3.2.2. Final output report Specification Requirements North Sea Region Ferry

Itransfer report
Robert Luth
Damen Shipyards Gorinchem
19.09.2013

The Interreg IVB North Sea Region Programme
investing in the future by working together for a sustainable and competitive region

European Regional Development Fund
Investing in your future

iTransfer sustainable ferry travel

DAMEN SHIPYARDS GORINCHEM

S-DSG-017-0104

Contents

1. Introduction

The intention of this project is to develop a new, innovative and clean ferry suitable for the North Sea Region (NSR). This region has a unique set of external parameters that have such an impact on the design of a ferry that it justifies to develop a dedicated ship design for this region. A general design ferry is just not suitable for this area. A number of these unique parameters are:

- shallow water, even with dry falling land during low water, having an impact on the draught of the vessel, but also on the sailing route.
- high tidal range, having an impact on the interconnection between vessel and shore
- high current velocities, having an impact on the maximum speed to be achieved and on the difference in absorbed power when sailing with the current and against the current
- high wind speeds, having an impact on the manoeuvring capabilities of the vessel
- confined ports, having an impact on the dimensions of the vessel
- environmental protection of area, having an impact on (mainly reducing) possibilities to expand existing harbours or to develop new harbours

This project was part funded by iTransfer (www.itransfer.eu), an INTERREG IVB North Sea Region programme project.

2. Goals

The goal set for the NSR ferry is to significantly reduce the impact of the vessel on the environment by reducing the exhaust gas emissions. The target is to achieve

- >90% reduction SOx
- >90% reduction NOx
- >90% reduction PM
- 50% reduction in CO2

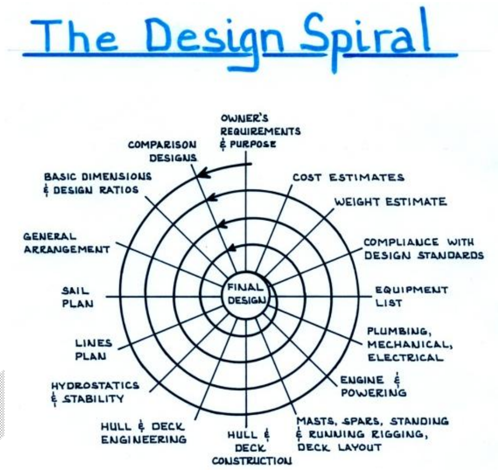
The first three can be achieved by after-treatment of exhaust gasses, or by using low sulphur fuels. The latter can only be achieved by using alternative fueles, such as LNG, or by reducing the overall fuel consumption of the vessel, for instance by reducing its resistance.

DAMEN

3. Approach of work

The general accepted method for ship design is to first establish the owner's functional requirements: the main functionalities that the design has to fulfil. The second stage consists of going through the so called "design spiral". In a number of loops, a series of design issues is evaluated, every loop in more detail until the final design is achieved. The design issues for the present vessel comprise of:

- The main dimension
- a general arrangement plan (drawing)
- weight and stability calculations
- powering calculations
- class and flag state rules
- costs

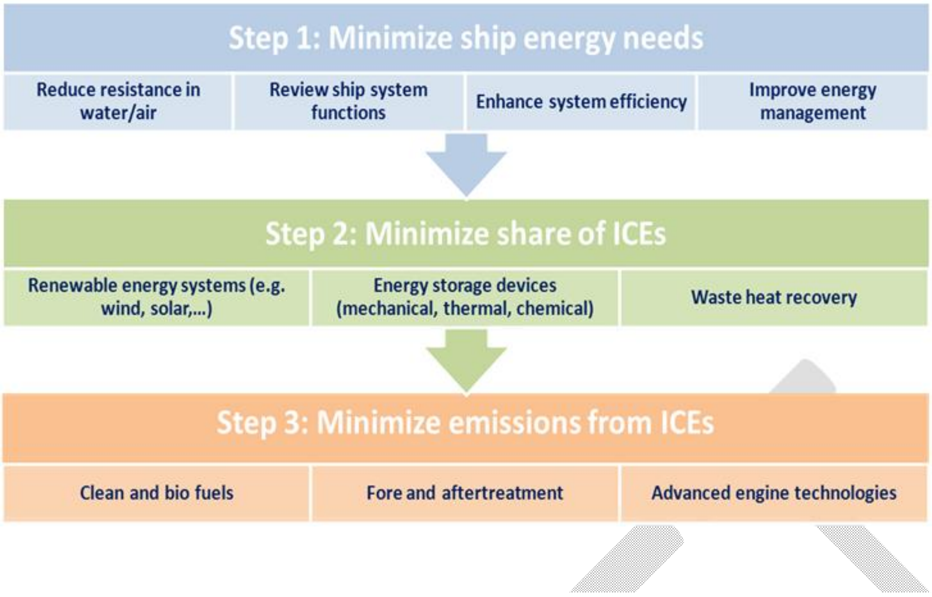


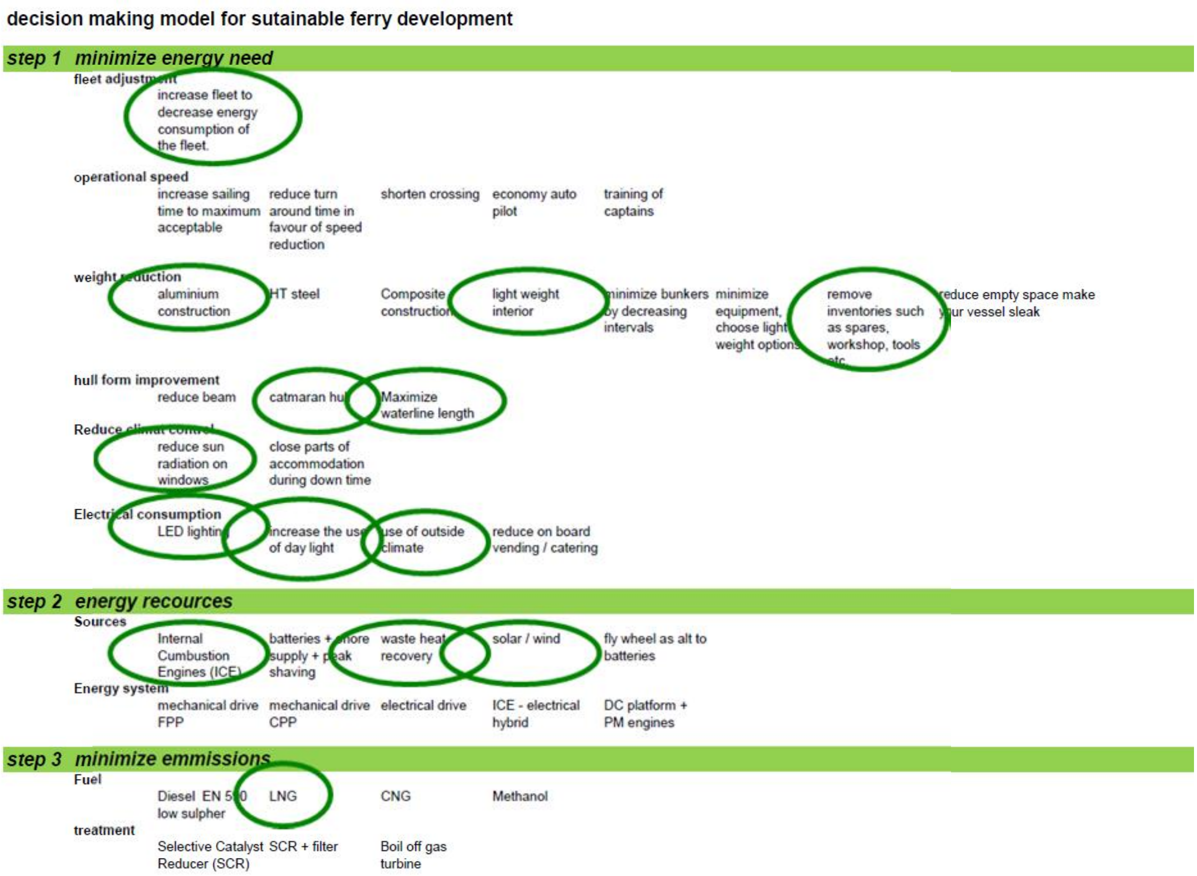
The owner's requirements were determined in cooperation with Rederij Doeksen and were checked and supplemented by all project partners during regular project meetings and the dedicated workshop at Damen Shipyards Gorinchem.

The design spiral was worked through by Damen. Results were presented to, discussed with and supplemented by Rederij Doeksen on a regular basis. The results were presented to, commented upon and supplemented by all project partners during regular project meetings and the dedicated workshop at Damen Shipyards Gorinchem.

The approach Damen adopted to achieve the most sustainable solution is shown in the figures on the next page. First the energy need of a vessel is reduced as far as possible by adopting measures to reduce the resistance of the vessel, by enhance the efficiencies of systems on board and by improving the energy management as much as possible. The second step is to minimise the share of Internal Combustion Engines (ICEs) by using renewable energy, energy storing devices and waste heat recovery where practical and useful. The third step is minimise the emission of any ICE that is still on board by adopting the use of clean and bio fuels, fore and after treatment of fuel and exhaust gasses and advanced energy technologies. This approach was adopted for the NSR ferry design. The second picture on the next page shows all the possible options that were evaluated for the design and it highlights the ones that were found to be useful and applicable for the present project.

DAMEN





S-DSG-017-0104

4. Functional requirements

The initial owner's requirements were determined in cooperation with Rederij Doeksen and were checked and supplemented by all project partners during regular project meetings and the dedicated workshop at Damen Shipyards Gorinchem. The following table summarises the main functional requirements

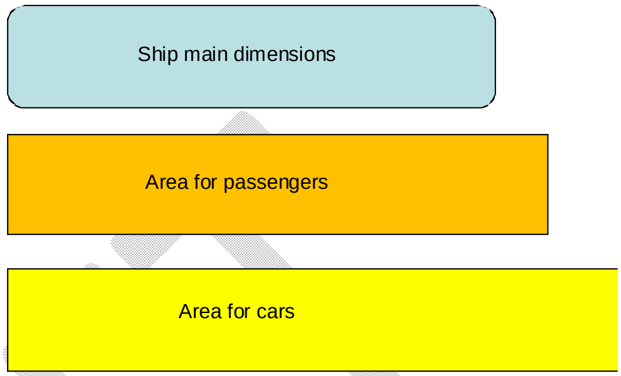
Functional requirements NSR Ferry

Maximum length	*75 m over all*
Maximum beam	*20 m over all*
Maximum draught	*2.6 m*
Number of passengers	*899*
Number of cars	*90 (each car spot 5 m in length)*
Number of trucklanes	*2*
Payload	*325 tons (cars + trucks + passengers+ luggage)*
Wind limit	*Up to and including Bft 9*
Wave limit	*2.0 m significant wave height*
Number of sailings	*6 single trips per day*
Sailing duration	*105 minutes from quay to quay*
(un-)loading time	*30 minutes turnaround time (unloading and loading)*
On-board services	*Toilets* *Restaurant* *Semi-enclosed bar* *Elevator* *Sick bay* *Crew mess and galley*
Rules and regulations	*Applicable for Waddensea*

5. First sketches and concepts

The first round through the design spiral consists of initial estimates of main dimensions ,weights and hull shape of the vessel.

An estimate was made of the average required area per passenger and per car. The results are given in the adjacent figure. It shows that for both the passengers and cars, the required area is more than the maximum ship dimensions accommodate. Therefore, more than one deck is required for both passengers and cars.



An initial weight calculation was made, comparing steel and aluminium as construction materials. A significant reduction in total weight, and consequently in resistance and fuel consumption of the vessel, was found for the aluminium hull and superstructure. In order to achieve the goals in reduction in CO_2 exhaust, aluminium was selected as construction material.

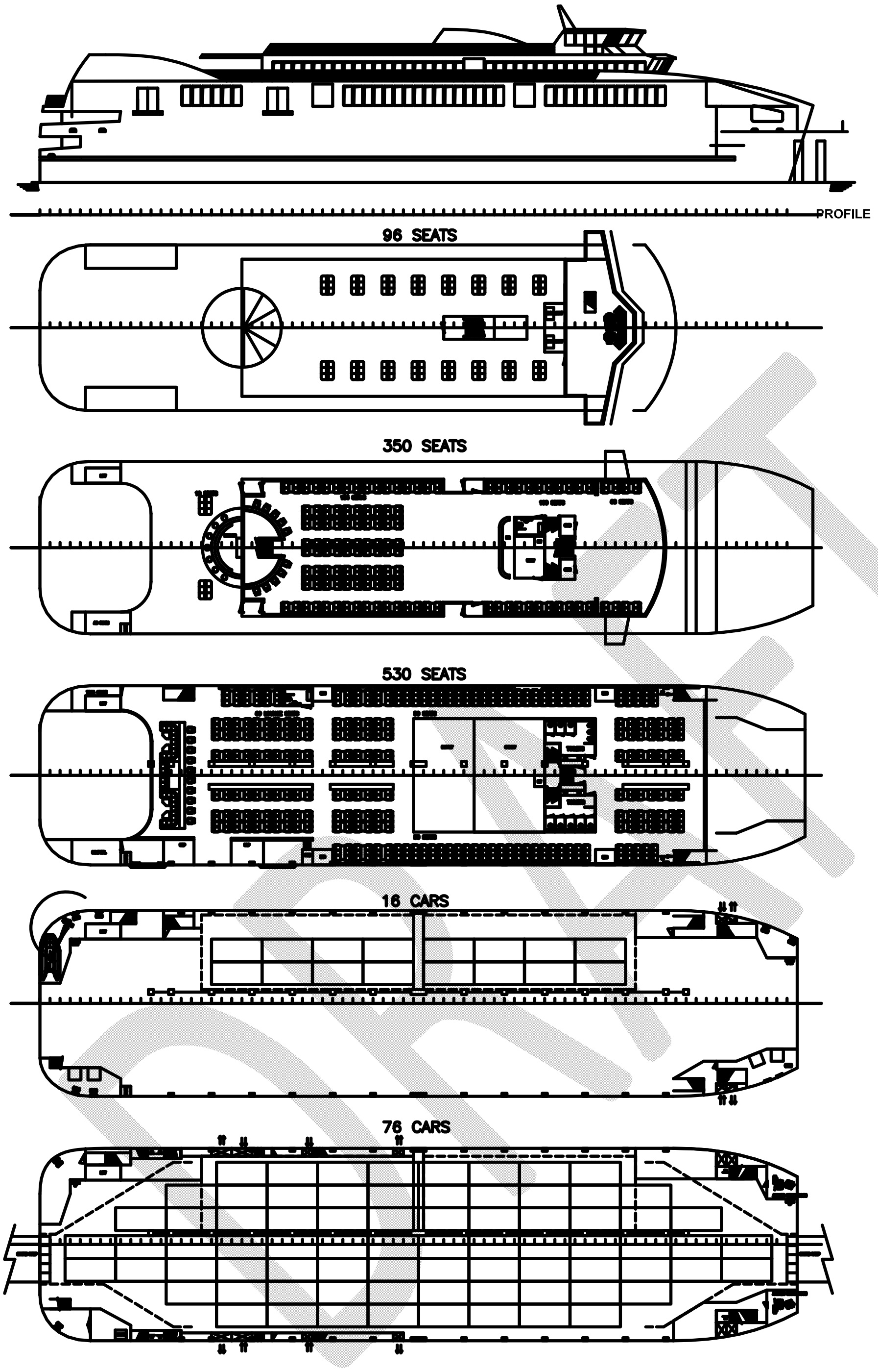
A comparison was make between a monohull and a catamaran hullform. A significant reduction in total resistance, and consequently in fuel consumption of the vessel, was found for the catamaran hull. In order to achieve the goals in reduction in CO_2 exhaust, the catamaran was selected as hull shape.

Initial intact and damaged stability calculations confirmed the viability of an aluminium catamaran concept.

A first design of the vessel was developed. The results are shown on the next pages.


REDERIJ DOEKSEN
GROENLAND


GROENLAND


PROFILE
96 SEATS
350 SEATS
530 SEATS
16 CARS
76 CARS

6. Contribution from the iTRANSFER project partner meeting

In this stage of the design, a workshop was organised at the Damen Shipyards Gorinchem premises on September 15 and 15, 2011. During this two day event, the results of the first design spiral loop were presented. Due to the excellent timing of this workshop, the design was developed far enough to show the innovative solutions to achieve the goals of the project, but still in a stage that the input of project partners could be incorporated in the design easily.

The workshop was attended by

- 6 persons from 4 ship operating companies
- 6 persons from 2 ship design offices
- 3 persons from 2 public bodies
- 5 persons from other fields of expertise, representing ferry passengers

The above summary shows that all parties involved in ship design and operation were present during the workshop.

The workshop was used to introduce the design of the vessel and the expertise of other participants and to exchange ideas and input on the ferry design. In this ways, optimum benefit was achieved from the available know how and day-to-day experiences of the project partners, representing operators, public bodies and engineering competences. This trans-national approach developed a new ferry design which increased the quality, operability, and sustainability to a maximum level. The North Sea Regions accessibility and sustainability of NSR passenger transportation benefits from this new ferry design.

Some basic statements extracted from the workshop:

- Passengers are prepared to pay for greener ferry vessels, because people are generally aware of CO2 and environmental issues
- The less choice passengers have in terms of different ferry services, the more advanced the sustainability issues with a negative impact on transport prices can be implemented
- A balance between higher charges and higher profit margins needs to be achieved
- The biggest cost in shipping is fuel and the crew, hence innovation in shipbuilding needs to focus on engine design and fuel cost reduction
- It is unrealistic to expect changes in landside infrastructure, e.g. landing facilities or port and docks infrastructure. If government wants real change, the landside infrastructure needs to be changed, modernised, standardised, etc. as well. There is a huge dis-synergy between policy and operations

By the discussion it was made crystal clear that sustainable ferry design cannot be achieved by design and construction only, because it's primarily influenced by the "landside" in terms of regulations and standards set by governmental and public national and international bodies (such as IMO).

Following outputs and results of the discussion in terms of greener ferries in the NSR have been jointly elaborated by the partners:

1. Innovative operational and landside design issues

- The landside and seaside ferry operation and infrastructure has to go hand in hand. The relevant public body responsible for the landside government has to make sure that landing stages are flexible and can be adjusted to the needs of the ferry operator
- Pre-sorting of cars at landside as well as wide landing bridge with several lanes ensures fast loading and unloading
- Training of ferry crew in terms of sustainability and efficiency must be further intensified (not just in terms of fuel efficiency, but also detergent use etc was discussed)
- Technical standardisation of government's ferry terminals limits market entrance threshold for new operators and enables fast and unrestricted access and operation by new concessionaire
- Clean cars on shore to get rid of salt. This reduces the corrosion onboard the vessel and reduces maintenance requirements

2. Innovative ferry design issues

- Reducing ship's weight by constructing an aluminium ship's hull (even made out of recycled aluminium) is a major factor for less fuel consumption respectively CO_2 emission.
- Intelligent allocation of landing bridge in line with the ship's centre avoids to install and use balance tanks to compensate weight unbalances on the ferry vessel. Less ferry weight – less fuel – less CO_2.
- Reducing thickness of walls and plates where possible.
- Bulbs on the deck to make sure that car drivers driving onto the ferry know where to park the car ensuring a maximum use of the limited car park space
- Using chemicals for ferry's window cleaning with negative impact on the NSR nature can be reduced by adapting window design to enable easier cleaning, e.g. footsteps underneath ferry windows.
- Car deck should not be painted to increase safety by less electrostatic and by better grip and safety for cars and passengers .
- Using LNG as the mode of propulsion will significantly reduce CO_2 emissions. However, this technology is still under investigation and requires further design work.
- Applying the business model from the air transport industry (Low Cost Carrier business model) the reduction of any catering or restaurants or duty free shops on board of a ferry vessel was discussed. Offering proper services at the port of destination or arrival might avoid the need for any facilities on board, leading to a major reduction of energy consumption (-10 %) and ferry's weight, ending up with a smaller engine and less CO_2.

However, also operator's commercial sustainability without any of those facilities on board must be considered.

- Balance the design for all loading conditions in such a way that no ballast water is needed to keep the ship in a condition without heel or trim. This reduces the weight of the vessel and consequently, its fuel consumption.
- Increase use of shore electrical supply to reduce local emissions of on-board generator sets
- Make the "green parts" on the ship visible for passengers.
- On-board storage for foot passenger hand luggage.

Discussion on Innovative ferry design issues

- Green ships can save the operators money, but can also cost more. Although there are reputational benefits for operators.
- Green ships can also be less efficient. For example 'green' engines can burn more fuel.

The raised issues and suggestions have been incorporated in the further loops through the design spiral.

7. Initial analysis and comparison of propulsion systems

A survey of available LNG engines was made. The conclusion was that at the time of the analysis, LNG engines direct driving a fixed pitch propeller are available only at power levels much higher than required for the NSR ferry. Smaller engines, within the applicable power range, are all constant speed engines suitable for electricity generating only. Therefore, an LNG-electric platform was selected. To compare the results of the LNG version, a diesel direct concept with exhaust gas cleaners was selected. This exhaust gas cleaning system comprises a Selective Catalytic Reduction unit and a sooth filter.

From the input of the project partners during and after the workshop it became clear that bunkering of LNG is a critical issue in the operation of an LNG-driven ferry. Issues are

- It takes a lot of time to connect hoses and prepare the system for actual bunkering.
- The actual bunkering process is time consuming
- For safety reasons, bunkering cannot be done during unloading and loading of passengers and cars.
- For safety reasons bunkering cannot be done at the normal (un-)loading facility. A special, fenced area is required.
- The vessel stay overnight at an island, while the bunker station is located on shore. Therefore, bunkering is not possible outside the normal sailing hours of the vessel. However, due to the long bunkering time, a conventional bunkering procedure it is also not possible within the normal operating hours. Together with international suppliers, a system of fast replaceable cartridges was developed, making it possible to change a fuel storage cartridge between unloading and loading of passengers and cars.

Another issue that became apparent is that during bunkering and burning of LNG in an engine, raw methane gas can escape from the system. Although the quantities are relatively low, the impact on the environment is approximately 20 times higher than that of CO_2. This so-called methane-slip is accounted in the environmental assessment as well.

An extensive analysis was made of the fuel consumption of the vessel over the route, including the effects of wind, current, tide and loading condition. The results are shown in the table below. It shows that a large benefit is found for the aluminium catamaran.

	Relative fuel consumption for an LNG-electric ferry	
	At a constant speed of 12.5 kn	Over the yearly sailing profile
Aluminium Catamaran	100%	100%
Aluminium Monohull	120%	110%
Steel Monohull	170%	145%

The table below shows that energy consumption over a day of the LNG and diesel version. It clearly shows that for this design, the energy consumption of the diesel version is lower than the NLG version.

	Relative fuel consumption for an NSR ferry	
	Diesel + SCR + sooth filter	LNG-electric
Daily energy consumption	100%	116%

The following issues explain this result

- The sailing schedule of Rederij Doeksen does not allow for refuelling outside the normal operating hours. This is solved by using LNG cartridges that can be interchanged between unloading and loading of passengers and cars. This realises a significant reduction in weight over one or two large fixed LNG tanks with a capacity of more than a week.
- LNG-direct drive is not possible at the power levels foreseen in the present design. Therefore a LNG-electric platform is required. This implies a significant energy loss in conversion from kinetic energy to electric energy, in distribution of electric energy and in conversion from electric energy to kinetic energy again.
- The efficiency of LNG engines at power levels lower than nominal is significantly lower than that of a diesel engine.

The following table shows the reduction of emissions of both propulsion options.

	Emissions based on daily sailing profile			
	Steel monohull	Aluminium catamaran		Goal
	Diesel	Diesel +SCR + sooth filter	LNG-electric	
NOx	100%	13%	15%	< 10%
SOx	100%	81%	0%	< 10%
PM	100%	3%	2%	< 10%
CO2	100%	81%	73%	50%
CO2 including effect of methane slip			92%	

The results show that there is a relatively small difference between the diesel and the LNG option. The goals as described in section 2 are (almost) met with both the diesel and LNG options if it concerns NOx, SOx and PM. The NOx figures can most probably be reduced to below the goal by slightly adjusting the SCR installation.

The goal for CO2 reduction is not completely met. This is mainly due to the energy conversion losses of an LNG-electric installation and due to methane slip. Once LNG drive engines suitable for direct driving a propeller become available in the applicable power range, it should be possible to achive this goal as well.

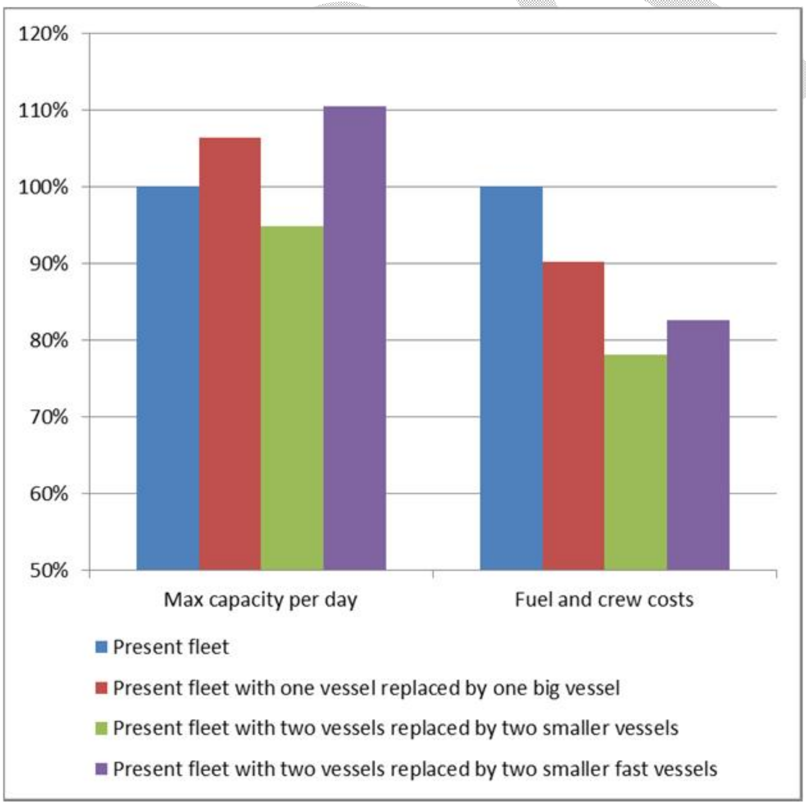
DAMEN

8. Fleet management

During the development of the first vessel it became apparent that the vessel became extremely large for the quay it had to use and for the shallow waters it had to sail in. The question was raised if two smaller vessels, each with a lower fuel consumption and easily fitting the quay and shallow waters, could be more economic that one big vessel. Therefore, a load carrying and costs analysis of the present fleet of five vessel was made and compare to three options where one or two of the existing vessels were replaced by new vessels. The following options were analysed:

1. Present fleet, consisting of a mix of passenger vessels, cargo vessels and a high speed vessel
2. Fleet of option 1, where one vessel was replaced by one new, big vessel
3. Fleet of option 1, where two vessels were replaced by two new vessels, each smaller than the new vessel of option 2
4. Fleet of option 1, where two vessels were replaced by two new, smaller vessels of option 3, but with a higher sailing speed.

The results are shown in the graph below. It shows that the capacity of option 2 and 4 are slightly higher than the present capacity and that the costs of option 3 are lowest. Based on these results, it was decided to focus on development of a smaller vessels with a normal operating speed.



The functional requirement of this smaller vessel are shown in the table below.

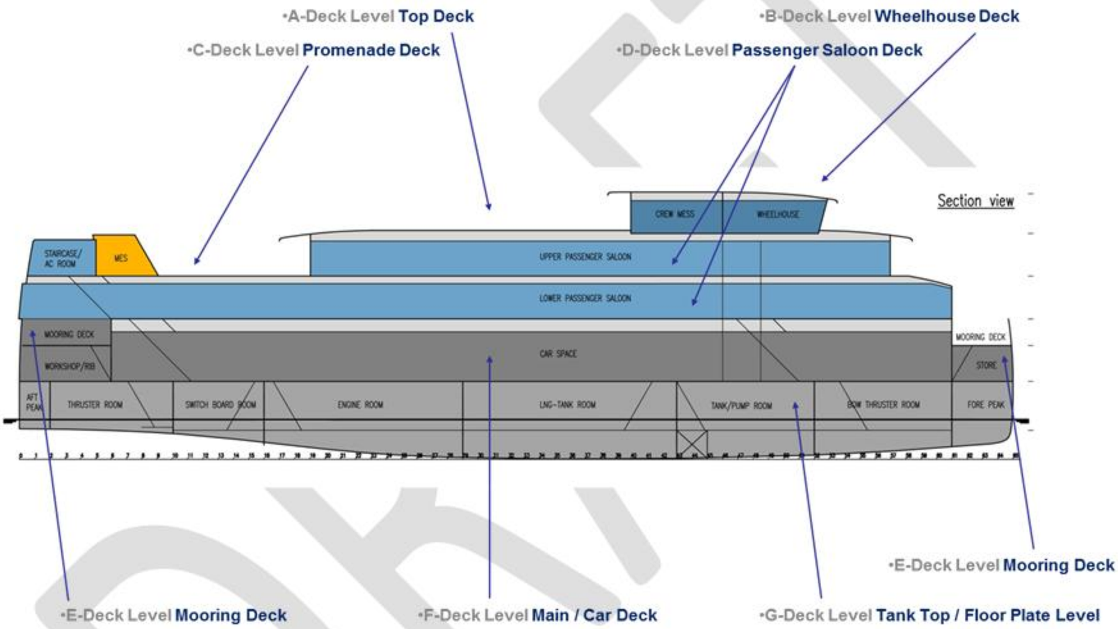
Functional requirements smaller NSR Ferry

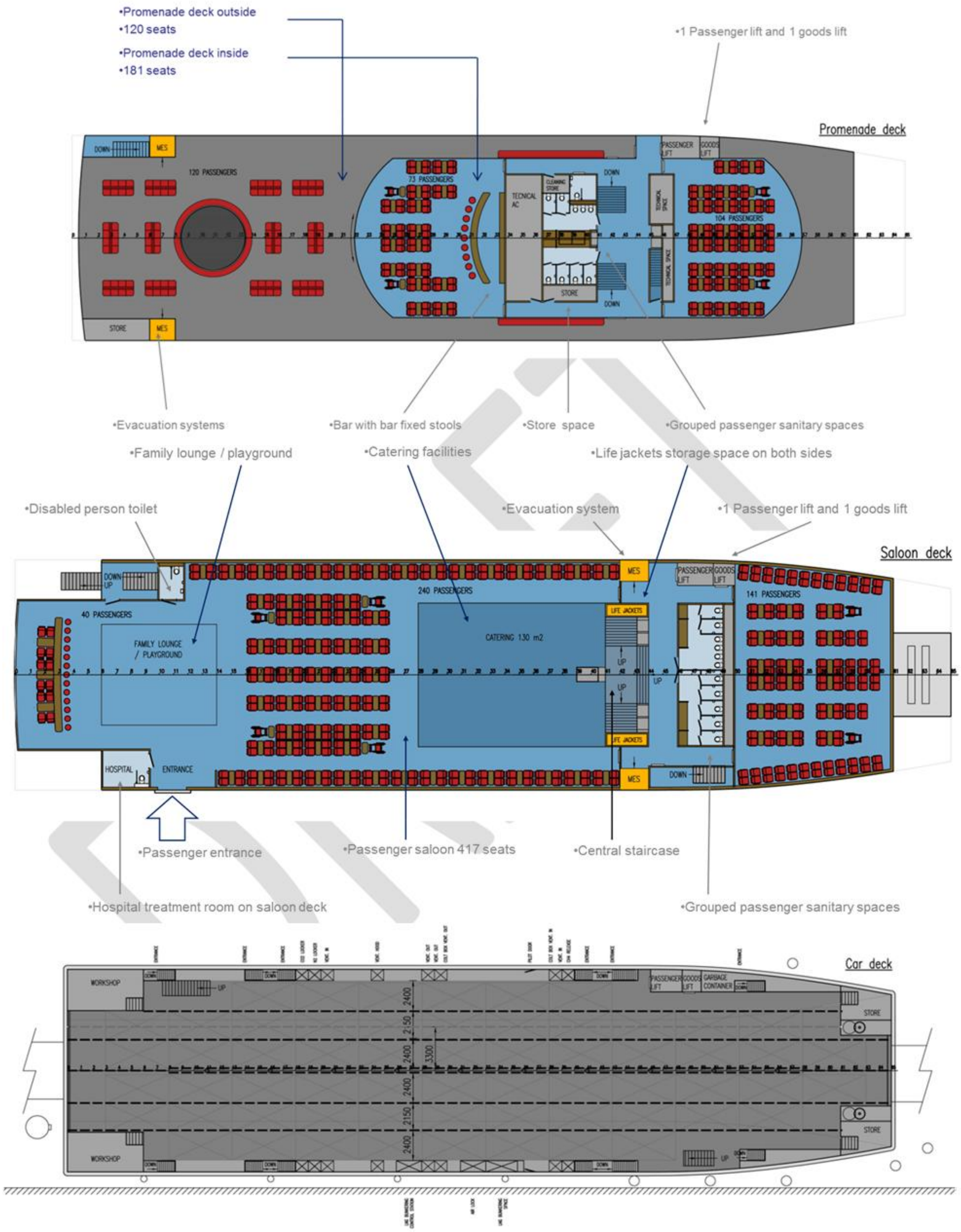
Maximum length	*66 m over all*
Maximum beam	*17 m over all*
Maximum draught	*2.6 m*
Number of passengers	*599*
Number of cars	*60*
Number of trucklanes	*1*
Payload	*140 tons (cars + trucks + passengers+ luggage)*
Wind limit	*Up to and including Bft 9*
Wave limit	*2.0 m significant wave height*
Number of sailings	*6 single trips per day*
Sailing duration	*105 minutes from quay to quay*
(un-)loading time	*30 minutes turnaround time (unloading and loading)*
On-board services	*Toilets* *Restaurant* *Semi-enclosed bar* *Elevator* *Sick bay* *Crew mess and galley*
Rules and regulations	*Applicable for Waddensea*

DAMEN

9. The smaller NSR Ferry

A new design was made according to the new requirements. The result is shown below and on the next page. Some features are highlighted. With the new design a more versatile use of vessels is possible. If it is very busy, two vessels can be used to increase the passenger and capacity. On the other hand, in quiet times only one vessel has to sail, which leads to a significant reduction in fuel consumption.



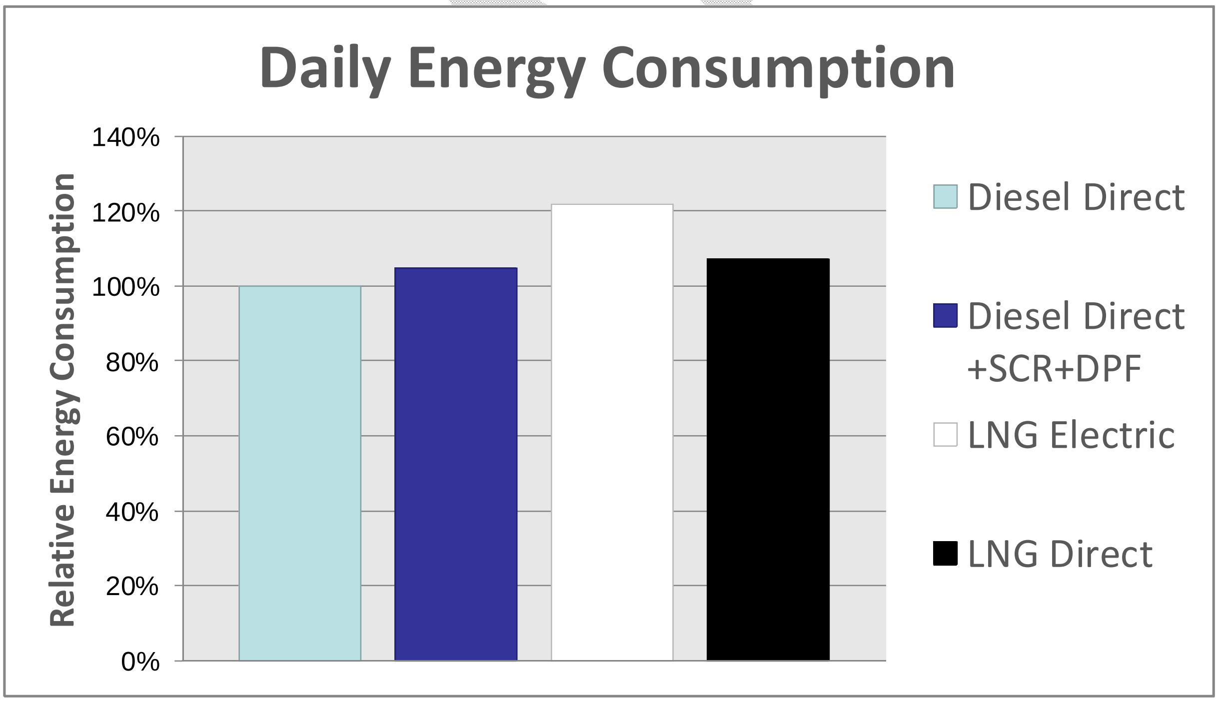

•Promenade deck outside
•120 seats
•Promenade deck inside
•181 seats
•1 Passenger lift and 1 goods lift
Promenade deck
120 PASSENGERS
73 PASSENGERS
104 PASSENGERS
•Evacuation systems
•Bar with bar fixed stools
•Store space
•Grouped passenger sanitary spaces
•Family lounge / playground
•Catering facilities
•Life jackets storage space on both sides
•Disabled person toilet
•Evacuation system
•1 Passenger lift and 1 goods lift
Saloon deck
40 PASSENGERS
FAMILY LOUNGE / PLAYGROUND
240 PASSENGERS
CATERING 130 m2
141 PASSENGERS
HOSPITAL
ENTRANCE
•Passenger entrance
•Passenger saloon 417 seats
•Central staircase
•Hospital treatment room on saloon deck
•Grouped passenger sanitary spaces
Car deck
WORKSHOP
STORE

10. Final development of propulsion system

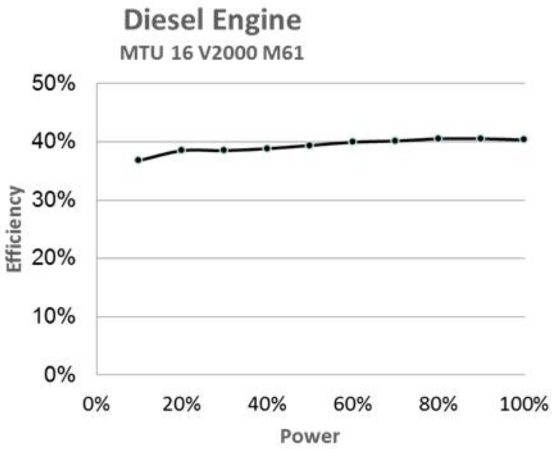
A new analysis of the propulsion system was made for the smaller NSR ferry. During this analysis it became apparent that NLG direct propulsion, in combination with azimuthing thrusters, would become available within the foreseen building period of the vessel. Therefore, is option was included in the analysis as well. The following propulsion configurations were analysed

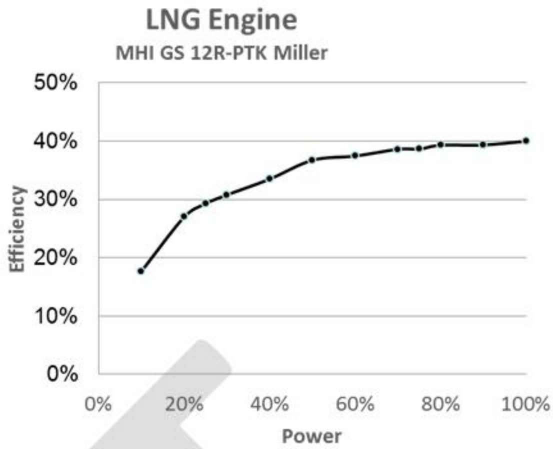
- Base: Diesel Direct with generator sets
- Alternative 1 Diesel Direct + exhaust scrubber) + particulae filter+ generator sets
- Alternative 2 LNG – electric propulsion
- Alternative 3 LNG direct propulsion

The average daily energy consumption was calculated over a year of operation. The results are included in the table below. It shows that the Diesel Direct option still consumes the least energy. Alternative 1 needs additional energy to run the exhaust scrubber and the particulate filter. Alternative 2 suffers significant energy loss due to conversion of energy from mechanical to electric and back. Alternative 3 suffers from very low efficiency of the engine at low power levels. This is illustrated in the figure on the next page.

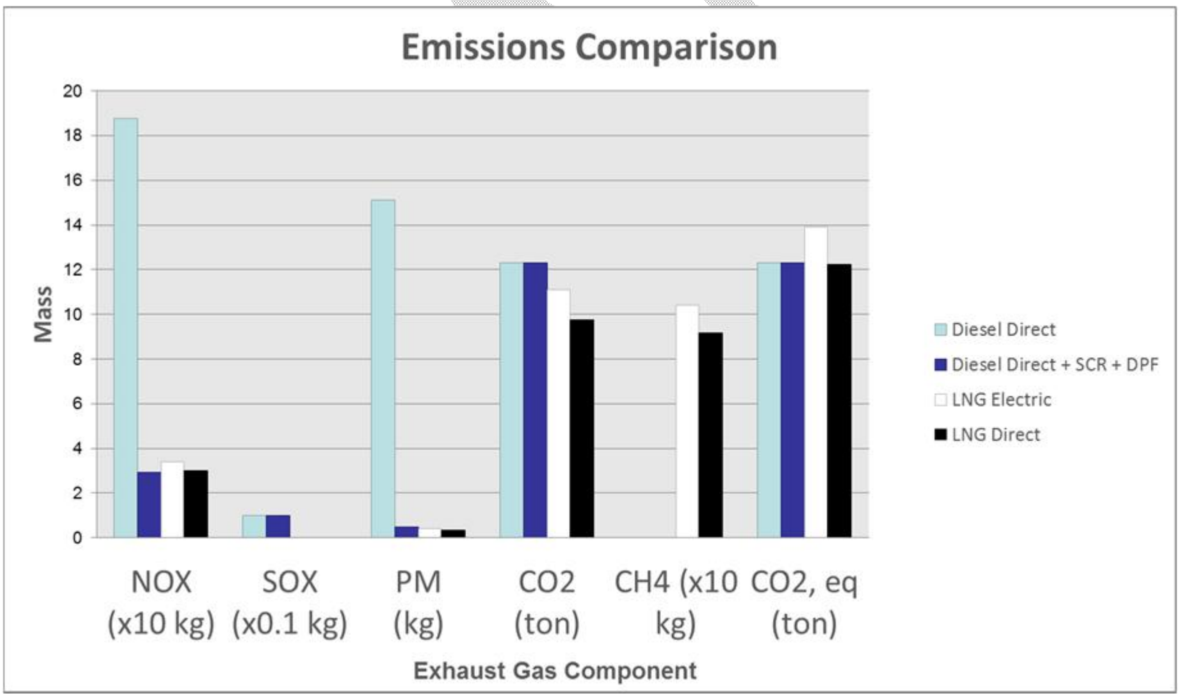


DAMEN





The average emissions in a year of operation are shown in the figure below. It shows that the diesel direct option performs bad in NOx and SOx reduction. Applying an exhaust scrubber and particulate filter (alternative 1) reduces the overall emissions to the lowest of all options, comparable with the LNG direct alternative. The LNG electric option shows the highest emissions, mainly due to high energy conversion losses.



An often mentioned argument for applying LNG is that LNG is cheaper than marine fuel oil. This should offset the higher initial costs for the LNG installation on board. The table below lists the costs of various alternatives. It shows that MGO is the most expensive fuel oil and that electricity from the land based grid is the cheapest.

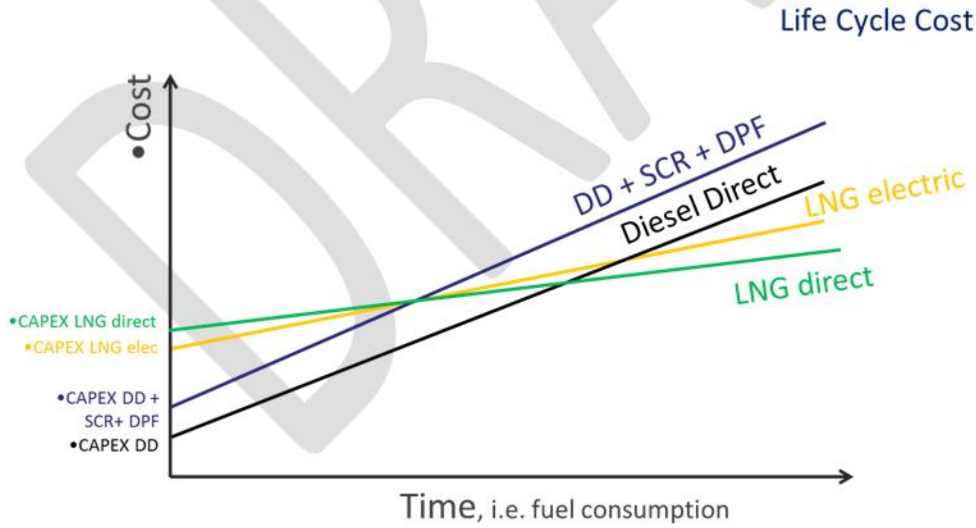
S-DSG-017-0104

DAMEN

- MGO EN 590 = (USD 864/ton) = E 0,137/kWh
- HFO 380 = (USD 864/ton) = E 0,084/kWh
- LNG = (65% of EN 590) = E 0,089/kWh
- Aardgas (NL) = E 0,110/kWh
- E-shore supply = E 0,062/kWh

Notes
- *Price level may 2013*
- *Fuel prices vary +/-25%*
- *LNG is linked to cost of MGO in many cases*
- *E-shore supply based on Delta energy NL.*
- *Aardgas based on retail price and quality "Dutch gas"*

The initial costs (Capex) and fuel consumption costs over time were determined for all four alternatives. The figure below shows the results. It can be seen that the initial extra costs for the LNG installation is off-set by lower fuel costs after a certain period. This period heavily depends on the operation profile of the vessel. When the vessel is used for a high number of hours per day, this period is shorter than when the vessel is used only a couple of hours per day. The result of the present project is that it is now possible to determine both the initial costs and operational costs so that the most suitable solutions can be determined for each individual ferry line.



11. Conclusions

From the results of this study the following conclusions can be drawn:

- In takes bold steps to significantly reduce the emissions of a ferry. For instance, only changing the lighting from conventional to LED, or installing solar panels will not result in significant emission reductions. In the present case, it took changing the building material, the basic shape of the hull, the size and number of vessels together to make a significant difference.
- The goals for reducing emissions are almost met. Meeting SOx, NOx and PM emission reductions in the order of 90% is possible, but comes at a price. Reducing CO2 emissions by 50% seems to be very challenging within the constraints of a service contract with fixed departure and arrival time.
- Changing the infrastructure around the vessel (quays, harbor entrance, depth on the route) can have a significant effect on the efficiency of a ferry operation. However, in many cases these are operated by another (governmental) entity and are therefore more difficult to be influenced by the ferry operator.
- Involving individuals not usually working on ferry design in the process of reducing emissions resulted in interesting viewpoints and out-of-the-box solutions.
- Developments in the LNG technology are progressing fast. The LNG-direct propulsion system that was regarded not feasible at the start of the project became a serious possibility in the course of the project.