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In recent years, sustainability in a climate and an environmental perspective has become an issue of highest priority. This is an agenda that cannot and should not be ignored. Therefore, I am pleased to see how the Danish Maritime Cluster has combined its forces to act constructively and innovatively to make green shipping a reality.

The financial crisis has revealed a vulnerable global society. Fortunately, the latest developments have shown signs of recovery thanks to deliberate and well-coordinated global political actions which have created new confidence among companies and consumers. This political commitment can be seen as a recognition that global production and trade create wealth for all of us – with shipping and associated maritime industries as the primary enablers.

In order to keep focus on the important agenda of sustainable and green shipping - even in difficult times - we must turn towards innovation and efficient regulation.

Within a foreseeable future, shipping will still be dependent on fossil fuels. We must work hard to develop energy efficient and environmentally friendly technologies encompassing shipboard energy production and propulsion of the ship as well as ship operation. What we gain on propulsion and operation will be valid in a non-fossil future.

Another important aspect is the work done by the International Maritime Organization, which is the key player in setting regulations applicable for all ships irrespective of flag. I appreciate the work done so far, recognizing that we still have an extensive workload in front of us. The regulations to be set for safe, secure and environmentally sustainable shipping must be goal-based instead of prescribing specific solutions. Such regulation creates ample room for innovation of new efficient technologies and operational standards.

In Denmark we have learned that successful innovation can only be achieved through interplay of cooperation and rivalry. Therefore, it is necessary to bring together companies, research, innovation and education. That is what the Green Ship of the Future project is about.

The Green Ship of the Future cooperation has embarked on the right course with a strong focus on near-to-market innovations addressing issues in relation to climate and the environment. As an open cooperation between companies and knowledge institutions, an active platform for innovation of new technologies and systems has been created.

The achievements of the Green Ship of the Future cooperation are a showcase of a vibrant Danish Maritime Cluster offering energy efficient and environmentally friendly products and services.

With these words I welcome you to the Green Ship of the Future.
Almost 90% of the world trade is carried by ship and for the vast majority of this trade there is little or no alternative to transport by ship. It is estimated that 2.7% of the global CO₂ emissions come from international shipping.

The environmental policies of the Danish shipping companies should be seen as a long term strategy to reduce energy consumption and improve energy efficiency. The Danish merchant fleet is among the most energy efficient in the world, due to its young age and the focus Danish shipping companies have for many years had on investments in new technology.

The Danish Shipowners’ Association would like to see international regulation adopted by the International Maritime Organization, IMO. Only IMO can guarantee international rules that apply to all ships regardless of flag, and this is of paramount importance to avoid distortion of competition in a global industry.

The Danish Shipowners’ Association believes that the merchant fleet will be able to increase its efficiency by at least 15% by 2020. Green Ship of the Future is a very important instrument because only by close cooperation within the industry can we achieve this target. Green Ship of the Future is a vital platform for the entire maritime industry when testing and developing new products, and the entire industry sends a strong signal when working closely together in research and development – and at the end of the day, the entire industry will benefit from Green Ship of the Future.

Danish shipping companies are doing their part and expect especially transport buyers to also focus on climate friendly transport solutions.

Ships are the most environmentally friendly form of transportation. Still, with 90% of the world trade being transported by ship, it is inevitable that shipping contributes to unwanted emissions from transportation. The Danish maritime cluster is very aware of this and has a strong focus on making waterborne trade even more environmentally friendly than it already is.

Danish maritime manufacturers have been developing their products in environmentally beneficial directions for many years. The main thrust is towards reducing the energy requirement of ships and the environmental impact of the production process and of the vessels themselves. We continue to develop still more environmentally sound solutions, and recent efforts have been focused on mitigating the climate effects.

Members of Danish Maritime develop equipment of many types from main engines to lifesaving equipment or scrubber systems. Most are major producers and front line developers. Their products are universally available and competitive all over the world. It would be difficult to find vessels that do not carry Danish equipment or engines. This implies that improving Danish products will reduce emission from vessel all over the world. This brings on a very important responsibility to ensure that modern environmentally friendly equipment is available.

The Danish maritime cluster wishes to play an important role in designing and developing environmentally responsible products that minimize emissions. With Green Ship of the Future the Blue Denmark is making an extra effort to protect the climate and environment.
Reducing emissions is not achieved simply by reducing the total transportation by ship. Growth in consumption and economy and a growing need for transport services with a greater share of transportation by sea brings about a need for more shipping.

In recognition of the ecological responsibility nested in the maritime industry, a group of private Danish maritime companies – including market leaders such as Aalborg Industries, A.P. Moller-Maersk, MAN Diesel and Odense Steel Shipyard – has initiated Green Ship of the Future with the primary objective of developing and demonstrating green technologies within shipping and shipbuilding.

Green Ship of the Future is a unique cooperation in which companies across the Danish maritime industry join forces in order to develop strategies to reduce CO₂ by 30 %, SOₓ by 90 %, NOₓ by 90 % and particulate emissions from both existing ships and newbuildings. Participation is open for all Danish companies and organisations that meet the condition of being able to demonstrate a technology for reduction of air emissions within one of the four focus areas: machinery, propulsion, operation and logistics.

Combining forces
Many elements are coming together in Green Ship of the Future: research, development, demonstration, innovation, education, training and dissemination of knowledge. Many fields of knowledge are involved such as: systems for recycling heat energy, optimization of the hull, propellers and rudders, optimization of the draft and speed for a given route and arrival time and monitoring the fouling of hulls and propellers. Engine technology is an essential factor for achieving the planned benefits.

This unique initiative is met with great interest all over the world.
In July 2009, Green Ship of the Future received the International Environmental Award from the Sustainable Shipping organisation for being the most environmentally friendly shipping initiative.

Since its foundation, Green Ship of the Future has experienced great success. From the starting point with four project partners, the group of companies has expanded dramatically and today consists of 23 dedicated project partners. The typical partner has its main business within the maritime industry, but also universities, interest groups and national authorities support Green Ship of the Future – underlining the impression that together we really do make a difference.
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TORM SHIPPIING WITH PRIDE
Exhaust gas scrubbers

The future international regulations regarding sulphur emissions from ships imply that low sulphur fuel should be used in the future; however, exhaust gas scrubbers are allowed as an alternative to actually lowering the fuel sulphur content.

Scrubbers can be used for washing the exhaust gas from the main engine and can, in principle, be compared to a large shower cabinet placed in the funnel of the ship. With Aalborg Industries’ newly developed scrubbing system, it is possible to reduce the sulphur emissions to a level as low as if low sulphur fuel oil was used. But because low sulphur fuel oil has a significantly higher cost price, it makes good financial sense to use scrubbers to clean off the exhaust gas and thereby continue using heavy fuel oil.

The method
The major environmental benefit from the scrubbing system developed by Aalborg Industries is that both seawater and freshwater mixed with caustic soda can be used for the scrubbing. This makes the scrubbing process more environmentally safe than using chemicals to clean the exhaust gas of emissions.

The scrubbing process in the Aalborg Industries system consists of three stages: At the first stage, the exhaust gas is cooled from approximately 350°C to 160-180°C in a conventional exhaust gas economizer that uses the extra heat in other parts of the system instead of just wasting it. At the second stage, the exhaust gas is treated with a special ejector. Here the exhaust gas is further cooled by injection of water removing the majority of the soot particles. Finally, the exhaust gas is led through an absorption duct where the exhaust gas is sprayed with water and thus cleaned of the remaining sulphur dioxide. To prevent visible condensation and corrosion, the exhaust gas is subsequently reheated before being discharged through the funnel of the ship.

Extensive testing
The scrubbing system has undergone extensive testing with good results.

Olav Knudsen from Aalborg Industries explains, ‘During the winter of 2008/09, a comprehensive range of tests was carried out together with MAN Diesel in their test facility in Holeby, Denmark. The test proved that we are able to remove almost 100% of the sulphur from the exhaust gas and up to 80% of the particles. In June 2009, our first scrubber installation was supplied and installed on a DFDS Ro-Ro cargo vessel and in late 2009, we expect to complete the installation and make the commissioning on board the ship.’

Project facts

Category: Machinery

Emission reductions:

- CO₂ 3 % (compared to converting HFO to MGO in refineries)
- SO₂ 98 %
- PM 80 %

Partners:

- Aalborg Industries A/S
- MAN Diesel
- DFDS
The ship resistance and the ship’s trim are closely connected to each other. When the ship has the right trim, the water resistance is at a minimum, and so is the fuel consumption. A project by CLIPPER GROUP and FORCE Technology will uncover the potential fuel reduction gained by sailing at optimum trim.

The purpose of the project is to demonstrate the fuel reduction when the ship is trimmed correctly and to validate SeaTrim as a tool to achieve this fuel reduction. The ship used in this project is an L-Class chemical tanker owned and operated by CLIPPER GROUP.

**How to trim correctly**

SeaTrim is one of the advanced tools in the SeaSuite portfolio from FORCE Technology. SeaTrim is based on a trim matrix where the optimum trim can be read as a function of displacement and ship speed. The SeaTrim application gives the ship operator a graphical presentation of the influence on the fuel consumption as a result of a change to trim and draught.

**Starting in model scale**

‘The most accurate and controlled way to obtain information about the propulsive power requirement for a ship is to build a scale model and test the model in our towing tank,’ says Rasmus Carstens, project manager on the project at FORCE Technology.

After building a scale model of the CLIPPER tanker, it was tested in FORCE Technology’s towing tank. To obtain data for the trim matrix, a series of tests was performed in the normal operation range of the vessel. During the tests the vessel speed, propulsive power, sinkage and trim were measured. More than 100 test points were evaluated in the operation range.

**Full-scale validation**

In order to validate the test results, the SeaTrim application has been installed on six of CLIPPER’s chemical tankers. In the coming period, SeaTrim will be used to optimize the tankers’ trim and measure their fuel consumption.

Before SeaTrim was implemented on board the six CLIPPER vessels, a desktop study of the saving potential was made. The study looked at the history of one of the six vessels regarding the trim and the ship’s speed. The desktop study showed that there was a potential for fuel oil saving in approximately 80% of the sea voyages.

Kaj Pilemand from CLIPPER Group says, ‘Even though we have very skilled crew on board our vessels, there is always room for improvement,’ and he continues, ‘With fuel oil consumption of 2.800 tons per year/ship, even small savings percentwise are welcome – This is healthy both for the environment and for business.’

In order to uncover the full potential of SeaTrim, FORCE Technology’s performance validation tool SeaTrend is installed on board the six ships. This program will monitor and validate the performance of SeaTrim. The results of the project will be known in approximately one year when the full scale data have been analysed.
Ships are designed for certain speeds. For a large range of ships, the required ship speed is declining due to increased focus on fuel oil consumption and CO2 emissions. Also, the present slow-down in the world economy has further increased the demand for lowering ship speeds.

A large part of the main propulsion engines installed on large ocean-going ships are low-speed two-stroke diesel engines. These engines are designed for a certain power output corresponding to the ship's speed. As the propulsion power demand decreases, changes to engine components and adjustments are beneficial for the improvement of fuel oil consumption, lowering of CO2 emissions and for improvement of the overall performance of the engine. This will lead to optimized low-load operation of the engine. However, the changes affect the environmental certification of the engine, especially with regards to NOx emissions.

When a ship engine is manufactured, it undergoes a certification test in order to assure that emissions are within the IMO regulation limits. When making changes on an original engine, it is necessary to renew the certifications, which is a time consuming and costly affair.

Therefore, this project tries to find solutions for low-load optimization of the existing vessel fleet within the current certifications.

**Low-load sailing and turbocharger cut out**

Many different possibilities have been investigated, and the two solutions with the greatest potential have been further developed. The first solution is sailing the ship at low-load mode which is possible for electronically controlled engines. Ship engines are constructed to have optimal fuel consumption at a certain speed. By sailing at low-load mode with electronically controlled engines, this optimum is reached at far lower speeds than normally. By doing so, the consumption of fuel and air emissions are reduced.

The second solution is cutting out the turbocharger which is possible on ships with multiple turbocharger engines. This solution has a wider scope as it is possible to gain larger reductions of fuel consumption than by using low-load mode on electrically controlled engines. Furthermore, turbocharger cut out can be used on both electronically controlled engines and mechanical engines. This increases the possible reduction of exhaust gas emissions as most ships today are propelled by mechanical engines.

The method of turbocharger cut out works by turning off one of the turbochargers and closing one of the throttles. This and in combination with reduction of the ship's speed, fuel oil consumption and CO2 emissions are reduced.

Turbocharger cut out is already implemented within the current certification on the A.P. Moller - Maersk 8,000 TEU container ship Maersk Salalah with a MAN B&W 12K98ME main engine. Tests on the ship shows that by lowering the ship speed from 24 knots to 22 knots, the main engine power will decrease approximately from 77% to 56% load. The lower ship speed will cut emissions by 25% per sailed nautical mile. The additional decrease of CO2 emissions due to the optimized engine operation with turbocharger cut out will reduce CO2 emissions by another 3%.

### Project facts

- **Category:** Machinery
- **Emission reductions:** CO2, NOx, SOx
- **Partners:** A.P. Moller-Maersk, MAN Diesel
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Large amounts of electric energy are consumed when cooling water is pumped to cool components in the engine room. A.P. Moller - Maersk targets the potential savings with a project set to scope out best practices for retrofit and building of new ships. Therefore, a 3 year industrial Ph.D. at Aalborg University will turn Gudrun Mærsk into a floating cooling lab in pursuit of the perfect cooling solution for the 21st century.

The cooling system is a key component in the ship’s safety, and the main challenge is to keep the low temperature cooling system stable. Today, a cooling system is driven by a constant speed pump which ensures a stable temperature when used together with mixing circuits and fixed flow restrictions. Unfortunately, by using a constant speed pump, the cooling system is running at an overall higher capacity than needed. By changing from constant speed pumps to variable speed pumps, the energy consumption will be reduced, and at the same time the need for mixing circuits will be removed. Furthermore, the use of valves on subsystems will replace the need for fixed flow restrictions.

On the 7,000 TEU container ship Gudrun Maersk, this should generate 980,000 kwh/year energy savings which equal 235 tons fuel oil and 731 tons CO2 a year. The energy savings are estimated in a master’s thesis from Aalborg University, which has been confirmed by cooling system simulations based on data collected by the A.P. Moller – Maersk Ship Performance System, MSPS. In addition to the environmental benefits, the payback time for the shipowner will be less than 2 years.

Keeping cool and stable
In order to obtain these savings, variable frequency drives (VFD), valves and smart control algorithms need to be implemented. VFD’s and valves are already off-the-shelf items but safe and energy-optimal control algorithms for ships have not been developed yet. The cooling system is a key component in the ship’s safety, and the main challenge is to keep the low temperature cooling system stable. Therefore, an industrial Ph.D. at Aalborg University will focus on combining fault tolerance and robust control with self optimization.

Long-term gains
The long-term goal of the project is to provide a decision package that scopes out different possible improvements and their impact on ship economy as well as the environment. The calculated savings are based on the simple constant pressure system which will be used in the beginning as it is a safe and predictable option. The project partners expect to increase savings with more advanced and self-tuning control algorithms. The fleet roll-out decision package is expected to evolve over time as more knowledge and experience is gathered.

Project facts

Category: Machinery
Emission reductions:
- CO₂
- NOₓ
- SOₓ

Partners:
- A.P. Moller-Maersk
- Odense Steel Shipyard
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Being in tune reduces fuel consumption

Auto-tuning ensures that the combustion process of a MAN Diesel engine is always optimized. This allows for continuous adaptation to wear, changed fuel properties and operating conditions. The result is a reduction of fuel consumption, CO₂ emissions and particulates.

Today, tuning of the engine performance is a process done manually by the marine engineer. Typically, it takes some hours once a month or whenever required, e.g. after engine overhaul. The tuning will make the engine run safely within recommended load limits but still leaves a margin for performance optimization as operating conditions and fuel oil properties change over time.

With Auto-tuning, this margin can be harvested by continuously and automatically tuning the engine for best performance, a task that is not feasible to be done manually.

Constant measuring and tuning

The Auto-tuning concept is based on online measurements of the combustion pressures in the cylinder chambers. This is an extremely hard environment for a sensor to function in as the exhaust gas passes with high temperature and at high pressure. However, sensor technology has reached a point that allows for constant measuring for more than 4 years of engine running. In comparison, a standard car engine will, in its lifetime, not run much more than a total of one year.

The developed engine control system constantly monitors and compares the measured combustion pressures to the reference value. Hereafter, the control system will automatically adjust the timing of the fuel injection in accordance with the deviation between the measured value and the reference value. This is done in order to reach the optimal combustion pressures during the next firings.

**Being in tune reduces fuel consumption**

The constant and automatic tuning to best engine performance allows for continuous adaptation to wear, changed fuel oil properties and operating conditions, e.g. sailing in cold or warm climate. This offers a wide range of benefits, namely reduction in fuel consumption, CO₂ emission and carbon particles, as well as reduced maintenance costs and risk of damage.

The reduction in fuel consumption for the average vessel is expected to be above 1%, whereas some vessels will have a potential of more than a 3% reduction.

If Auto-tuning is installed on the more than 10,000 MAN Diesel two-stroke engines in service worldwide, the total fuel consumption will be reduced by estimated 2 million tons. This is equivalent to 5 million tons of CO₂ or about 10% of the total annual Danish emission of CO₂.

**Retro-fitting without docking**

The Auto-tuning system is simple to install, also as retrofit on vessels already in service. Installation does not require docking but can be done while in normal service.

Pay-back time is estimated to 5 - 20 months of operation, depending on engine size and operation schedule. Thus, with the MAN Diesel Auto-tuning concept, shipowners are being offered an easy way to reduce vessel operating costs and at the same time contribute significantly to the reduction of CO₂ emissions.
ABB turbocharging reduces fuel consumption, CO$_2$ and NO$_x$

ABB Turbocharging has retrofitted MV Alexander Maersk with a new, high efficiency turbocharger. As well as direct benefits in form of reduced fuel consumption and emissions, the turbocharger’s variable turbine geometry is an ‘enabling technology’ of the ship’s exhaust gas recirculation system.

A turbocharger is a small radial fan pump driven by the energy of the exhaust gases of an engine. The purpose of a turbocharger is to increase the density of air entering the engine to create more power. By increasing the amount of air reaching the combustion chamber, the engine can burn fuel more completely. This offers some obvious advantages as more complete combustion results in increased power, producing fewer emissions.

The overall effect is more power for a given engine size, lower fuel consumption for the work done by the engine and reduced noxious emissions. Since marine engines burn hydrocarbon fuels, lower fuel consumption automatically means lower emissions of the greenhouse gas carbon dioxide for the amount of freight transported.

Retrofitting Alexander Maersk
On the Alexander Maersk, ABB Turbocharging fitted the advanced A175-L turbocharger (Figure 1) featuring the variable turbine geometry system (VTG). The functions of VTG can be compared to the principles of Venetian blinds that control the light entering a room through a window; instead of controlling the light, VTG employs adjustable vanes ahead of the turbocharger turbine to vary the amount of exhaust gas reaching the turbine (figure 2).

This controls turbine speed and allows variations in the amount of air compressed by the compressor. Under electronic control, the quantity of air entering the engine cylinder is closely matched to the amount of fuel injected into the combustion chamber. As stated above, the right amount of air + the right amount of fuel = efficient, clean combustion.

**Triple Benefits**
The installation of the ABB type A175-L turbocharger with VTG technology on the engines of the Alexander Maersk has three major benefits:

Firstly, the overall efficiency of one of the most modern and advanced turbochargers in the world results in significant improvements in the engine’s fuel consumption and the formation of oxides of nitrogen (NO$_x$).

Secondly, close matching of the amounts of combustion air and fuel means very efficient combustion and very close alignment of the power the engine produces to the power needed to propel the ship. The latter varies according to whether the ship is fully or partially loaded, on the high seas or entering port, or has a tail wind or a head wind, for example.

Thirdly, the Alexander Maersk has one of the first large marine engines to be fitted with Exhaust Gas Recirculation (EGR) for NO$_x$ emissions reduction. EGR recirculates the engine exhaust gases back into the combustion chamber to influence the burning of the fuel in the air and thus the formation of NO$_x$. Close control of the quantity of air entering the engine is thus essential for efficient EGR. ABB Turbocharging’s VTG system is the ideal technology to achieve this control.

**HOW DO TURBOCHARGERS WORK?**
As shown in Figure 3, turbochargers use the energy in an engine’s exhaust (3) to drive a turbine (2) located on the same shaft as a compressor wheel (1). The turbine thus drives the compressor which forces air (4) into the engine cylinders where it is further compressed. By increasing the amount of air reaching the combustion chamber, the engine can burn more fuel more completely.
MAN Diesel has developed an Exhaust Gas Recirculation (EGR) system for low-speed two-stroke engines, which can reduce harmful NOx emissions from ships by 80%.

The newly developed EGR system reduces harmful NOx emissions by directing part of the exhaust gas back into the scavenge air of the engine. This reduces the oxygen content of the air in the combustion chamber, thereby reducing the combustion temperature. The lower combustion temperature results in a reduced formation of NOx.

Tests carried out on MAN Diesel’s test engine in Copenhagen have shown very promising results with EGR technology on a two-stroke engine. The results show that it is possible to comply with the International Maritime Organisation’s (IMO) forthcoming requirements for NOx emissions with EGR alone.

In addition to EGR process tests in Copenhagen, it is necessary to assess the effect of EGR on the engine over a period of time, particularly with the use of Heavy Fuel Oil which contains sulphur and is the most common form of fuel on low-speed two-stroke marine engines. A. P. Moller - Maersk is participating in a development partnership by providing a ship for a service test of the prototype EGR system. The prototype EGR system is being installed on the container ship Alexander Maersk from July 2009 to January 2010, and once the installation is complete, the EGR system will be put into service until the end of 2010.

There are great expectations towards the EGR system. Especially in light of the new emission rules set by IMO, coming into force in 2016, whereby NOx emissions must be reduced by 80%. MAN Diesel has led the initiative in developing emission reduction technologies. The EGR system is the first of its kind to be installed on a ship.

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**Project facts**

*Category: Machinery*

Emission reductions:
- NOx: 80%
- SOx: 19%

*Partners:*
- A.P. Moller-Maersk
- Aalborg Industries
- MAN Diesel
- Odense Steel Shipyard
Many different factors influence the fuel economy of a large ship, and in combination these factors create a very complex system. GreenSteam is a new solution made to handle this complexity in order to achieve the best possible fuel economy for large ships.

When a 200 meter long ship is propelled through the sea by a 10,000 kW engine, it is not an easy task to calculate the resulting speed. The direction and speed of winds and waves, the loading of the ship and the angle of the rudder are some of the factors that affect the amount of resistance that the ship must overcome. Some factors, such as the propeller settings – typically revolutions per minute – and the ship’s trim, can be controlled by the crew, but many factors relate to systems only manageable through complex calculations.

Yet, all these factors interact. For instance, if the ship is fully loaded, a greater part will be submerged than when the ship is partly loaded.

Adjusting the controllable factors so that the fuel economy of the ship is optimized is therefore a very complicated problem, and even more so when adding non-constant factors such as wind direction and speed.

**An exciting opportunity**
At the same time this presents a great opportunity. If the controllable factors can be adjusted correctly to the ship’s changing conditions, it will be possible to improve the fuel economy significantly.

GreenSteam achieves this through advanced mathematical modelling of the complex realm of ship fuel economy. All of the involved factors are measured and recorded over a long period of time. For some of these factors, specially adapted sensors are used to capture the necessary information. This comprehensive data collection is then ‘fed’ to the GreenSteam software which is able to observe and correlate the interplay and patterns that exist in the data. This means that instead of calculating your fuel economy based on a long range of simplified assumptions, you use the actual data from the individual vessel.

The optimal controls are dynamically calculated by GreenSteam and displayed on the bridge through a carefully designed user interface that allows the captain to quickly and easily determine any needed adjustments.

GreenSteam is currently being operated on board one of Damskibsselskabet NORDEN A/S’s tanker vessels. Current estimates indicate that this vessel can improve fuel economy by around 4 percent. Such an improvement corresponds to a reduction in annual CO₂ emissions of roughly 1,200 metric tons and reduces annual fuel costs by around €100,000.

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**Project facts**

**Category:** Operation

**Emission reductions:**

- CO₂: 4 %
- NOₓ: 4 %
- SO₂: 4 %

**Partners:**

- GreenSteam
- Norden
Green Ship of the Future is the vision of a shipping industry that is green in the sense of being sustainable. The primary purpose of the project is to develop green ships that – by virtue of environmental and energy-efficient technology – contribute to reducing the harmful emissions caused by shipping.

However, sustainability is not achieved by energy-efficient technology alone. Green technology is definitely a necessary, but not necessarily a sufficient, condition for cleaner shipping. Only when the technology is operated by a person with a green consciousness does it come up to its full potential, because only then it will be operated in accordance with its design.

Green consciousness
Due to their education, the next generation of maritime leaders has developed a natural focus on optimization and energy efficiency. An underlying consciousness of our climate ensures that the environment is automatically taken into consideration whenever a routine, process or operation is carried out on board a ship or planned and supervised ashore.

Covering both theory and practice
When SIMAC students pass their final exam, they possess this very consciousness of green shipping. It has grown from the polytechnic learning environment they have been trained in. Graduating with a professional bachelor degree, each and every one of our students has learned to adopt a critical-reflective perspective on the very practice they participate in. They are trained to challenge what others might take for granted. And to do so systematically.

But at the same time – and not less importantly – SIMAC students graduate with a massive amount of practical experience. During their training as cadets on board ships, they are continuously working with environmental and energy-efficient technology – for instance when collecting relevant data for use in research, product development or the like.

At SIMAC, we educate and train maritime officers capable of sailing and operating ships with a constant focus on optimization and energy efficiency, but of equal importance we educate future maritime leaders capable of handling management issues ashore.

This combination of theory and practice puts SIMAC students in the borderland between maritime research and the maritime industry. Their systems of terminology cover both areas, and this makes them particularly qualified as the connecting link between the two entities. Not only do they possess the theoretical insight necessary to understand the research, they are also capable of operating the technological solutions resulting from the research. And continuously they contribute to the further development of the very same.

To illustrate the fruitful collaboration, one can imagine a group of cadets performing experiments and measurements for use in a research project initiated by a university or a shipping company. The researchers profit by the empirical data produced by the students. In return, the students gain an insight into the methods of research, and at the same time they collect data that can be used as the empirical foundation for their own theoretical projects. In the long run, the collaboration helps qualify the students to become the world’s best maritime leaders.

**Project facts**

- **Category:** Operation
- **Emission reductions:**
  - CO₂
  - NOₓ
  - SO₂
- **Partners:**
  - DCMT
  - SIMAC
When was the last time you could simply lean back and relax with a spectacular view in front of you? Knowing that a superb gourmet would be waiting for you later on and that even later, you’d be dancing the night away... The possibilities onboard the DFDS Seaways ships are as inviting and boundless as the magnificent seascape. Whether you’re sailing from Denmark, Holland, England or Norway, your course is set for a day like no other.

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Today with questions of sustainability being asked of all industries in the face of the climate change challenge, shipping is urgently considering how to reduce its CO2 emissions. NanoNord A/S, J.Lauritzen and Lloyd’s Register are working together to pilot the Lab-On-A-Ship™ concept in a collaboration to help international shipping better manage its fuel resources and reduce emissions.
Learn more about Lab-On-A-Ship™ – go to www.nanonord.com
A group of Danish and Swedish companies has discovered a new way of saving 8 tons of oil per day by utilizing existing components in 75,000 tdw tankers.

Modern diesel engines have high energy efficiency, but there is still a lot of waste heat to be utilized. In this project, the possibility of using the waste heat from the main engine to heat up the cargo areas aboard the ship has been investigated. The initial analysis shows that it is possible to save up to 20% of the yearly fuel consumption, and thereby saving both money and CO2 emissions.

John Nielsen, Global Sales Manager at LR Marine, explains, 'We've taken the existing system and changed the outlet for the cooling water. This happens by inserting a modified heat exchanger between the existing components, channelling the heat from the water into the supporting systems on the ship. This provides heat for the cargo tanks, bunker tanks, accommodation and such systems, and furthermore provides the heat and energy for all the supporting elements of a ship while under way.' John Nielsen continues, 'This basically means that a ship of this size does not need an oil driven boiler while sailing but only when the ship is not using the main engines. Calculations show that 8 tons of oil is saved each day from a ship with a normal use of 42 tons of oil per day. This means that a lot of oil and money can be saved each year.'

**Can be installed in two weeks**

LR Marine is a company specialized in constructing and installing the piping on the top decks, mainly on large tankers. They are currently cooperating with the specialized pump producing company DESMI and the producers of heat exchangers, APV. The cooperating companies are mainly focusing on ideas from the technical manager of the Swedish ship owning company Marinvest, Roger Karlsson, who brought several issues to the companies' attention. If Marinvest accepts and implements the system in its modern ships, new piping, heat exchanger and pumps will have to be installed. Also all pipes have to be insulated to minimize the loss of heat.

John Nielsen explains, 'For a 75,000 tdw tanker, the new system can be installed in two weeks. The current calculations show that the investment by a shipowner in this system will have a payback time of two years. The installation is a onetime expense, whereas the savings can be felt immediately and will last through the 20-30 years the ship is expected to last. 8 metric tons of oil per day is a significant amount of money saved per year. On top of this, the ship becomes less vulnerable to any new environmentally related taxes, due to the significant amount of oil saved.'

By stopping the waste of energy, the environment is helped as well. The oil saved means that the CO2 emission is reduced by a significant amount. Calculations show that the 8 tons of oil is the equivalent of 24 tons of CO2 emission per day, meaning that the new system will help the global environment.

**Talk and brainstorming**

The basic idea for all this came from a quite common conversation at a marine convention, which quickly turned into a creative brainstorming process resulting in a way to stop a tanker from using the boiler while the ship was sailing, while still maintaining all systems. The participants quickly realized that this system could be implemented directly on new tankers without any changes to the basic design.

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**Project facts**

**Category:** Machinery

**Emission reductions:**

- \(\text{CO}_2\) 20 %
- \(\text{NO}_x\) 20 %
- \(\text{SO}_x\) 20 %

**Partners:**

APV
DESMI
LR Marine
Thanks to our shipping history and global reach, we know this planet like few others. That is why we not only believe in the business and environmental advantages of sustainability - we act on them.

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Headquartered in Copenhagen, the A.P. Moller - Maersk Group includes Maersk Line, Maersk Oil and a number of other companies within shipping, oil, logistics and retail, employing 120,000 people in 130 countries.

DESMI Marine Pumps - The Naturel Choice for high quality

Looking for a pump that meets future requirements? DESMI rises to the environmental challenge of the future.

- We are a teamplayer in the global fairplay
- Our pumps make a difference, saving energy and CO2
- One supplier - We offer complete pump packages
Machinery for high-speed LNG-ferries

In this project, Mols-Linien A/S and DTU Mechanical Engineering cooperate on studying the machinery for future gas-powered high-speed ferries. Computational tools developed within the Danish Center for Maritime Technology (DCMT) are used for the modelling work. The use of gas will reduce the pollutant emissions significantly, thereby lowering ferries’ contribution to global warming and pollution in coastal regions.

One way to reduce pollutant emissions from ferries is to change to liquid natural gas (LNG) as fuel. Considering a propulsion system with the same efficiency, using LNG instead of diesel reduces the carbon dioxide emissions (CO₂) by about 25%, the nitrogen oxide (NOₓ) emissions by about 35%, and eliminates the sulphur oxide emissions (SO₂). In addition, further emission reductions can be attained by advanced design of the machinery.

Scope and objectives
The aim of this project is to design highly efficient machinery suitable for LNG-fuelled ferries. By application of mathematical models developed within DCMT, different possible configurations are investigated by performing numerical simulations. The ferry under consideration is a 112 m Incat catamaran vessel. Normally these ferries are powered either by diesel engines or gas turbines, of which there is one in each hull. Each of the engines is connected to waterjets which propels the vessel. In this project, advanced designs of machinery based on gas turbines are considered. Using machinery with more components will increase the weight and volume requirement of the engine, which, to some extent, will increase the propulsion power demand of the vessel. Therefore, the improvement in vessel performance is expected to be less than the performance improvement of the machinery.

Machinery designs
A promising option, which is considered in this study, is to introduce recuperation in the gas turbine. This implies that the compressed air is heated prior to the combustion chamber using the exhaust gases, resulting in less fuel input. Another option considered is to use a combined cycle. That is, use the exhaust gases from the gas turbine to generate vapour which is expanded in a turbine. Due to the additional power from the vapour turbine, the efficiency of the machinery is increased. The most frequently used working fluid in combined cycles is water/steam. However, for small-size plants, where minimum weight and volume of the equipment is paramount, a so-called Organic Rankine Cycle (ORC) is suitable. In such plants, an organic fluid is used instead of water/steam.

Results
The first preliminary results suggest that if the recuperated gas turbine is combined with an ORC, an efficiency of about 48% would be achievable which is about 30-35% higher than in existing machinery. It is expected that these improvements can be increased by further optimizations of the processes. One of the tasks for future work is to evaluate the machineries with respect also to the vessel performance, taking into account their increased weight and volume.

Project facts
Category: Machinery
Emission reductions:
CO₂ 25%
NOₓ 35%
SO₂ 100%
Partners:
DTU
Mols-Linien

Recuperated gas turbine combined with Organic Rankine Cycle (ORC).
Optimization of CO₂ emission and fuel efficiency

MAN Diesel

MAN Diesel is constantly looking into technological developments that can improve fuel efficiency and thereby reduce CO₂ emissions. This project combines two recent developments and aims to implement them on a tanker owned by TORM, to demonstrate the improvements in fuel efficiency that are possible today.

The MAN B&W low speed marine engine is the prime mover for over half of all transported goods world-wide, and MAN Diesel offers a wide range of engines to meet vessel propulsion power requirements. The combination of two recent innovations will further improve fuel efficiency and reduce CO₂ emissions:

1. MAN Diesel’s Variable Turbine Area turbocharger
2. The MAN B&W ME-B main engine with electronically controlled fuel injection

Variable Turbine Area turbocharger

The advantage of the Variable Turbine Area (VTA) turbocharger is that the turbine area can be continuously controlled, via the control system, to increase the scavenging air pressure at part load. This is not possible with a conventional turbocharger with a fixed turbine area and thus a static optimization point at a pre-determined engine load.

Application of a VTA turbocharger is of particular relevance in the current situation, with many vessels operating continuously at part load. In this case, a VTA turbocharger offers significant improvements in fuel efficiency when compared to a fixed turbine turbocharger, due to the possibility of part load optimization. Use of the VTA will also typically lead to a reduction of soot and smoke at part load, and an improved dynamic response of the engine.

MAN B&W ME-B main engine

The MAN B&W ME-B main engine combines electronic control of fuel injection with mechanical control of exhaust valve timing. Electronic control of fuel injection facilitates easy adjustment of the fuel injection parameters, depending on the requirements of the operator, whilst retaining the simplicity, and reliability, of a light camshaft for opening and closing of the exhaust valves. The ME-B engine provides an extremely flexible solution with regards to fuel optimization and meeting emission limits according to regulations.

Integration of two technologies

MAN Diesel developed a control strategy for a VTA turbocharger on an electronically controlled engine and integrated the VTA control system into the engine control system, thereby allowing the combination of these two technologies.

The first installation of a MAN B&W 6S50ME-B8, combined with a MAN Diesel VTA turbocharger, TCA66, will take place in partnership with TORM. The initial engine performance test was carried out in July 2009, including performance and emission measurements, whilst optimizing Specific Fuel Oil Consumption (SFOC) in conjunction with NOₓ emissions. An improvement in SFOC is to be expected at part loads where the VTA can be optimized. Based on an average load profile for the vessel, this results in an annual saving in fuel oil of 95 tons, and reduced CO₂ emissions of 300 tons.

SeaTrend
Performance Monitoring
Fuel efficiency

SeaPlanner
Voyage planning
Reduction of emissions

SeaTrim
Trim optimization
Reduction of water resistance

Green and cost saving engineering know-how

www.SimFlex.dk/SeaSuite
Ships are one of the biggest sources of NO\textsubscript{x} emission in the world. NO\textsubscript{x} emissions from ships cause pollution over land and cause eutrophication of the seas. DANSK TEKNOLOGI has developed an SCR (Selective Catalytic Reduction) system with multipoint, airless urea injection that reduces NO\textsubscript{x} emission from marine engines.

During the last two years, DANSK TEKNOLOGI has developed a unique SCR system for NO\textsubscript{x} reduction on marine engines. The system, which is developed to be installed in one of the Danish Navy’s Diana class patrol vessels, is based on airless, multipoint injection of urea.

Trucks and buses

Originally, the airless technology was developed for use in heavy trucks and busses, where DANSK TEKNOLOGI started testing four years ago by retrofitting a complete SCR system on four MAN-trucks owned by the Danish Defence Acquisition and Logistics Organisation (DALO). Since then the technology has been extensively tested by leading truck engine manufacturers.

The heart of the system is derived from the innovative Digital Dosing pump technology that DANSK TEKNOLOGI has developed for GRUNDFOS. Based on this unique knowledge, an SCR system suited especially for marine engines has been developed. During the development period, DANSK TEKNOLOGI has been cooperating closely with DALO, and a full-size prototype system has been successfully tested at the naval base in Korsør.

The NO\textsubscript{x} reduction is expected to be above 80 %, meaning that the patrol vessel is from 2016 and on.

How airless SCR technology works

The SCR technology functions by spraying a mixture of urea and deionized water known as AdBlue into the exhaust gases. The heat in the exhaust system transforms urea into ammonia which reacts with the nitrogen oxides in a catalytic converter, converting them into harmless nitrogen and water vapour. The multipoint, airless technology reduces NO\textsubscript{x} considerably with no need for a mixer or compressed air, and it has a very compact size. This again means that the complete SCR system takes up the same space as the traditional silencer which it substitutes.

The developed SCR system is based on a modular concept and can be adapted to any engine running on marine diesel.

The system is fully developed and is ready for production and installation on a wide variety of vessels, e.g. generator sets or other auxiliary engines on drilling rigs, container ships, bulk carriers and main engines on ferries, tug boats etc.

### INSTALLATION ON DANISH NAVY PATROL VESSELS

- 4 stroke MTU engine 2040 kW (2 engines on each ship)
- From approximately 11.5 -> 2 g NO\textsubscript{x} / kWh -> more than 80% reduction
- Catalyst volume 1744 l (16 elements)
- Urea consumption max 42 l/h
- Dosing temperature 315-520°C
- Fuel: Marine Gasoil S<0,035-0,2% (350-2000ppm)

### Project facts

**Category:** Machinery

**Emission reductions:**

- NO\textsubscript{x} 80 %

**Partners:**

Royal Danish Navy
DANSK TEKNOLOGI

The picture above show the prototype installation at the naval base in Korsør and the patrol vessel chosen for the first installation.
A collaboration to help international shipping better manage its fuel resources

Understanding and measuring the composition of the fuel oil is vital. NanoNord A/S and the leading marine classification society, Lloyd’s Register, are working on ensuring that fuel oils are adequately pre-treated and then burned in the most efficient manner.

World trade is enabled by shipping. The maritime industry has successfully provided increased productivity to better support world trade, and as global trade volumes have grown, shipping capacity has grown in response.

Reduction of CO₂ emissions is a global concern, and like all other industries the shipping industry is working on reducing its overall emission of greenhouse gases.

Over the last ten years, considerable progress has been made in reducing shipping’s emissions to the atmosphere. Today, shipping emits approximately 3% of the world’s anthropogenic CO₂. But the task of reducing shipping’s overall CO₂ emissions is far from easy, and it is likely to require some radical rethinking as to how the industry operates.

All parts of the industry need to drive this development: shipowners, charterers, shipbuilders, engine builders, classification societies and so on – each contributing with their unique expertise in order to reduce the total emission figure.

**Lab-On-A-Ship**

Fuel management is a very important discipline on board a ship, both in relation to fuel economy and CO₂ emissions, which makes it necessary to know the fuel composition. Marine fuel oil needs particular care and attention as the composition is of variable standards. Because of this variation, analysing the fuel oil for e.g. sulphur is necessary in order to get the highest fuel efficiency.

Normally, it is a time-consuming and complex assignment to perform these tests, and therefore they are rarely performed. Lab-On-A-Ship is an innovative approach to solving this task. By monitoring fuel oil, lubricating oil and exhaust emission automatically on board the ship, Lab-On-A-Ship provides the ship’s engineer with the needed information to optimize the treatment and use of the fuel oil, thus making the fuel consumption more effective.

**Practical tests**

As a first step, the Lab-On-A-Ship systems were installed on Lauritzen Bulkers AS’s Sofie Bulker and Amine Bulker. In parallel, Lloyd’s Register’s Fuel oil and bunker analysis service (FOBAS) service was commissioned to provide in-depth fuel oil management training of the ship’s engineers, superintendents and technical management.

Lauritzen Bulkers AS is positive that Lab-On-A-Ship will enable them to optimize their ships’ operations, thus reducing both their environmental impact and operating costs. Lauritzen’s Technical Manager, Poul Martin Kondrup, is clear on this point:

‘Our goal is to extend the on board measurement capability to encompass the highly variable fuels and lubricant quality issues encountered by shipping. This will represent a substantial step forward in making the correct machinery management decisions which enable targeted action, the minimization of waste and impact on the environment.’

The Lab-On-A-Ship project is being piloted on other ships. Initial findings are expected by early 2010.

### Project facts

**Category:** Operation

**Emission reductions:**
- CO₂ 0-5 %
- NOₓ 0-5 %
- SO₂ 0-5 %

**Partners:**
- Lauritzen Bulkers A/S
- Lloyd’s Register
- NanoNord

**LR Marine AIS** is a total supplier of solutions for marine and off shore businesses.

**Our core business are within the fields of:**
- Pipe systems
- Pre-insulated Pipe Systems
- LNG Bunker Pipe Systems
- Machinery units / Skids
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Optimization of pump and cooling water systems

Cooling systems are one of the largest energy consumers on board a vessel, and optimized design of the systems leads to significant savings. For a bulk carrier, the main sea water cooling system and the main engine lubrication oil system consume the majority of the energy used for cooling.

Project background

In the project, the focus has been on the sea water cooling system and the main engine lubrication oil circulation system for a MAN B&W diesel engine installed on board a 35,000 DWT bulk carrier.

The case studies for the project have been calculated and evaluated in a fluid calculation program, named Fluid Flow, which is a design and simulation tool for pipe systems. The Fluid Flow designing tool facilitates quick and effective evaluations such as: Pressure loss calculations for fluid, gas and slurry systems, selection of optimal pumps, cavitation control of pumps and calculation of air pipes connected to tanks for pressurized systems.

Sea water cooling system

The sea water cooling system is most commonly designed according to preliminary demands stated in the building specifications for the vessel with no specific knowledge of flow resistance for coolers, filters and vertical location of the equipment.

The practice of using the ‘first, qualified guess’ as the final specification for purchasing the pump has, been seen especially at the yards in the ‘young’ shipbuilding nations where the yards have less technical experience.

Reduction of pressure

Our studies show that the pressure drop of the cooler is essential. The cooler is the component in the sea water cooling system causing the highest resistance, and consequently it has a significant impact on the overall system pressure. By choosing a bigger cooler, the resistance is reduced and in that way it facilitates the installation of smaller pumps.

Therefore, the chosen cooler pressure drop should be specified very clearly when the coolers are selected. Studies show that it is possible to save up to approx. 90% of the energy required to run the pumps in this system by installing the correct combination of pump and coolers. 90% of the pump energy equals 10% of the total generated electrical power on board or more than 160 tons of CO₂ per year per pump.

Lubricating oil circulation system

The main engine lubricating oil system is a circulation system where the pumps take the lubrication oil from the main engine bottom tank and discharge it through an oil cooler. Then the lubrication oil is pumped through a thermostatic valve, an automatic back-flushing filter and back into the main engine which by gravity discharges oil back to the engine bottom tank.

The parameters of the optimisation is the needed oil pressure, oil temperature and oil flow at the main engine inlet. From these figures, the cooler, filter and oil pump is optimised to fit the circulation system of the vessel.

The lubricating oil circulation system has been calculated with three different pump types, a three-stage submersible deep-well centrifugal pump, a vertical inline centrifugal pump and a screw pump.

The pipe fluid studies in conjunction with data given by the co-operating partners, which are suppliers of main engines, coolers, pumps and filters, have shown that savings up to 5% electrical power are achievable corresponding to more than 110 tons of CO₂ per year.

Project facts

Category: Machinery

Emission reductions:

- CO₂: 1.5 %
- NOₓ: 1.5 %
- SO₂: 1.5 %

Partners:

- APV
- DESMI
- Gronmij | Carl Bro
Founded in 1884, J. Lauritzen A/S (JL) is one of Denmark’s leading shipping companies. We combine tradition with innovation and create value for our business partners worldwide through the constant emphasis on customer service, safety at sea and environmental protection. As a leader in international ocean transport, JL owns and operates a diversified and modern fleet of bulk carriers, gas carriers, product tankers, dynamically positioned shuttle tankers and offshore support vessels. For further information please visit www.j-lauritzen.com

**HEMPASIL X3**
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Guaranteed to save ship-owners money on fuel, HEMPASIL X3 is the world’s most advanced fouling release system. It uses HEMPEL’s unique hydrogel technology for unparalleled antifouling capability. Recognised as a major fuel-saving breakthrough for the maritime industry, Hempasil X3 is the proud winner of three industry awards. Find out more, and see what you could save at hempel.com

Hempasil X3 is the proud winner of the Seatrade award for “Protection of the Marine and Atmospheric Environment”, Ingeniørens PRODUKTPRISEN 2009 and “European Antifouling Coatings Product Differentiation Innovation of the Year” Award.
Exhaust gas waste heat recovery

Even though a two-stroke engine has very high energy efficiency, it can be optimized. One of the ways this can be done is by utilizing a waste heat recovery system in order to change the engine’s waste heat into valuable electric power, thus reducing the CO₂ emissions from the ship.

When the exhaust gas leaves the engine, it has a very high heat potential. By utilizing this potential in an exhaust gas boiler, it is possible to recover a large part of the heat from the exhaust gas and to use it to generate steam.

The waste heat recovery system (WHR) consists of an exhaust gas boiler supplying steam to a steam turbine. The steam turbine is connected to a generator, and thereby the waste heat is recovered as electrical energy.

To obtain the highest electrical production, the optimal solution is to use a dual steam pressure system or even a triple steam pressure system if the engine is equipped with a system for exhaust gas recirculation.

If the multi steam pressure system is of a more complex nature, it is necessary with further supplementary waste heat recovery to heat the feed water. For these systems, the available heat in the jacket water and scavenge air is utilized to pre-heat the feed water up to just below the saturation temperature.

To further boost the electrical output, the system can be extended with a gas turbine utilizing the energy in the exhaust gas not used by the turbo charger.

For dual steam pressure WHR systems, the available electrical power output can be increased to 11 – 12 % of the shaft power when a gas turbine is included and approximately 7 % without the gas turbine.

When designing the systems, a coordinated optimization of the engine, the exhaust gas fired boiler and the turbines was found beneficial. An example is that the temperature of the steam can be heated significantly in a super heater situated on the pressure side of the gas turbine or the turbo charger. The position of the super heater influences the design of the engine, boiler and turbines.

Obtainable electric power output
Single steam pressure WHR systems are relatively simple, and the total power production in percentage of the main engine shaft power is limited; however adequate for some kinds of vessels – bulk carriers and crude oil tankers. For these systems, the available electric power production without a gas turbine is approximately 5 %, and when a gas turbine is added, the electrical power output can be as high as 9 - 10 % of the main engine shaft power.

Further possible developments
When it comes to systems where NOₓ is reduced by means of exhaust gas recirculation, there is an opportunity for increasing the power output due to the very high exhaust gas temperature in the EGR string of the WHR system. For these systems, a triple steam pressure system has been found beneficial. Investigations have shown that a power production of up to 14 % of the engine power is available at 85 % MCR for a large slow speed diesel engine.

The WHR systems have been found to be a beneficial contribution to reducing the CO₂ emissions from ships as well as lowering the fuel costs for the owners.

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Project facts

**Category:** Machinery

**Emission reductions:**
- CO₂ 7 - 14 % depending on installation
- NOₓ 7 - 14 % depending on installation
- SO₂ 7 - 14 % depending on installation

**Partners:**
- Aalborg Industries A/S
- AP Møller Maersk
- MAN Diesel
- Odense Steel Ship Yard
Every year, DFDS sails 2.1 million nautical miles in the North Sea and the Baltic Sea, so even a small reduction of fuel consumption per voyage will result in a considerable fuel reduction per year.

By using accurate information on sea current, weather and shallow water in combination with accurate mathematical models of the ship's propulsion plant, it is possible to determine the most fuel efficient route and thereby reduce CO₂ emissions.

Originally, SeaPlanner was an application used for deep sea shipping. In 2008, DFDS and FORCE Technology agreed to further enhance SeaPlanner by making it feasible for short sea shipping as well. Short sea shipping requires a route planning system with a very high level of detail, when sailing in waters with rapidly changing weather and sea conditions, including the influence of shallow water.

Intuitive fuel saving
A key element in the SeaPlanner application is the up-to-date weather forecasts from the Danish Meteorological Institute (DMI). For the areas in question – the North Sea and the Baltic Sea – a special model has been developed to cater for the rapidly changing conditions; in particular the currents which are primarily determined by the tide and overlaid by wind-driven currents. The geographical resolution of the model is about 0.1° in steps of 1 hour up to 54 hours which is unique for a route planning tool.

The effect of shallow water is considerable in many areas of the DFDS route network, and a detailed bathymetry model for the areas has been established with a resolution of 1/180°, which is required to simulate crossing of e.g. Dogger Bank.

Furthermore, by using a precise mathematical model of the propulsion plants, SeaPlanner is able to estimate the resistance components of a ship in a seaway, i.e. the still water resistance, resistance from waves and wind and the effect of shallow water. By means of the propeller characteristics, the required power of the main engines is calculated and eventually also the fuel oil consumption.

Choosing the optimal route, adjusting the speed and avoiding hard weather reduces the fuel consumption significantly. FORCE Technology and DFDS agreed on installing a newly developed and advanced route planning tool, SeaPlanner, on six of DFDS' ships operating in the North Sea and the Baltic Sea. The initial tests confirm that it is possible to save a considerable amount of fuel.

The entire process of retrieving updated weather data and selecting the optimal route is done within a few minutes.

The application has been thoroughly tested on two DFDS vessels in the North Sea for usability and precision in route planning, and SeaPlanner will now be installed on four more ships due to a good experience.

Project facts
Category: Operation
Emission reductions:
- CO₂ 2 %
- NOₓ 2 %
- SO₂ 2 %

Partners:
- DFDS
- FORCE Technology
Fouling of the ship's hull leads to added ship resistance and thus increase fuel consumption and CO₂ emissions. In 2008, Hempel introduced the fouling release coating system HEMPASIL X3 which is copper and biocide free paint that reduces the water resistance.

In order to determine the potential fuel savings from the new hydrogel silicone coating, HEMPEL and FORCE Technology have started a project in which both model test and full-scale validation are key components. During the next 12 months, FORCE Technology’s performance monitoring application, SeaTrend, is used to investigate the anti-fouling abilities of HEMPASIL X3 in order to determine the fuel savings on different ship types.

The primary new technological feature in HEMPASIL X3 is the hydrogel which is a network of polymer chains that are water-insoluble. The hydrogel is superabsorbent and possesses a high degree of flexibility due to the significant water content. The hydrogel works by forming an invisible barrier between the solid silicone coating and the seawater. As a consequence, fouling organisms perceive the hydrogel as a liquid and will not be able to attach to the hull.

Fuel savings of above 8 % are confirmed from tests applying HEMPASIL X3 to a number of different ship types with significant differences in hull shapes, wetted area and operation. Saving fuel is a big issue in the shipping industry as the cost of oil is 75-85 % of the daily running costs for a container ship operator. To give an example of the actual value of HEMPASIL X3, a 7500 TEU container vessel and a fuel consumption of 75 tons per day could save around 1.3 million USD during a five-year docking interval, given a fuel price of 220 USD per tons. This corresponds to reduced CO2 emissions of 18,500 tons.

HEMPASIL X3 not only saves the operator money on the bottom line, it also dramatically reduces the carbon footprint, thus securing a healthier environment. HEMPASIL X3 has been developed to cater for both operational economy and global ecology, and by guaranteeing fuel savings, HEMPASIL also guarantees a reduction in the CO₂ emissions. A reduction in a vessel’s CO₂ emissions is a valuable asset as many ship owners strive to reduce their fleet’s carbon footprint.

**Project facts**

**Category:** Operation

**Emission reductions:**
- CO₂: 3-8 %
- NOₓ: 3-8 %
- SOₓ: 3-8 %

**Partners:**
- FORCE Technology
- HEMPEL
Nitrogen oxides, NO\textsubscript{x}, are created in the extremely high temperatures reached through the combustion process. By lowering the peak temperature in the combustion process, the NO\textsubscript{x} formation will also be lowered. However, reducing the peak temperature might introduce a drawback on the CO\textsubscript{2} emissions.

A way to lower the peak temperature is by adding water to the fuel, as the water will evaporate and increase the heat capacity of the gas in the combustion chamber. This will lower the peak temperature and thereby reduce the NO\textsubscript{x} formation.

Experiences already obtained show that by adding water to fuel, the reduction of NO\textsubscript{x} can be as high as 30-35%. This reduction, however, comes with the price of an increase in CO\textsubscript{2} emissions of 1-2%. However, using water in fuel oil opens for additional possibilities, namely the advantage of using other settings of the engine than the ones needed without WIF to adapt the engine’s IMO Tier II certification and thereby improving fuel consumption. Another advantage is the reduction of fuel consumption when used in combination with e.g. turbochargers with variable nozzle areas. Normally, the maximum potential of using turbochargers to reduce fuel consumption cannot be utilised as the NO\textsubscript{x} emissions would exceed an acceptable level; but the lowered temperature gained by adding water to the fuel oil eliminates this restriction.

What does it take to introduce a WIF system? In order to apply water in fuel systems aboard, it is necessary to make some minor alterations to both the engine and the auxiliary system. In this project, we have thoroughly investigated an A.P. Moller - Maersk vessel built at Odense Steel Shipyard. Our study shows that, in general, the need for changes on MAN Diesel electrically controlled ME/ME-C and ME-B engines is very limited, whereas the mechanical camshaft engine types MC and MC-C require more extensive changes.

Regarding the auxiliary system, it is necessary to heat the emulsion to a higher temperature when adding water to the fuel oil, and the pressure in the system has to be increased in order to avoid evaporation of the water.

Furthermore, fuel to the auxiliary engines will have to be supplied from a separate fuel oil system as they will not be capable of operating on the same amount of water. Therefore, a larger freshwater generator is needed. For existing vessels, this means that the piping system and many of the components need to be replaced which will be relatively costly and very time consuming unless it is done at a shipyard.

For newbuildings, the extra investment is limited, as many of the components differ only a little from their usual specifications and placements in the systems.

**Project facts**

**Category:** Machinery

**Emission reductions:**

NO\textsubscript{x} 30-35%

**Partners:**

A.P. Moller-Maersk

Aalborg Industries

MAN Diesel
Danish Marine Group

Over the last decades, the Danish maritime industry has overcome large changes in the global market conditions. From being a strong shipbuilding nation in the 1980s, the industry has gradually changed towards equipment and shipping.

To support this development, Danish Marine Group was established in the 1970s with the objective of organizing international exhibitions, conferences and other promotion activities. Today, Danish Marine Group has grown to become the largest and strongest maritime network in Denmark, representing almost 150 companies of all sizes.

Danish Marine Group is an active international partner in the ‘Green Ship of the Future’ arrangement. We act as partner and organizer of the international promotion campaign for the ‘Green Ship of the Future’. Conferences and workshops have been organized in Hamburg in 2008 followed by Shanghai, Athens, Hanoi and Ho Chi Minh City in 2009, and they will be followed by Singapore in 2010 and possibly by other maritime centers around the world.

The Transport Innovation Network

With The Transport Innovation Network, the Danish transport sector, has gained a broad national network that works to strengthen Denmark’s competitive position globally, and for sustainable, green transport solutions through increased innovation.

The Transport Innovation Network (TINV) is a national, cross disciplinary network aimed at the Danish Transport sector. The primary objectives of TINV are to create synergy, encourage match-making and generate research and development projects between stakeholders in the transport sector and research- and educational institutions, as well as related sectors such as energy and infrastructure. Among the TINV focus areas are climate and environment, energy-, logistics- and transport optimization, matchmaking and safety.

Current activities and networks
A1 Electric Transport
A2 Intermodality, Short Sea Shipping and Port Design
A3 Vehicle- and Ship Technology (incl. Sustainable Fuels)
A4 ICT in Transport and Logistics (incl. E-business)
A5 City Logistics of Tomorrow
A6 Corporate Social Responsibility
A7 Mobility, Traffic Congestion, and Behavioral Management
A8 Integrated Product/Service Systems

TINV and GSF
TINV is part of the GSF project as a network partner. Our primary role is to convey and disseminate results. We also contribute with knowledge and results from surface transport and logistics.

Background
TINV was initiated by the Danish Technological Institute, FORCE Technology, Maritime Development Centre of Europe and the Society for Danish Transport Economics. The secretariat is shared between these partners, and backed by a consortium that further includes University of Southern Denmark and Technological University of Denmark.

TINV is funded by the Danish Agency for Science, Technology and Innovation and is planned to run for a period of 4 years.

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