmark's realized energy savings.

We have extensive experience with optimising fishing vessels and ferries in the field of retrofit projects and newbuildings. Over the past 4 years, we have completed more than 100 projects on vessels in the Danish fishing and ferry fleet, in which we have been involved in the development and documentation of the energy savings projects and completed applications for subsidies.

Established in Denmark in 1933, today the DEIF Group is a global market leader in green, safe and reliable control solutions for decentralized power production on land or at sea. In simple terms, we make sure power is always available. Privately owned by the founder's son, the DEIF Group is staffed by more than 550 employees and represented in 50+ key markets in all regions of the world.

All production facilities are located at the Danish HQ in Skive and a stunning 20% of our employees work in R&D identifying new environmentally friendly ways of increasing overall performance, reducing maintenance intervals and fuel consumption for the world's power generating industries. Our Purpose is to supply the world's best and most reliable control solutions. We make our planet greener by improving global energy efficiency.

Altogether, we call it: POWER EFFICIENCY.

DESMI is a global company founded in 1834 and one of Denmark's oldest companies and we are proud of having a long history supplying good, reliable solutions, maintaining an innovative approach and utilizing the opportunities on the global market. DESMI offers more than 100 types of pump designs and variations, covering all applications of the engine room, ensuring that you will always get the right pump for the job. The pump range covers centrifugal pumps and gear pumps. All DESMI pumps are designed for high efficiency and lowest possible power consumption.

Proven technology and energy efficient pumping solutions you can rely on: Engine Room Pumps, OptiSave™ Energy Saving System, Ballast Water Management System, Scrubber Pumps Solutions, Cargo Pumps, FineFog™, Oil Spill Response Solutions, Service

GreenSteam is on a mission to make the world shipping fleet more efficient. Using a cutting-edge machine learning approach, we have developed very advanced and effective solutions to improve the fuel efficiency of the big ships that our customers operate around the globe. On board, our decision support solutions help captains waste less fuel and thus reduce emissions that are harmful to the environment. In the office, our web application helps ship owners and operators understand and analyse the performance of their fleets.

As a world-leading supplier of trusted coating solutions, Hempel is a global company with strong values, working with customers in the protective, marine, decorative, container and yacht industries. Hempel factories, R&D centres and stock points are established in every region. Across the globe, Hempel's coatings protect surfaces, structures and equipment. They extend asset lifetimes, reduce maintenance costs and make homes and workplaces safer and more colorful. Hempel was founded in Copenhagen, Denmark in 1915. It is proudly owned by the Hempel Foundation, which ensures a solid economic base for the Hempel Group and supports cultural, social, humanitarian and scientific purposes around the world. Hempel is committed to supporting the maritime industry in reducing their impacts on the environment. Through product innovation we are able to provide marketing leading hull coatings that minimize biocide release, reduce waste, and significantly improve on fuel use in the global fleet. Over 1700 vessels are now coated with Hempaguard X7 which has saved more than 10 million tonnes of CO_2 from the world fleet. Supporting our customers sustainability targets is at the core of what we do and will continue to form a significant part of our strategic ambitions for the future.

We are determined to provide our customers with innovative and dependable marine systems that ensure optimal operation at sea. By utilizing and integrating our technology, experience and competencies within design, deck machinery, propulsion, positioning, detection and automation we aim to give our customers the Full Picture - shaping the future of the maritime industry.

MAN Energy Solutions is the world's leading provider of large-bore diesel and gas engines and turbomachinery. Our portfolio includes two-stroke and four-stroke engines for marine and stationary applications, turbochargers and propellers, as well as gas and steam turbines, compressors and chemical reactors.

Our commitment to minimizing fuel consumption while meeting even the most advanced emission regulations plays a vital role in safeguarding the environment for future generations.

MAN Energy Solutions convert energy into sustainable progress and prosperity and drives the transition towards a carbon-neutral world together with our partners.

NORSEPOWER

Norsepower Oy Ltd is a Finnish clean technology and engineering company pioneering modern auxiliary wind propulsion for the global maritime industry. Its award-winning Rotor Sail Solution technology is a proven, low-maintenance, easy to use, and reliable fuel saving technology, supporting the decarbonization of the shipping industry.

Our vision is to set the standard in bringing sails back to ocean transportation and empower shipping towards reaching the goal of zero carbon emission. Our entire team is strongly motivated by our mission to reduce the environmental impact of shipping with our Rotor Sails.

OPTIMUM VOYAGE

Optimum Voyage delivers an algorithm driven route optimization service directly applicable for all commercial vessels. A fuel consumption model is tailored individually for each ship, and accounts for the influence of weather on voyages. In order to utilize the full voyage potential an optimization is run daily based on latest position and available weather forecast.

orcan The Efficiency Company

Orcan Energy has developed and introduced a State-of-the-Art and proven Waste Heat Recovery System for marine applications. In total more than 1,000,000 efficiency PACK fleet running hours have been collected, with already 48,000 running hours achieved on one Waste Heat Recovery plant. Currently an average availability rate in excess of 99.5% is achieved on a deployed fleet of > 200 installations worldwide in Orcan's key markets.

Royston

Royston is a privately-owned UK company with over 40 years' experience in diesel power sales, repair and maintenance with a highly skilled and experienced team of over 50 OEM trained engineers. Collectively, our team brings over 70 years of experience and a wide range of expertise to the table, in disciplines including: customer services, technical support, industrial marine research, software development, electrical engineering, data analytic algorithms, automation system design and new product

WÄRTSILÄ

Wärtsilä is a global leader in smart technologies and complete lifecycle solutions for the marine and energy markets. By emphasising sustainable innovation, total efficiency and data analytics, Wärtsilä maximises the environmental and economic performance of the vessels and power plants of its customers. The company has operations in over 200 locations in more than 80 countries around the world.

The Retrofit Project

GREEN SHIP OF THE FUTURE
2020

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Lisa Lang Graphic Design

The Retrofit Project

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