https://www.oecd.org/sti/ind/48365833.pdf

Green Ship of the Future

Green Ship of the Future (GSF) is a partnership, a joint initiative in which companies across the Danish Maritime Cluster join forces to develop and test environmentally and climate friendly technologies that increase energy efficiency and reduce operational costs.

The private and public partners have cooperated on GSF since its conception in 2008. The public partners do not finance or direct the project, but remains involved. The private companies pool knowledge but each bears its own costs. The unique initiative combines public and private interests and encompasses maritime companies of all kinds, creating a cutting edge of maritime technology and green industry.

Concept Studies

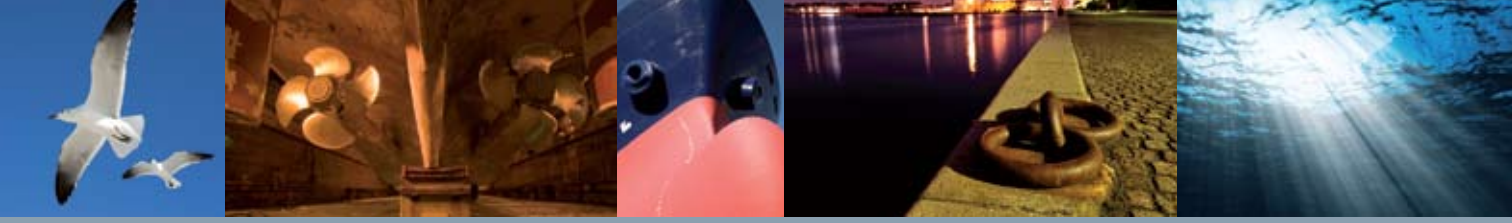
The GSF partners have worked together on concept studies. In these, various available technologies from the GSF projects were implemented on specific ships in order to show the possible overall emission reductions when the technologies are implemented already in the design phase of new ships. The concept studies have been carried out for two different ship types, an 8,500 teu container vessel and a 35,000 dwt handy size bulk carrier. Without reducing speed, siqnificant emission reductions were achieved for the two concept ships as illustrated in the graph *Achieved Reductions*.

Green Projects

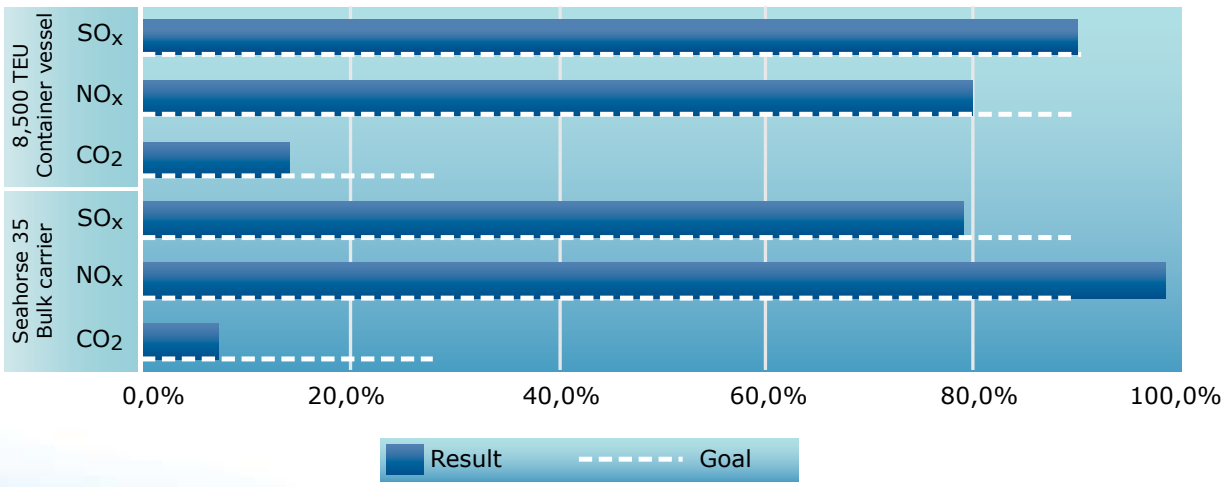
The overall target of GSF is to reduce total CO_2 emissions by 30 %, total SO_x emissions by 90 % and total NO_x emissions by 90 %. Individual GSF projects have come close or even surpassed these targets by achieving individual reductions of up to 25 % for CO_2, up to 98 % for SO_x and up to 80 % for NO_x. Products developed within GSF projects have been introduced on 40 ships from Danish shipowners. In some cases, these green ship technologies have already become standard products, especially with respect to machinery equipment and onboard systems.

Making an Effort

The Danish Maritime Cluster wants to play an important role in designing and developing environmentally responsible products that minimize emissions. With Green Ship of the Future the Danish Maritime Cluster is making an extra effort to protect the climate and environment.



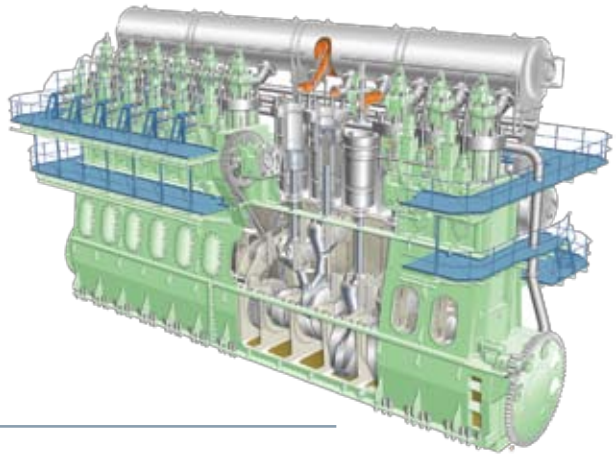
Achieved Reductions



Green Technologies

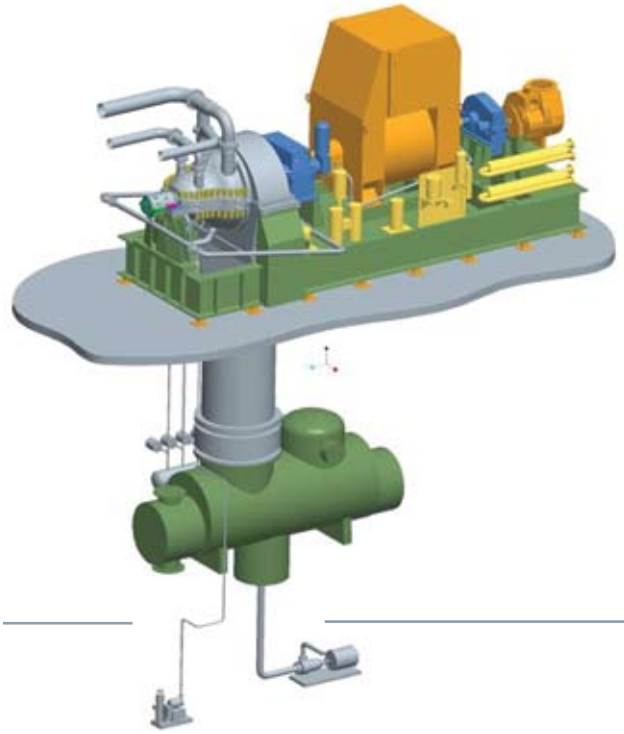
1 Engines

Several GSF projects focus on optimizing engine efficiency in order to reduce emissions. More precise and flexible technology promises significant energy savings. Auto-tuned engines and optimized *low speed marine engines* replace infrequent, manual adjustments with ongoing electronic ones. They potentially reduce fuel consumption by up to 3 % by constantly adjusting to factors like engine load and operating conditions. This kind of innovation in GSF has also adapted Selective Catalytic Reduction (SCR) systems to marine engines. The SCR prototypes achieved an 80 % reduction of NO_x emissions over the same engine without SCR.



2 Fuel

GSF members seek both immediate and long term solutions to reducing fuel consumption. Frequent, onboard fuel composition analysis on existing ships can help to reduce especially SO_x emissions. At the same time, GSF members are exploring liquid natural gas (LNG) as a future alternative fuel. For instance, it has been shown that a high speed ferry by moving from diesel to LNG can cut CO_2 emissions by 25 %, NO_x by 35 % and eliminate SO_x emissions completely. When moving from heavy fuel oil to LNG the reduction of NO_x emissions can naturally be significantly higher, possibly 85-90 %.



3 Waste Heat

GSF partners have developed ways to recover wasted heat either as electrical power or use it to heat up cargo areas. Committed to practical, feasible solutions, members have focused on how to install Waste Heat Recovery/Utilization systems while retaining the ship's basic design. Fuel accounts for a very large part of a ship's operating costs. Reusing the waste heat from engines to heat up cargo areas can save up to 20 % of a ship's total annual fuel consumption, thereby reducing CO_2 emissions and saving fuel costs. Also, studies show that recovering waste heat as electrical power can save up to 8 tons of fuel oil per day for a tanker that would normally use 42 tons per day. In tests, emissions were reduced up to 14 % by recovering otherwise wasted heat as electrical power.

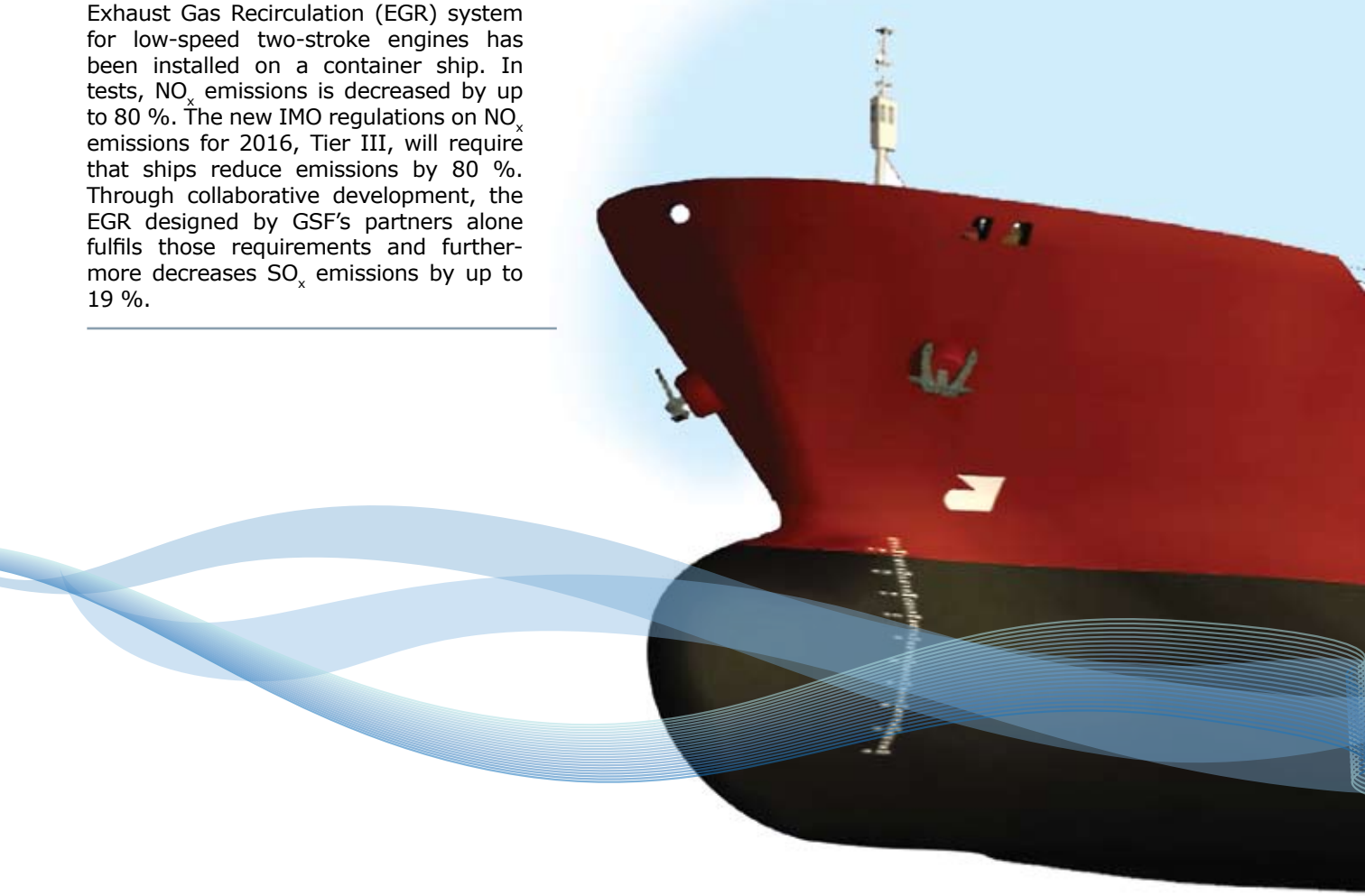



4 Scrubber Systems

Particulate matter (PM - mostly soot) pollutes the environment. Several GSF members together have developed a scrubber system that reduces PM by up to 80 % and SO_x emissions by up to 98 %. The system makes it possible to reduce the sulphur emmissions to a level as low as if low sulphur oil was used. Through the GSF partnership, Danish companies have created a cost-effective alternative that not only meets international requirements, but uses environmentally friendly materials like seawater to achieve its results.

5 Exhaust Gas Recirculation

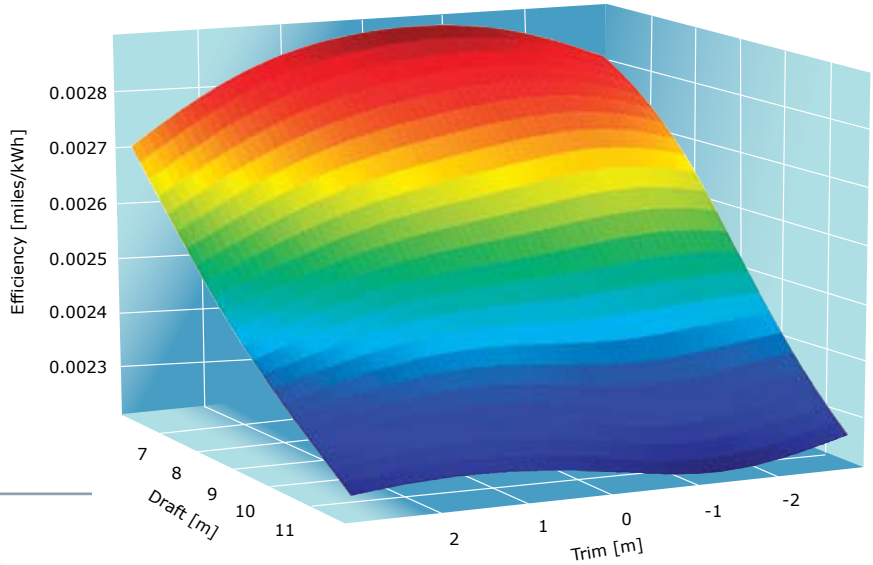
Through the GSF initiative, the first Exhaust Gas Recirculation (EGR) system for low-speed two-stroke engines has been installed on a container ship. In tests, NO_x emissions is decreased by up to 80 %. The new IMO regulations on NO_x emissions for 2016, Tier III, will require that ships reduce emissions by 80 %. Through collaborative development, the EGR designed by GSF's partners alone fulfils those requirements and furthermore decreases SO_x emissions by up to 19 %.





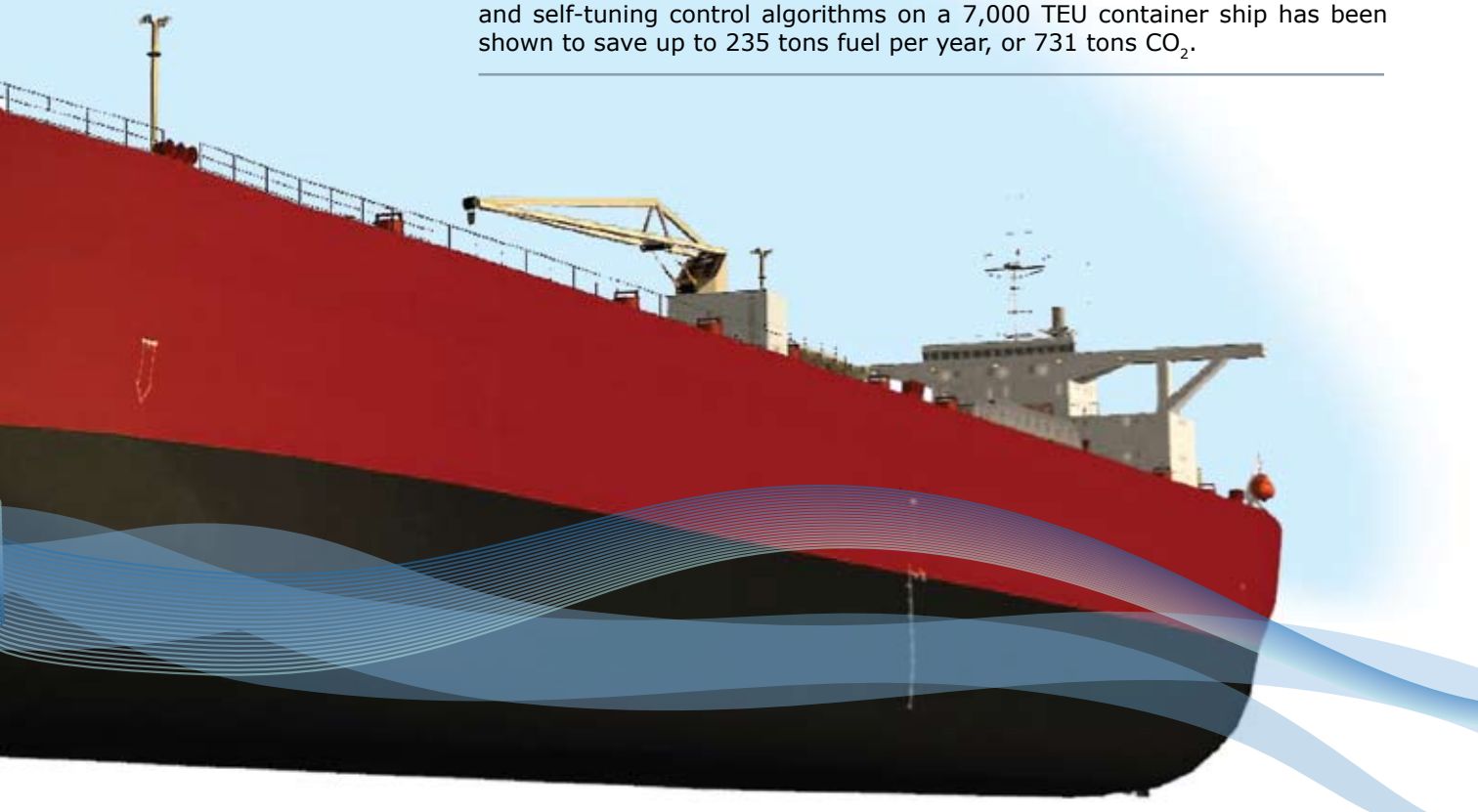
6 Trim Optimization

Optimizing trim can also reduce emissions. Optimal trim minimizes water resistance and reduces fuel consumption. Using not machinery but cutting edge programming, GSF partner companies have created a trim matrix that gives ship operators graphic representation of the relation between fuel consumption, trim and draft. Studies, now being validated, have shown that a specific chemical tanker can save fuel in app. 80 % of its sea voyages by optimizing trim.



7 Cooling Systems

Cooling systems are one of the larger energy consumers on board a vessel. Studies show that it is possible to save up to 90 % of the energy required to run the pumps by by optimising the system and using frequency controlled pumps. GSF members have developed *decision packages*, which discuss possible improvements to cooling systems efficiency, both for retrofitting and new ships. For example, installing a variable speed pump with more advanced and self-tuning control algorithms on a 7,000 TEU container ship has been shown to save up to 235 tons fuel per year, or 731 tons CO_2.






8 Operations

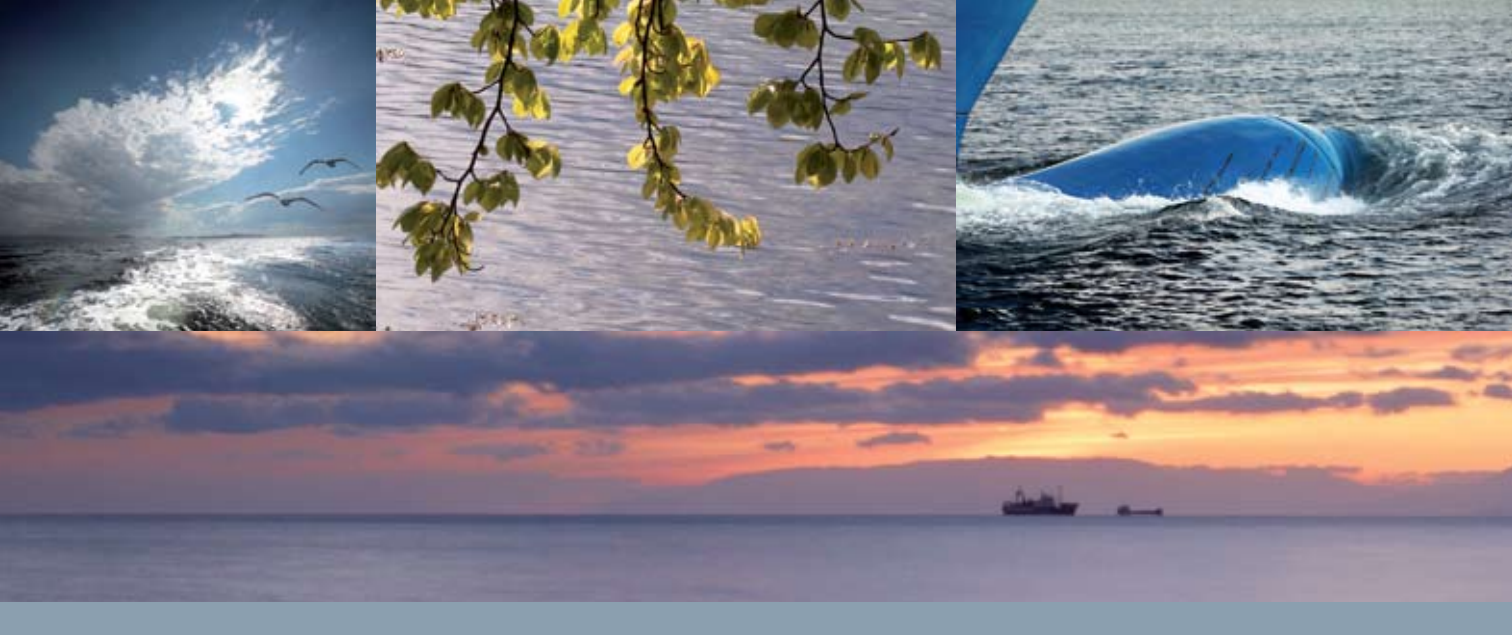
To reduce emissions, operators require the right tools to monitor and attune the machinery to maximize energy savings. New ship operation systems collect data from sensors and use mathematical modelling which enables optimized performance and energy efficiency. Along with effective route-planning software that continuously updates meteorological information and resistance calculations, GSF partners have proved that effective operational tools alone can optimize fuel economy and reduce CO_2emissions by up to 4 %.

9 Turbochargers

Turbochargers radically affect the efficiency of fuel consumption. GSF partners are using turbochargers to develop cost-saving ways to reduce emissions and improve fuel economy. Retrofitted high-efficiency turbochargers improve energy efficiency by enabling more complete fuel combustion. This significantly reduces NO_x formation. Similarly, cutting out a turbocharger can allow ships to optimize fuel efficiency at low engine loads within IMO certification limits. Low-load optimization decreases emissions up to 25 % per nautical mile and cuts CO_2 emissions, yet without necessitating expensive recertification.

10 Biocide-free Paint

Toxic biocides in antifouling paint, like copper and tributyltin compounds, can harm aquatic life. In addition, fouling of the hull leads to increased ship resistance and thus higher fuel consumption and CO_2 emissions. A GSF partnership showed that biocide-free paint with hydrogel coating both keeps pollutants out of the sea and reduces CO_2 emissions, as the paint lessens resistance and saves fuel. A wide range of ships with different hull shapes achieved fuel savings of up to 8 %.



A Joint Co-operation

2.7 % of global CO_2 emissions come from international shipping. Despite being a country of just 5 million people, Denmark is home to companies that carry app. 10 % of global shipping measured in value. The GSF partner companies are committed to minimizing their environmental impact and by joining forces they seek solutions to the issues of climate change and the increasing demands for climate and environmentally friendly technology and methods. Projects range from machinery like turbochargers, scrubber and exhaust gas recirculation systems to ship operation optimization software and antifouling paint.

For further information, please visit www.greenship.org

GSF Network partners:

Danish Environmental Protection Agency	**Danish Maritime**	**Danish Shipowners' Association**
Danish Maritime Authority	**Danish Marine Group**	**The Transport Innovation Network**

Published by Danish Maritime, www.danishmaritime.org