Productivity-improving measures on steel-structures in ships and their relative effect on the CO2-emissions over a lifespan

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Productivity-improving measures on steel-structures in ships and their relative effect on the CO2-emissions over a lifespan

This master thesis should look into the consequences of designing a simplified (efficient to produce) ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle. An LCA (Life-Cycle Analysis) approach is to be used to analyze the effects and the relative impact of changes. A sample ship (e.g. "EK River") is to be used as case, potentially being used for generalization purposes. Samples of measures taken during production, and that may affect the CO2-emissions, are:

- A simplified steel structure results in fewer welding meters in the production and less work with edge trimming
- A simplified structure gives better resistance against corrosion due to better surface treatment, and less structural replacement is both economical and environmental profitable.
- A simplified steel structure gives an added lightship weight.

The work will consist of:

- Developing a LCA (lifecycle analyses) of the total amount of CO2 emissions and the economical changes trough the ships lifecycle. The LCA should consist of data from the sample ship, if possible should it be scaled to be applied to other ship sizes and types.
- As stated in the pre-study report, and from former studies, low emissions in the operational phase are not always equally to low CO2-emmisions over a lifespan. The LCA method is for that reason the perfect method to measure the carbon footprint from different hull designs. Key number should be the total CO2 emissions during the lifetime, divided by the sum of nautical miles sailed and the amount of cargo freighted.

- It is always desirable to have as low CO2 emissions as possible, but low emissions solutions are not always the most economical. For that reason should an LCC-analysis (Life Cycle Cost) be connected with the LCA-analysis to get a key number on the cost of lower emissions.

- The sample ship EK River should be used in the LCA / LCC-analysis and as a help should DNVs program PCT ”Pre Contract Tool” should be used so it is possible to compare the original ship with the modified and simplified ship. As mentioned before, if possible, should the results and the information data be scaled to be applied to other ship sizes and types.

Preface

This master thesis is written at the Institute of marine systems at the Norwegian University of Science spring 2011. The task is defined in collaboration between Professor Arnulf Hagen and student Lasse Wichstrøm and is essentially a continuation of the work done on the project autumn 2010. The main task have been to look into the consequences of designing a simplified (efficient to produce) ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle. Work has been both interesting and demanding, the biggest challenge has been to find trustworthy information and to make good assumptions based on the information gathered.

I would like to thank my supervisor Arnulf Hagen and his colleagues at DNV proNavis for good and constructive feedback throughout the work with the thesis.

Trondheim 10 June 2011

Lasse Wichstrøm

Summary

Although maritime transport are surely the most environmentally friendly way to transport , number of tones cargo shipped versus total CO2 emissions, is it great opportunities and possibilities for further improvement. *A life cycle assessment is a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave.* LCA analysis is not as common in the shipping industry, but is on its way to becoming an important tool to outline and hopefully reduce emissions. It has earlier been shown that the operation phase is the phase where a ship pollutes the most during a lifetime[1], so the main goal in this thesis is to take a look into the consequences of designing a simplified (efficient to produce) ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle.

Building as cheap as possible has always been important in the shipping industry, one way to cut the building cost can be to simplify the steel structure of the ship and in that way reduce the man hour cost. In a collaboration with the MARINOR project ”production and maintenance friendly steel constructions” (source [2]) a rapport containing results from strength analyzes on a ship structure was made. The goal was to reduce or remove number of profiles, results showed that this was possible with a moderate increase in plate thickness. The chosen sample ship could remove 943 profiles with a following dead weight increase of 30 tons for a 17,500 dwt product tanker. This case has then been used to evaluate the effect a simplified steel structure has on the total emissions of CO2 during a ships lifetime. Results from the MARINOR project has been generalized to fit other ship sizes and results from the LCA showed the following results:

- Emissions from the building phase alone is about the same, only about 0,5 percent raise and that is mainly due to higher lightship weight. The saved emissions due to less welding, burning and edge trimming are not enough to actually bring some difference to the total emissions.
- The added steel weight is too little to give added emissions in the operation phase alone.
- The difference between the two ship structures are mainly the operation profile and the added life length of the ship.
- With the assumption of a added life length from 20 to 30 years the factor(g CO2 / Ton Freighted x Nm) have improved from 1,5 to 4 percent depending on the ship size, the reason is added lifetime and less steel replacement. Results show that the ships with higher Dwt/lightship factor trends to have higher environmental effects of a simplified steel structure.

At the economical point of view a ship with a simplified steel structure seems to cost about the same as a conventional design. With the assumption of an added lifecycle are the new design is about 30 percent cheaper. The reason is that the original ship needs three ships for a 60 year lifecycle, while the modified hull only needs two ships.

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Abbreviations

LCA-data: Data to be used in a Life Cycle Assessment

LCA: Life Cycle Assessment

MWh /kWh : Mega / Kilowatt hour

CO2 : Carbon Dioxide

Tonkm – The amount of cargo (in tons) transported over a distance (km)

Lightship weight: The weight of the ship without cargo

Dwt: Dead weight tonnage is a measure of the size or cargo carrying capacity of a ship

Displacement: Dwt + lightship weight

HFO : Heavy Fuel Oil

Introduction

Increased globalization and declining significant barriers in trade has led to increased transport, and today is as much as 90 percent of total freight handled by international maritime transport. Although maritime transport are surely the most environmentally friendly way to transport, the number of tones cargo shipped versus total CO2 emissions, there are great opportunities for further improvement. Increased focus on environmental impact and increased activity in the sector will result in stricter requirements for environmental considerations in transport[3]. Figure 1 shows the supremacy of ships as the most environmental way to freight cargo.

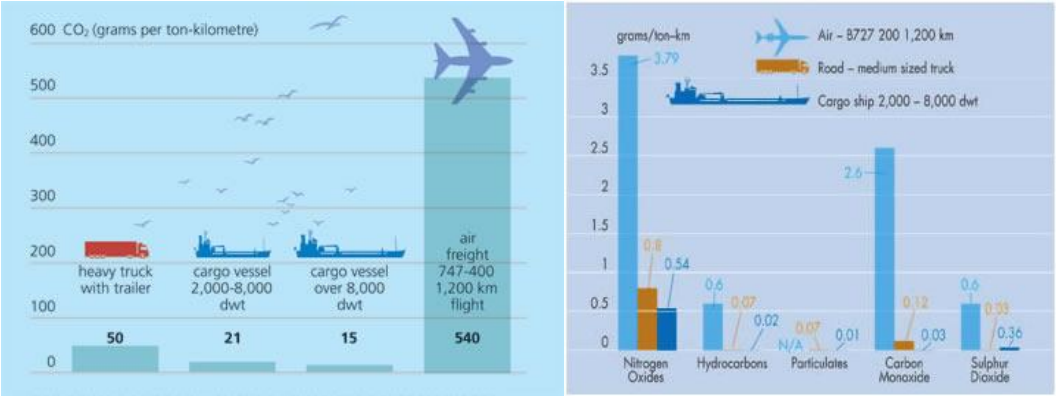

Figure 1 Emissions pr ton-kilometer for different ways of transport. (NMT Swedish Network for Transport and the Environment)

Other industries, and specially the automotive industry have started to use life cycle analysis (LCA), this analysis examines the emissions of a car, from production until it eventually gets scrapped and recycled. From source [4] it is stated the following *"A life cycle assessment (LCA, also known as life cycle analysis, ecobalance, and cradle-to-grave analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). LCA's can help avoid a narrow outlook on environmental concerns by:*

- *Compiling an inventory of relevant energy and material inputs and environmental releases;*
- *Evaluating the potential impacts associated with identified inputs and releases;*
- *Interpreting the results to help you make a more informed decision."*

LCA analysis is not as common in the shipping industry, but is on its way to becoming an important tool to reduce emissions. It has earlier been shown that the operation phase is the phase where a ship pollutes the most during a lifetime[1], this thesis shall look at the changes in the total emissions due to choices in the construction and design phase.

CO2 is not the only emission from shipping, the emissions with the greatest impact on air pollutions are CO2, SO2, NOx, and PM-emissions. This report shall be concentrated about (CO2) Carbon dioxide, the gas that is naturally presented in the atmosphere, it is a greenhouse gas and is a part of the temperature control of the planet. CO2 carbon dioxide is an odorless, colorless gas, which is faintly acidic and non-flammable. It is released into the atmosphere from combustion of fuel that contains carbon or from respiration from living organisms. Planet earth can convert CO2 into oxygen with a process called photosynthesis, but environmentalists are worried that an increased concentration of CO2 in the atmosphere could lead to an increase in the global temperature, which is referred to as global warming.

The main goal in this thesis is to take a look into the consequences of designing a simplified (efficient to produce) ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle. An LCA (Life-Cycle Analysis) approach is to be used to analyze the effects and the relative impact of changes. The actual environmental impact from CO2 emissions has been discussed and there are many theories about the phenomena, but this thesis should not look at the actual environmental impact, but rather concentrate about the actual difference in total CO2 emissions during a ships life.

Figure 2 Illustration picture: The impact of global warming

Designing a simplified (efficient to produce) ship structure

Building as cheap as possible has always been important in the shipping industry. Raising wages in the west have led to growth in shipbuilding activity in South-East Asia, especially yards in Korea like Hyunday and Samsung have a large amount of the marked of steel intensive ships. Further economical development has resulted in raised wages trough developing countries and man hour cost is becoming an important cost driver in ship building. The solution to cut man hours is to design and build a simplified steel construction. It can be done in many ways, but since the main task in this thesis is to look at the effect this has on the total amount of CO2 emissions trough the ships lifecycle, a sample ship with a simplified structure has to be chosen. As stated in the pre study report, the MARINOR project can be used as an example of a simplified steel structure.

In a collaboration with the MARINOR project ”production and maintenance friendly steel constructions” (source [2]) a rapport containing results from strength analyzes on a ship structure was made. The goal was to reduce or remove number of profiles, results showed that this was possible with a moderate increase in plate thickness. The chosen sample ship could remove 943 profiles with a following dead weight increase of 30 tons for a 17,500 dwt product tanker. A ship structure without profiles would make a construction that was easy to build, had lower cost according to material management and would get an increased quality on the surface treatment.

The interesting about this project is that this ship could be used as an example on how productivity-improving measures on steel-structures in ships affects the total CO2 emissions trough the ships lifecycle. In the building phase would the reduction of profiles lower the amount of welding meters and accordingly fewer working hours. A les complex steel construction would also have less sharp edges, something that leads to extended quality and durability on the surface treatment.

This analyze was done on a existing ship delivered by Sterkoder called M/T Ek-River, it is a product tanker with a length of 144,9 meters and a lightship weight of 5409 tons. An added steel weight of 30 tons after the structure modifications can results in a higher usage of fuel trough its lifetime. Further details about the sample ship, can be seen in appendix 1.

To evaluate the effect of a simplified steel structure in other ship types, two other sample ships are to be chosen. Since this evaluation is most likely to be important in steel intensive ships a 75000 dwt panamax bulk ship called Golden Saguenay and a VLCC tanker called Golden Victory are used. All data from the sample ships are collected from source [5].

It is assumed as a simplification that the reduction in number of profiles and the added steel weight is linear with the lightship weight of the sample ships.

The simplified steel structure in the MARINOR project led to an added lightship weight of 30 tons. Shipyards and ship owners have always promoted the concept of carry cargo not steel, so an added lightship weight is looked upon as less economical. The result is that ship structures has tend to been over-optimized because ship-owners thought it was more beneficial to construct ships that way. Studies from Gratsos and Zachariadis, 2005 (source [6], shows the opposite. The study showed that the reduced cost from replacing steel, reduced downtime and the increased lifetime had larger economical benefits than the added steel weight cost trough the ships life cycle. The results from source [6] is the background in the research to find out if a simplified steel structure can have some of the same qualities that a ship structure with additional corrosion factors have. The simplified steel structure is looked upon as a less expensive way to build a ship, and if it is both economical and environmentally profitable is it a good solution.

Figure 3 Illustration picture: Steel replacement

Methodology

The methodology in this thesis is a simplified LCA (Life Cycle Assessment), the reason why it is a simplified LCA is because it does not take the shipwrecking into account in the LCA. The reason is that data from emissions when wrecking ships is very unsecure and is likely to be independent of type of steel structure. The simplified LCA should then follow the following steps:

1. Gather as much as possible information about CO2 emissions from shipbuilding and develop an LCA-database.
2. Find a suiting case and sample ships that can be used to evaluate the consequences of designing a simplified (efficient to produce) ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle.
3. Adapt the LCA-data to fit the chosen sample ships and develop a general LCA-database.
4. Use the general LCA-database to calculate the emissions from the building phase, so there is possible to evaluate each phase in the LCA independent of each other.
5. Do step 1,3 and 4 for the operation phase alone. The operation phase can be evaluated with the program PCT (Pre Contract Tool) from DNV proNavis.
6. Gather LCA results from both phases and calculate the total emissions for the sample fleet.
7. Evaluate the results and compare the results with similar researches.

To get a trustworthy result could the process be repeated, but with different sample ships or a ship with a different example of a simplified steel structure. With the evaluation of the result as a background, can LCA-data that seem to have the biggest influence on the result be evaluated again.

LCA-data

Total emissions from steel production, building phase and repairs

To calculate the emissions from the building phase, data from source [7] the RINA rapport, has been used in the further calculations. It is divided into emissions from steel production, shipbuilding and emissions due to repairs. The rapport describes its assumptions and simplifications in parts, 5.3, 5.4 and 5.5 and is for that reason listed underneath.

"5.3 CO2 emissions due to steel fabrication
CO2 produced at the steel fabrication stage is assumed to be 1.75 tons for each ton of steel produced (Oxera, 2004). These accounts only for emissions produced at the steel mill, and do not account for emissions due to:

- *Mining of the raw materials (iron ore, coal, limestone or other)- these emissions will not be examined here, but can be substantial*
- *Transport of these raw materials to the steel mill (various modes will generally be involved, including the maritime one)- these are included into the 'transport of raw materials' emissions, see below*
- *Transport of steel from the steel mill to the shipyard- these are included into the 'shipbuilding' emissions, see below*
- *Cutting and welding of the steel and other energy use to fabricate the ship these are also included into the 'shipbuilding' emissions, see below It should be mentioned that the factor of 1.75 is likely to be encountered in 'state-of-the-art' steel facilities, but can be higher if this is not the case. Also, the fact that emissions due to mining of raw materials are not taken into account means that the factor of 1.75 quite likely underestimates this component of emissions.*

5.4 CO2 emissions due to shipbuilding
*This involves shipyard energy use for various reasons (electricity for equipment and offices, welding, gas heating, gas cutting, transport of plates and equipment, sea trials of ship, etc). Kameyama et al (2004) estimate CO2 due to yard activities, including electricity, welding, cutting and plate forming, transport within the yard, etc, at 11% of total CO2, the rest (89%) being attributed to steel production. Therefore one can use a factor of 1.75*11/89 = 0.216 per tonne of steel processed at the yard.*

5.5 CO2 emissions due to repairs
*Here we are talking about repairs for steel replacement only, as all other repairs are assumed to be the same. Emissions due to fabrication of this steel are accounted for in section 5.3 above. These repairs involve all shipyard-related activities to cut, transport and weld the replacement plates on the ship. As some 43% of the CO2 directly emitted at the shipyard is due to sea trials (Kameyama et al, 2004), the rest (57%) amounts to 0.216*0.57 = 0.123 tones of CO2 per ton of steel. In addition to that, we have to account for cutting off the old steel from the ship, assumed to be of equal weight to the replacement steel . Data from specialized Greek repair companies (e.g. NAVEP Ltd) indicate that cutting one ton of steel uses some 60 kg of liquid propane (C3H8). That produces exactly 3 times as much CO2 in weight; therefore the CO2 factor for cutting can be estimated to be 0.18 per ton of steel cut. Thus, the total CO2 factor for repairs is estimated at 0.123+0.18 = 0.303 per ton of replacement steel."*

Electricity consumption

To evaluate the difference in emissions from the building phase a general distribution of where the electricity is used, is to be made. The background is key numbers from source [8] "Development of LCA software and LCI Analysis based on actual shipbuilding and operation (National Maritime Research Institute)". Especially some good numbers from electricity use during construction of a bulk ship (76,000 dwt), are used and further generalized. Underneath are the results from source [8]

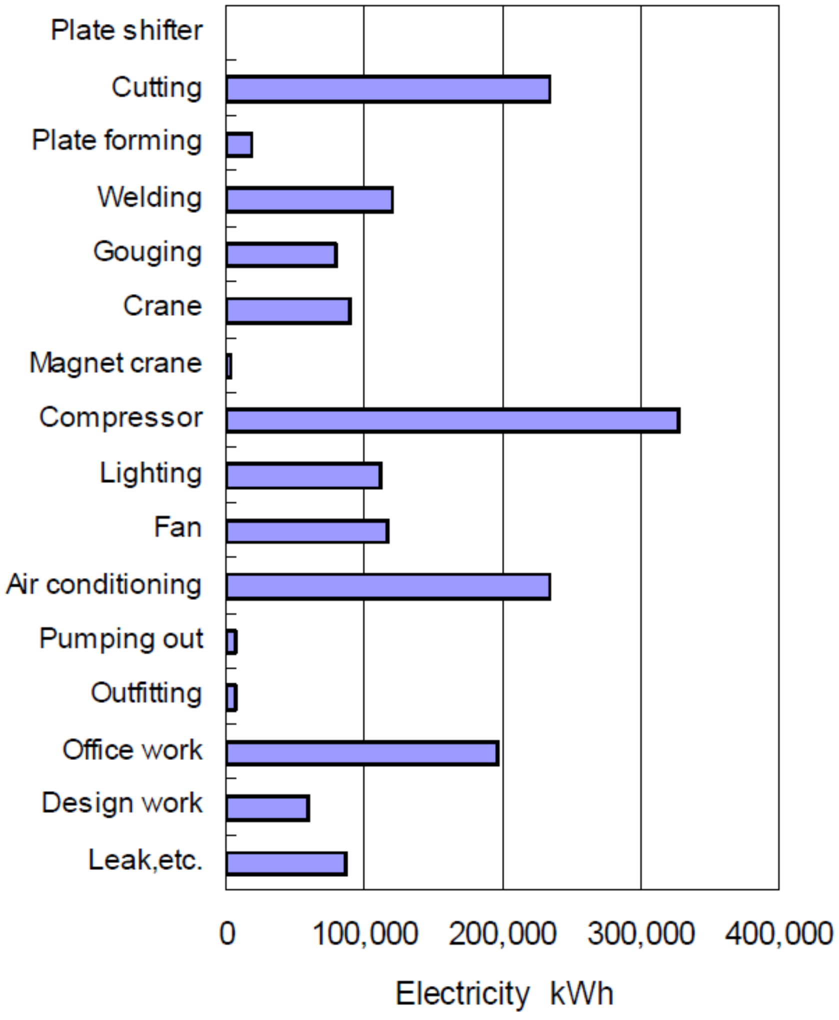

Figure 4 Electricity use during construction bulk ship 76,000 dwt [8]

Steel work is previously shown to be the biggest contributor of CO2 emissions during shipbuilding, this is confirmed by source [8]. At the figure underneath the left part of the figure is the total distribution of CO2 and at the right side the distribution of CO2 emissions direct from the yard. These results are important to keep in mind when evaluating the differences in different building methods.

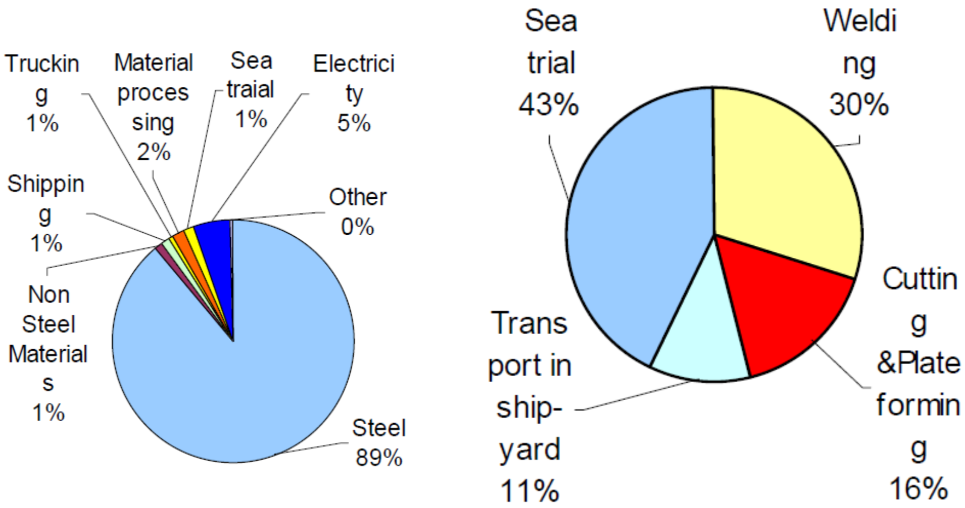

Figure 5 Proportion of CO2 emission from shipbuilding (left) and CO2 directly emitted at shipyard (Right), from source [8]

With the results from source [8], a general distribution of electricity consumption based on their lightship weigt is made. The new distribution is simplified and divided into 4 major groups, steelwork, machines, lighting and office. As we see from the figure underneath they are pretty equal parts of the total consumption of electricity at the yard. Results show that from the 5 percent of CO2 produced by elecricity figure 5, only 2-3 percent is used in the actual steelwork.

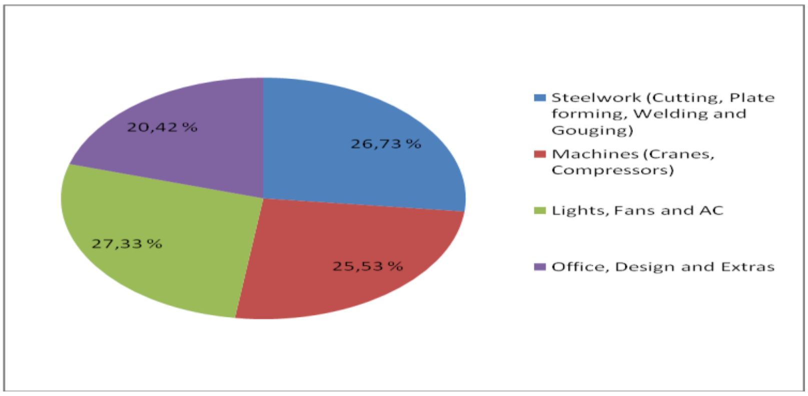

Figure 6 Simplified distribution of electricity use at yard

To further use of these key numbers they are scaled by the deadweigth of the sampleship from source [8], this will give key numbers that can be used as an quality check for further evaluations. Since this report is about steel intensive ships, it is assumed that the electricity consumption is linear to the lightship weight of the ship. The results from this scaling is listed underneath.

Electricity consumed to build a ship each 1000 tons of lightship weight. Numbers in MWh		
Steelwork (Cutting, Plate forming, Welding and Gouging)	34,80	[MWh]
Machines (Cranes, compressors)	33,24	[MWh]
Lights, fans and AC	5,99	[MWh]
Office, Design and extras	26,59	[MWh]
Total	130,22	[MWh]

Table 1 Distribution of electricity used to build a ship each 1000 tons of lightship weight

Electricity production:

Since it is assumed that the ships are to be produced in China, will the emissions from electricity production be based on how electricity is produced in China. From source [9] it is stated that coal is used to generate about three-quarters of China’s electricity. To simplify the calculations it is assumed that all of Chinas electricity is from coal power plants. From source [10] we have a key number on the emissions from coal power plants. This source bases its calculations on emissions on a modern coal power plant and gives the following key number for electricity production:

- 1020 Kg of CO2 / MWh

Figure 7 Illustration picture, one of Chinas coal power plants (www.eastasiaforum.org)

Sample ship Ek-River, what is changed?

From the detailed report [2] we have the following changes in the building phase. For further use and generalization, is it assumed that reduction in welding, burning and edge trimming is equal to the lightweight of the ship.

	Quantity	Cost	Comment
Welding	23x1,5=34,5 m Total about 1400 m	Kr 11,500 Totally about. NOK. 470,000	100 min. at each welding-meter. 200 kr. an hour
Burning	23x3=46 Totally about 1900 m		Reduced procurement price or less load on burning machine
Surface treatment	23x0,3=6,9 m^2 Totally about 280 m^2		Less cost with blasting, priming and painting
Edge trimming	23x3=46 m Totally about 1900 m		Time saved on grinding edges and better quality on primer and painting
Other handling	23 Totally 943 pieces		Less cost with internal transportation and storage
Durability			Reduced amount of sharp edges increases the durability of the paint. Removing the horizontal brackets also reduce the danger of accumulation mud and the following corrosion.
Maintenance			Easier inspection, painting and repair
Production buckling			No aligning after welding on brackets

Table 2 Sample ship, what is changed. Data from source [2]

Welding Consumption of electricity

Welding machines need electricity during use and to find the emissions saved from less welding it is important to find out how many kWh a welding machine need and calculate the amount of CO2 emissions reduced due to less welding.

Again an estimate is used based on similar research, data from source [11] gives the following estimate. *"The welding process is based on the knowledge about a specific ship with 1300 tones of steel having 117 200 m welding. As a conservative assumption we say that the ratio between welding meters is the same as the ration in tonnage. 15.1 MJ of electricity is used per meter welding".*

Calculated for the sample ship, when reducing the amount of welding by 1400 meters, it is equivalent to a reduction in electricity for a total of (15.1 [MJ / m] x 1400 [m] = 21140 [MJ] = 5880 [kWh]). It is assumed that the electricity is made from a coal power plant who have an emission factor of CO2 by 1,02 ton of CO2 / MWh, based on source [9] and [10]. This will give the sample ship an reduction of 5,8 [MWh] x 1,02 [ton CO2 /MWh] = 5,9[ton CO2]. In the further evaluation the same calculations are used and the key numbers are scaled by the deadweight of the ship in order to evaluate other ship sizes.

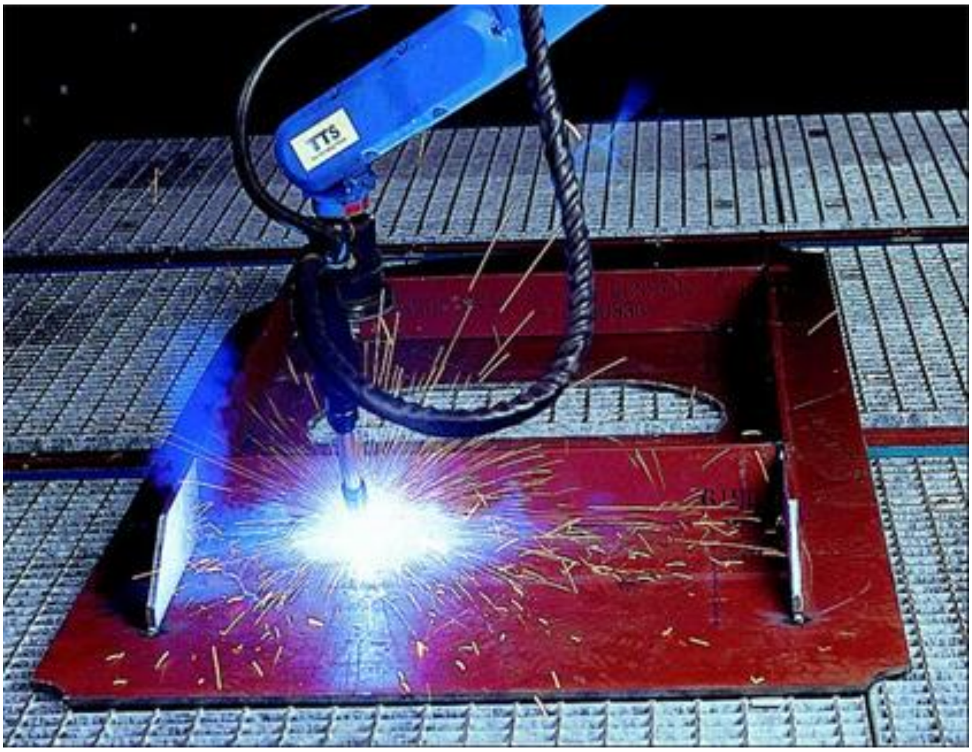

Figure 8 Illustration picture welding machine

Cutting

To calculate the electricity / emissions saved from less cutting an estimate on cutting machines use of electricity is used. From source [11] it is stated from similar research that: *"The main emissions from the cutting phase is production of electricity. It is known from Johnsen et al11 that 8.5 MJ of electricity is consumed per* m^2 *during the cutting process."*

Converted from Mega Joule to kWh (8,5 MJ = 2,2 kWh). Based on the following assumptions is it possible to calculate the savings on the environment due to less cutting activity, one meter of cutting equals an estimate of 1,1 [kWh /m].

Assumptions:

- Electricity is from a coal power plant who have an emission factor 1,02 [ton CO2 / MWh].
- 1m^2 cutting is equal to 2[m] of reduction in cutting.
- The burning machine can handle 5 meters of burning an hour.

In the further evaluation the same calculations are used and the key numbers are scaled by the deadweight of the ship in order to evaluate other ship sizes.

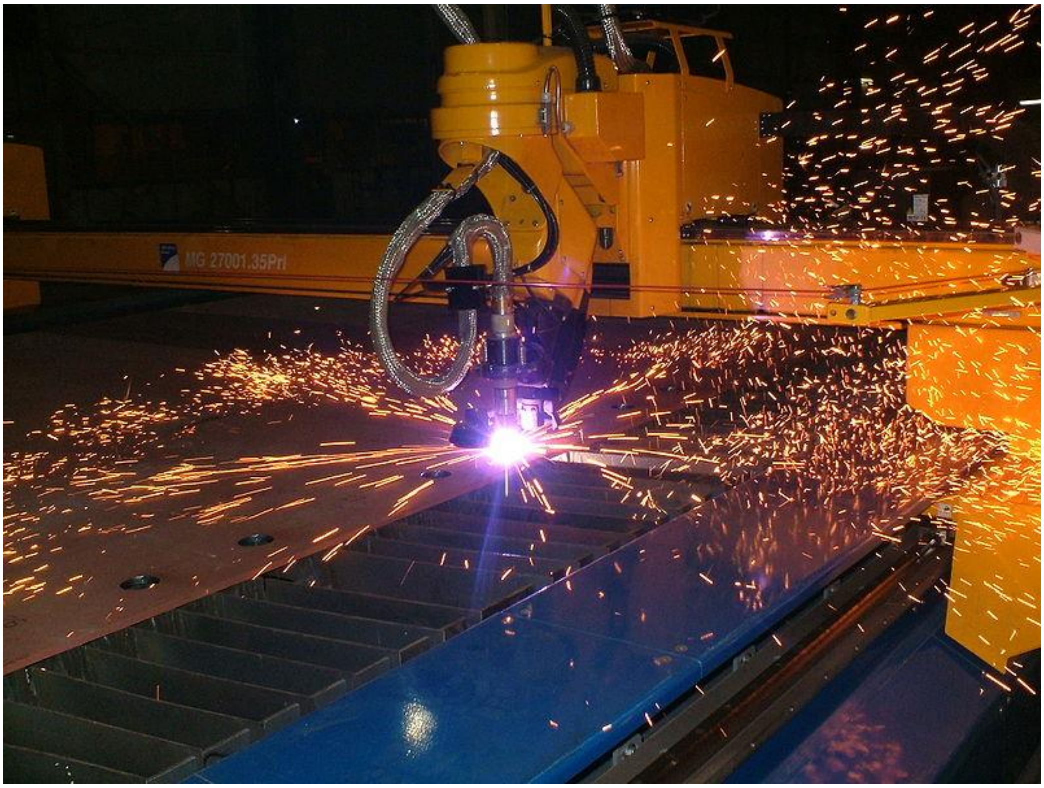

Figure 9 Illustration picture cutting machine

Edge trimming

Reduction of profiles reduces the edge work, and again leads to less use of electricity and CO2 emissions. It is assumed that a manual grinder of 1 [kWh] is used and that an operator can trim about 5 meters an hour. Again we assume that the electricity is made from coal power plants who a have an emission factor of CO2 by 1,02 ton of [CO2 / MWh]. One meter of edge trimming is then equal to 0,2 [kWh] or 0,0002 [ton CO2 / m]. In the further evaluation the same calculations are used and the key numbers are scaled by the deadweight of the ship in order to evaluate other ship sizes.

Figure 10 Illustration picture edge trimming

Added weight

Removing profiles and adding ticker plates gives an added dead weight of 30 tons, that resulted in a added steel production of 30 tons (source [2]). Increased steel production will of course give added CO2 emissions in the building phase. We have as an assumption from source [7] [5.3 "emissions due to steel fabrication"] a god indication on the added emission from added steel production. The source quotes that a 1,75 tons of CO2 is produced per ton of steel, the increased CO2 emissions at the sample ship is then (1,75 [CO2/ ton] x 30 [ton] = 52,5 [ton CO2]). In the further evaluation the same calculations are used and the key numbers are scaled by the deadweight of the ship in order to evaluate other ship sizes.

Maintenance

The reduction in profiles will result in easier inspection, painting and repair. This will help to increase the life cycle length of the ship. This will be further discussed in the chapter about replacement of steel and in the chapter about scrapping age.

Surface treatment, other handling and production buckling

Changes in emissions from surface treatment, other handling and production buckling is not considered in this rapport because of limited sources and trustworthy LCA-data .

General LCA-data results

LCA-data are here generalized and used to calculate the total emissions from the building phase. As mentioned the reduction in welding meters, burning meters and edge trimming are assumed linear to the ships deadweight. The table underneath consist of data about the reduction of welding meters, burning meters and edge trimming for each of the 3 sample ships.

Sample ships:	**Lightship weight [ton]**	**Reduction of welding [m]**	**Reduction of burning [m]**	**Reduction of edge trimming [m]**
Ek-River	5409	1400	1900	1900
Golden Saguenay	12786	3310	4490	4490
Golden Victory	38953	10080	13680	13680

Table 3 Reduction in welding, burning and edge trimming

Reduction in steel work and the electricity saved is calculated and converted into tons CO2 saved due to a simplified steel construction. The results are based upon the sample ship Ek-River and the MARINOR report (source [2]) and the LCA-data described in previous chapters.

Results: Reduction of emissions during welding simplified steel structure		
Ek-River	6	[ton CO2]
Golden Saguenay	14	[ton CO2]
Golden Victory	43	[ton CO2]
Results: Reduction of emissions during burning simplified steel structure		
Ek-River	2	[ton CO2]
Golden Saguenay	5	[ton CO2]
Golden Victory	15	[ton CO2]
Results: Reduction of emissions during edge trimming simplified steel structure		
Ek-River	0,5	[ton CO2]
Golden Saguenay	1	[ton CO2]
Golden Victory	3	[ton CO2]
Reduction of emissions due to less (Cutting, Welding and Edge trimming) simplified steel structure		
Ek-River	9	[ton CO2]
Golden Saguenay	20	[ton CO2]
Golden Victory	61	[ton CO2]

Table 4 Reduction in emissions due to less welding, burning and edge trimming

Results building phase

Based upon the LCA-data from source [7] and the result from table 4 the total emissions from the building phase is calculated for both the original and the simplified steel structure. As a reference to see the amount of electricity saved due to a simplified steel structure, the total electricity use is calculated with data from source [8] and with the simplifications and assumptions presented in the chapter about electricity consumption and production. The results are presented in table 5,6 and 7.

Results building phase Ek-River

Results Original ship Ek- River: Building phase		
Emissions from yard electricity EK-River, based on electricity from coal power plants.	720	[ton CO2]
Emissions production at Yard EK-River , based on RINA numbers	1170	[ton CO2]
Emissions from steel production (Based on RINA numbers)	9470	[ton CO2]
Total emissions from production (steel production and emissions from yard) RINA	10630	[ton CO2]

Results modified ship Ek-River: Building phase		
Emissions from Yard electricity EK-River, based on source 4 (electricity from coal power plants)	720	[ton CO2]
Emissions production at Yard EK-River , based on RINA numbers	1180	[ton CO2]
Emissions from steel production (Based on RINA numbers)	9520	[ton CO2]
Total emissions from production (steel production and emissions from yard) RINA	10690	[ton CO2]

Reduction of emissions due to less (Cutting, Welding and Edge trimming) simplified steel structure		
Welding (fewer welding meters)	6	[ton CO2]
Burning (less burning)	2	[ton CO2]
Edge trimming	0,5	[ton CO2]
Total reduction	8	[ton CO2]

Total emissions from production modified hull Ek-River	10680	[ton CO2]
Difference in emissions original ship vs modified ship building phase	50	[ton CO2]

Table 5 Results building phase Ek-River

Results building Phase Golden Saguenay

Building phase:		
Emissions from Yard electricity Golden Saguenay, based on electricity from coal power plants.	1700	[ton CO2]
Emissions production at Yard Golden Saguenay, based on RINA numbers	2760	[ton CO2]
Emissions from steel production (Based on RINA numbers)	22380	[ton CO2]
Total emissions from production (steel production and emissions from yard) RINA	25140	[ton CO2]

Results modified ship Golden Saguenay: Building phase		
Emissions from Yard electricity Golden Saguenay, based on source 4 (electricity from coal power plants)	1710	[ton CO2]
Emissions production at Yard Golden Saguenay, based on RINA numbers	2780	[ton CO2]
Emissions from steel production (Based on RINA numbers)	22500	[ton CO2]
Total emissions from production (steel production and emissions from yard) RINA	25280	[ton CO2]

Reduction of emissions due to less (Cutting, Welding and Edge trimming) simplified steel structure		
Welding (fewer welding meters)	14	[ton CO2]
Burning (less burning)	5	[ton CO2]
Edge trimming	1	[ton CO2]
Total reduction	20	[ton CO2]

Total emissions from production with modified hull Golden Saguenay	25260	[ton CO2]
Difference in emissions original ship vs modified ship building phase	120	[ton CO2]

Table 6 Results building phase Golden Saguenay

Results building phase Golden Victory (VLCC)

Results Original Ship Golden Victory: Building phase		
Emissions from Yard electricity Golden Victory, based on electricity from coal power plants	5170	[ton CO2]
Emissions from construction at Yard GOLDEN VICTORY a based on RINA numbers	8410	[ton CO2]
Emissions from steel production (Based on RINA numbers)	68170	[ton CO2]
Total emissions from production (steel production and emissions from yard) RINA	76580	[ton CO2]

Results modified ship Golden Victory : Building phase		
Emissions from Yard electricity Golden Victory, based on source 4 (electricity from coal power plants)	5200	[ton CO2]
Emissions from construction at Yard Golden Victory a based on RINA numbers	8460	[ton CO2]
Emissions from steel production (Based on RINA numbers)	68550	[ton CO2]
Total emissions from production (steel production and emissions from yard) RINA	77000	[ton CO2]

Reduction of emissions due to less (Cutting, Welding and Edge trimming) simplified steel structure		
Welding (fewer welding meters)	43	[ton CO2]
Burning (less burning)	15	[ton CO2]
Edge trimming	3	[ton CO2]
Total reduction	61	[ton CO2]

Total emissions from production with modified hull Golden Victory	76950	[ton CO2]
Difference in emissions original ship vs modified ship building phase	360	[ton CO2]

Table 7 Results building phase Golden Victory (VLCC)

Scrapping age and replacement of steel

Scrapping age:

A typical lifecycle for a ship is between 20 to 30 years and there are many factors that contribute to the life length. As mentioned before, the simplified steel structure has a positive impact on the corrosion margins and will give the modified ship an increased life length. It has been difficult to find the exact improvement of corrosion -resistance and -margins, but using results from similar researches gives an approximately result.

From appendix source [7] RINA, table 8 is it given details about a panamax ship with added corrosion margins, the added steel gives an added steel weight of 450 tones, but change the lifecycle from 20 to 30 years. Thicker steel plates results in higher corrosion margins and thus less replacement of steel, in that way it is economical and practical to increase the life length.

The sample ship Golden Saguenay, who is also a panama ship, with a modified steel structure has an added steel weight of 220 tons. Thicker plates gives better resistance to corrosion and removal of many of the horizontal brackets also reduces the danger of accumulation mud and the following corrosion. Reduction of sharp edges due to the removal of horizontal brackets also results in better surface treatment and thus less corrosion.

Due to the similarities between ship A and B in the RINA report and the original ship versus the modified steel structure, is it assumed that the original ship has a lifecycle of 20 years, while the modified ship structure have a 30 year lifecycle.

Figure 11 Illustration picture: ship way beyond its scrapping age (http://wallpapers.net/)

Replacement of steel:

Trough the lifecycle of the ship replacement of rusty plates will give added CO2 emissions in the lifecycle. When reducing the number of sharp surfaces increases the durability of the surface treatment significantly, in addition reduces the removal of the horizontal struts risk of accumulation of sludge and subsequent corrosion. Increased durability on the surface leads to increased resistance to corrosion and thus less replacement of panels across the lifecycle of the ship. Maintenance will also be much easier, that is easier inspection, painting and repair. Easier maintenance and particularly an easier inspection results in a better control of corrosion, which could contribute to more frequent maintenance and as a result, the steel lasts longer. Due to the fact that it is difficult to find the exact improvement the simplified structure will give, it is assumed that the simplified ship has the same qualities when it comes to replacement of steel as the modified ship in source [7]. Results are presented in the table underneath. We have the following assumptions:

- Same percentage of steel replacement based on light ship weight.
- The corrosion and need for replacement of steel is the same as in source [7]ship A and B.

Percentage of steel replacement from source [7] RINA, Ship A (original) 1700/11400 = 15 %, ship B (modified) 900/12200= 7,5 % . Ship A is based on lifecycle of 20 years while ship B has a lifecycle of 30 years.

Emissions from steel replacement:

Based on RINA standards source [7] (5.3 CO2 emissions due to steel fabrication and 5.5 CO2 emissions due to repairs) is it assumed a replacement emission factor of 1,75+0,303 = 2,053 (Ton CO2/ton steel replaced). Results are presented in the table underneath.

	Light ship weight [ton]	Replecement steel 60 years [tons]	Emissions Annual [ton CO2]	Emissions 60 years lifecycle [ton CO2]
Ek-River	5409	2434	83	5000
Ek-River Modified	5439	816	28	1680
G SAGUENAY	12786	5754	197	11810
G SAGUENAY Modified	12857	1929	66	3960
G VICTORY	38953	17529	600	35990
G VICTORY Modified	39169	5875	201	12060

Table 8 Replacement of steel and emissions from steel replacement

CO2 emissions during operation

Operation days:

The difference between the two ship types, original and modified, are the amount of steel been replaced and the payload, in operation a difference in days in dry-dock. The results are presented in the table 9 “downtime due to steel replacement”.

To calculate the days used to replace steel a steel replacement rate has to be assumed. Steel is assumed replaced in China due to a lower cost. The replacement rate is then assumed to be, based on the length of the ship and source [7]:

- 7 ton/day rate 17000 dwt tanker
- 14 ton /day 75000 dwt bulk
- 21 ton/day rate for the VLCC size.

Down time due to steel replacement	Days at yard percent [%] of total time
Ek-River	0,02
Ek-River Modified	0,01
GOLDEN SAGUENAY	0,02
GOLDEN SAGUENAY Modified	0,01
Golden VICTORY	0,04
Golden VICTORY Modified	0,01

Table 9 Downtime due to steel replacement

Operation profile

All the chosen sample ships often freight cargo one way and go empty handed back, the result is that the ship runs with ballast half the time and will for that reason have no difference in the weight of the ship during ballast condition. Power required for propulsion is the same as the original ship, and CO2 emissions is for that reason the same in parts of the operational profile.

The operation profile are based upon a standard operational profile established by the “PCT Pre Contract Tool“ software[12] and collaboration with consultants at DNV proNavis. The added dry-dock time at the original ship is directly withdrawn from the sailing time. MCR is the percent of engine power used at the various operation modes.

Operation Profile	Sailing Ballast % 0,6 MCR	Sailing % 0,8 MCR	Loading / Unloading % 0,2 MCR	Dry dock % 0 MCR	Maneuvering 0,2 MCR
Ek-River	0,30	0,48	0,10	0,02	0,10
Ek-River Modified	0,30	0,49	0,10	0,01	0,10
GOLDEN SAGUENAY	0,30	0,48	0,10	0,02	0,10
GOLDEN SAGUENAY Modified	0,30	0,49	0,10	0,01	0,10
Golden VICTORY	0,35	0,36	0,15	0,04	0,10
Golden VICTORY Modified	0,40	0,39	0,10	0,01	0,10

Table 10 Operational profile

Emissions from operation:

To get the correct estimate of the total CO2 emissions during the operational phase a software developed by DNV, called “PCT Pre Contract Tool“ is used. This software can, with the help of a database, calculate the total emission of CO2 in the operational phase. To find the difference from the original ship, to a ship with the reduction of profiles, is it possible to add deadweight into the calculations so that the program calculates the total emissions of CO2 in the operational phase of the modified ship. PCT software can provide results for emissions in tons per year, 10^6 tons DWT / nm and 10^6 tons DWT / km.

The “PCT Pre Contract Tool“ software is used to calculate the emissions from the operation phase. When the annual sailed distance are calculated, based on sailing speed and the operational profile, and the possible freighted cargo(DWT) is calculated is it possible to find the emissions from the operation phase in (g CO2 / Ton Freighted x Nm). The software uses statistical data about the engines HFO bunkers use and emissions due to combustion of HFO. Table 11, and 13 shows the results from the PCT software.

Results from PCT:

Sailing distance, bunkers and CO2	Annual sailing distance Laiden nautical miles	Annual CO2 emissions Tons	CO2 emissions 60 years super cycle	Sailing speed Knots
Ek-River	61379	18700	1122000	14,8
Ek-River Modified	62657	19000	1140000	14,8
GOLDEN SAGUENAY	58061	32000	1920000	14
GOLDEN SAGUENAY Modified	59270	32400	1944000	14
Golden VICTORY	48211	65700	3942000	15,5
Golden VICTORY Modified	52229	70800	4248000	15,5

Table 11 Annual sailing distance and CO2 emissions from operation phase emissions adjusted to freight

	Light ship weight [ton]	Dwt	Displacement
Ek-River	5409	17259	22668
Ek-River Modified	5439	17229	22668
GOLDEN SAGUENAY	12786	75750	88536
GOLDEN SAGUENAY Modified	12857	75679	88536
Golden VICTORY	38953	300155	339108
Golden VICTORY Modified	39169	299939	339108

Table 12 Dwt differences between modified and standard ship

Emissions from operation phase (g CO2 / Ton Freighted x Nm)		
Ek-River	17,6	[g CO2 / Ton x Nm]
Ek-River Modified	17,6	[g CO2 / Ton x Nm]
GOLDEN SAGUENAY	7,2	[g CO2 / Ton x Nm]
GOLDEN SAGUENAY Modified	7,2	[g CO2 / Ton x Nm]
Golden VICTORY	4,5	[g CO2 / Ton x Nm]
Golden VICTORY Modified	4,5	[g CO2 / Ton x Nm]

Table 13 Emissions from operation phase (g CO2 / Ton Freighted x Nm)

Emissions from operations [g CO2 / Ton x Nm], compared to the rest of the fleet

The Pre Contract Tool software can be used to compare the original and the modified ship versus the rest of the fleet, the software uses the data source Fairplay. To compare Ek-River, tanker sample ships from 10000 dwt to 25000 dwt are chosen. The plot shows that it is small differences between the modified and the original ship.

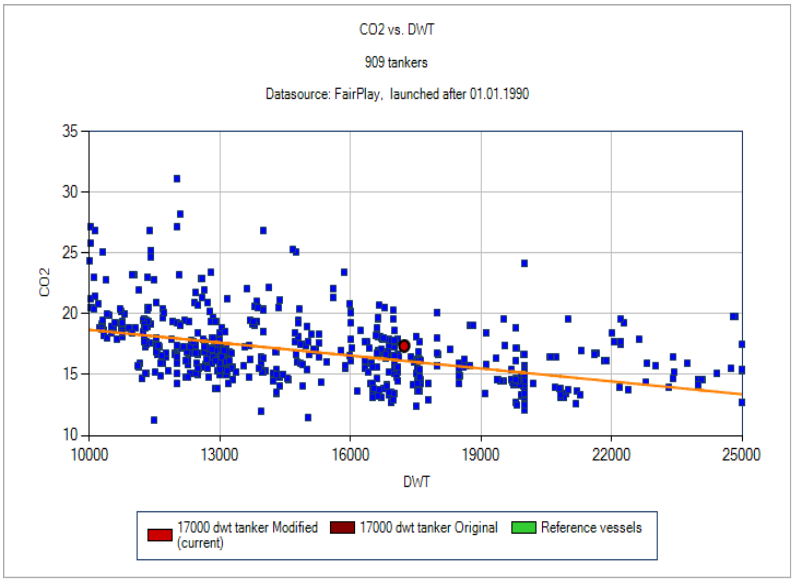

Figure 12 17000 dwt product tanker Ek-River versus similar ships

To compare the 75000 dwt bulk ship, Golden Saguenay, bulk sample ships from 60000 dwt to 160000 dwt where chosen from the Fairplay database. The plot shows that the sample ship has a typical amount of emissions compared to the Fairplay database. Differences between the modified and the original sample ship are too small to even show at the plot, se figure 13.

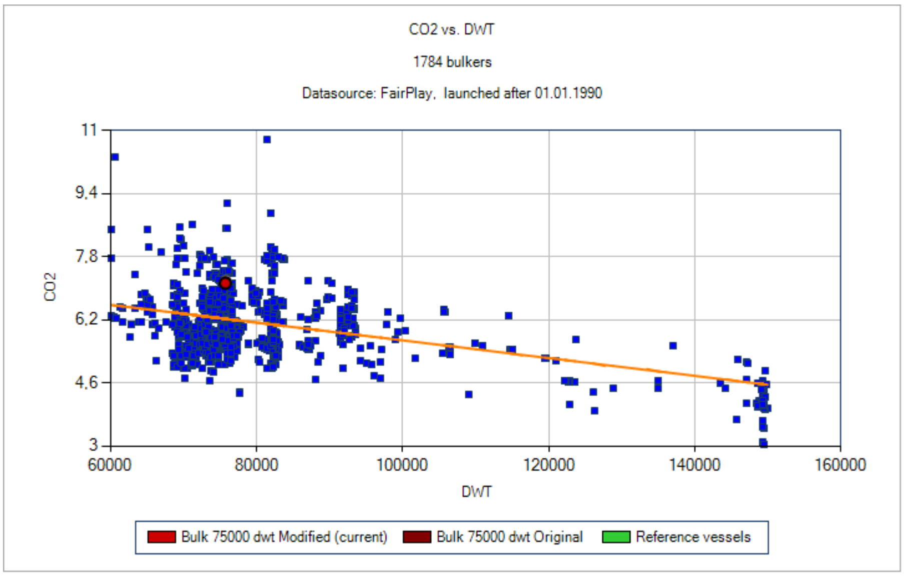

Figure 13 75000 dwt bulk carrier compared to the rest of the fleet

The VLCC ship is a very typical VLCC when it comes to CO2 emissions, to compare it against other large tankers sample ships from 100000 dwt to 350000 dwt where chosen from the Fairplay database. Again as the two other sample-ships the difference between the modified and the original hull is too small to even show at the graph (figure 14).

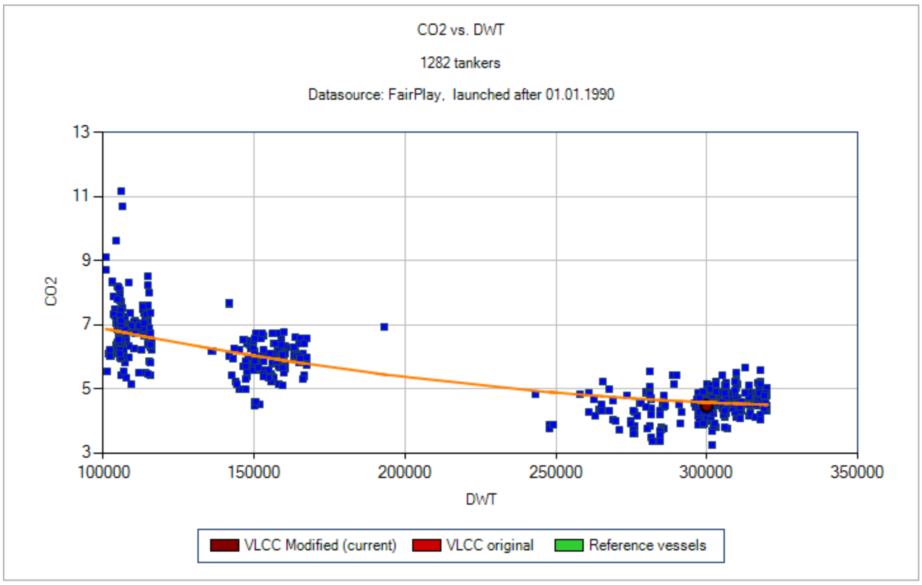

Figure 14 VLCC Golden Victory compared to the rest of the fleet

LCA Ek-River, Golden Saguenay and Golden Victory

LCA-data is now used to make a total LCA of the sample ships Ek-River, Golden Saguenay and Golden Victory, it can be used further to evaluate the differences.

Building Phase			
	Original Ship 20*3 super cycle	Modified Ship 30*2 super cycle	
Ek-River	31900	21370	[ton CO2]
Golden Saguenay	75410	50510	[ton CO2]
Golden Victory	230560	153890	[ton CO2]
Operation Phase			
	Original Ship	Modified Ship	
Ek-River	1122000	1140000	[ton CO2]
Golden Saguenay	1920000	1944000	[ton CO2]
Golden Victory	3942000	4248000	[ton CO2]
Replacement of steel			
	Original Ship	Modified Ship	
Ek-River	5000	1675	[ton CO2]
Golden Saguenay	11810	3960	[ton CO2]
Golden Victory	35990	12060	[ton CO2]
Total emissions 60 years super cycle			
	Original Ship	Modified Ship	
Ek-River	1158900	1163050	[ton CO2]
Golden Saguenay	2007220	1998470	[ton CO2]
Golden Victory	4208540	4413950	[ton CO2]
Total Sailing distance			
	Original Ship	Modified Ship	
Ek-River	3682740	3759420	[Nm]
Golden Saguenay	3483660	3556200	[Nm]
Golden Victory	2892660	3133740	[Nm]
Dwt			
	Original Ship	Modified Ship	
Ek-River	17260	17230	[Dwt]
Golden Saguenay	75750	75770	[Dwt]
Golden Victory	300150	299940	[Dwt]
Total emissions (g CO2 / Ton Freighted x Nm)			
	Original Ship	Modified Ship	
Ek-River	18,3	18,0	[g/TxNm]
Golden Saguenay	7,60	7,4	[g/TxNm]
Golden Victory	4,9	4,7	[[g/TxNm]

Table 14 LCA sample ships

Building cost

To evaluate the economical change due to a simplified steel structure a difference in the newbuilding price is established. The cost of the original ship is based on similar sales and estimated newbuilding cost from the Norwegian shipbroker Fearnleys done in week 13, 2011.

Original Ship:

- Similar to Golden Victory 300'dwt VLCC: estimated price 102 mill USD, source Fearnleys week 13
- Similar to Golden Saguenay 76'dwt Panamax bulk: estimated price 36 mill USD, source Fearnleys week 13
- Similar to Ek-River product tanker 17'dwt: Source Tradewinds Jun 2010 Samho Global Tank 17000 2010 Samho MAN-B&W IMO 2 22. Sale price 22 mill USD

It is important to remember that shipping is a multi-cyclical industry and prices may vary from day to day, newbuilding price is for that reason only used to compare the original ship versus the original.

To calculate the price of the modified ship following assumptions has been taken:

- Added steel cost, based on the price of steel per ton.
- Reduced welding cost, based on man hour cost.
- Reduced burning cost, based on man hour cost.
- Reduced edge trimming cost, based on man hour cost.

Assumptions steel cost:

Steel is assumed to be delivered in Carbon steel plates with a price of: 800 USD / ton[13]

Assumptions man hour cost:

- Ship is assumed produced in China with minimum wage
- The minimum wage is 140 USD/month [14]

When calculating the minimum wage an assumption of 200 work hours a month is to be used. This will give a man hour cost of 0,7 USD/hour

Results Building Cost

Newbuilding cost original ship		
Ek-River	22000000	[USD]
GOLDEN Saguenay	36000000	[USD]
Golden Victory	102000000	[USD]

Table 15 Newbuilding cost original ship

Data		
Added steel cost	800	[USD/ton]
Man hour cost	0,7	[USD/hour]
Time spent on 1 meter of welding	1,67	[hours/meter]
Time spent on 1 meter of burning	0,2	[hours/meter]
Time spent on 1 meter of grinding	0,2	[hours/meter]

Table 16 Data: Cost and time assumptions

Changed building price modified	Added Steel Cost	Reduction in welding Cost	Reduction in burning cost	Reduction in edge trimming cost	Changes in building cost
Ek-River	24000	1600	300	300	21800
GOLDEN S.	56700	3700	600	600	51800
Golden VICTORY	172800	11800	1900	1900	157200

Table 17 Changes in building cost

New building cost modified ship		
Ek-River modified	22021831	[USD]
GOLDEN SAGUENAY modified	36051606	[USD]
Golden VICTORY modified	102157183	[USD]
Changes in building cost		
Ek-River modified	0,1	[%]
GOLDEN SAGUENAY modified	0,1	[%]
Golden VICTORY modified	0,2	[%]

Table 18 Newbuilding cost modified ship

Testing with different man hour cost gives the following results:

- Man hour cost lower than 7,75 USD/hour → increased building cost.
- Man hour cost of 7,75 USD/hour → No changes in building cost.
- Higher than 7,75 USD/ hour man hour cost → reduction in building cost .

Comments about the result

Building Phase

Results from the building phase alone shows that the emissions from building phase increases with about 0,5 % with the simplified hull. The reason is because steel production is the largest contributor to the total emissions in the building phase and the simplified steel structure needs about 0,5 % more steel . Taken into account the possibility of a longer lifecycle of the simplified structure changes the results dramatically, the total emissions in 60 years super cycle results in a 33 % reduction in emissions. The assumption is here that the original ship has a 20 year lifecycle while the simplified hull has a 30 years super cycle, the exactness of this assumption can be discussed and is the major reason to the dramatically reduction during the building phase.

Operation Phase

As mentioned before the main difference between, the two hulls in operation are the amount of days in dock, the amount of cargo that can be freighted at one trip and the lightship weight. The modified ship gets more days at sea and will, if you look at the operation phase alone, have from 1-8 % higher emissions. If the differences in cargo space and nautical miles sailed is taken into the equation, we have that (g CO_2 / Ton Freighted x Nm) is about the same in both hull types. Lesson learned here is that the added steel weight is too little to give noticeable added emissions in the operation phase. That is confirmed by the plots from PCT, se figure 12,13 and 14. The result of the added steel weight could give a difference in the result if it would have been larger, that would have required another set of sample ships with a different modification to the steel construction / hull to test.

Replacement of steel

During the ships lifecycle there has to be replaced tons of steel, results show that the amount of steel changed at the simplified structure is about 1/3 compared to the original structure. Since the emission from steel replacement is mainly from steel production will the total amount of emissions from steel renewal be linear with the amount of steel changed. Again the contribution to a difference between the two different steel structures are based upon assumptions, the exactness of these assumptions can be discussed. To further improve the exactness of the results should the assumptions be quality checked and further studies should contribute to the quality of the assumptions.

Total emissions during super cycle

To evaluate the total amount of emissions during the ships theoretical 60 year super cycle, the most important is to look at the distribution of emissions. As an example numbers from the results from sample ship Ek-River is put together, it clearly shows that the operation phase is the biggest contributor to the total emission. In figure 16 we see that emissions from the building phase and replacement of steel is reduced in the modified ship. In figures 15 and 16 it follows that 1: building phase, 2: Steel replacement and 3: Operation phase.

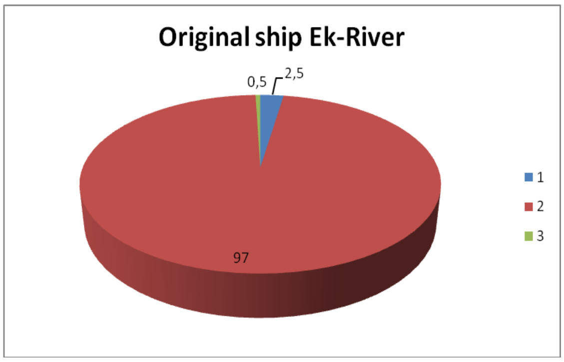

Figure 15 Original ship Ek-River distribution of emissions during super cycle

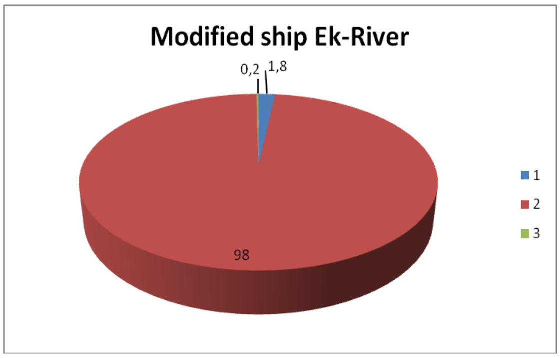

Figure 16 Modified ship Ek-River distribution of emissions during super cycle

When comparing the total amount of emissions the most important is the factor(g CO2 / Ton Freighted x Nm), the results shows that the modified ship structure have the following improvement.

Ek-River	1,5	%
Golden Saguenay	2,5	%
Golden Victory	4	%

Table 19 Improvement of (g CO2 / Ton Freighted x Nm) in percent

It seems like the ship with higher Dwt/lightship factor trends to have higher environmental effects of a simplified steel structure.

Building cost

The most unsecure cost in the building cost is the newbuilding cost, the reason is because shipping is a multi-cyclical industry and prices may vary from day to day. Results showed that there was nearly no difference in the building cost when calculating with a steel cost of 800 usd/ ton and a man hour cost of 0,7 USD an hour. Even when testing with Norwegian minimum wages, there was no difference to care about in the newbuilding price. As an example of the variation in newbuilding price a plot from source [15] is showed in figure 17.

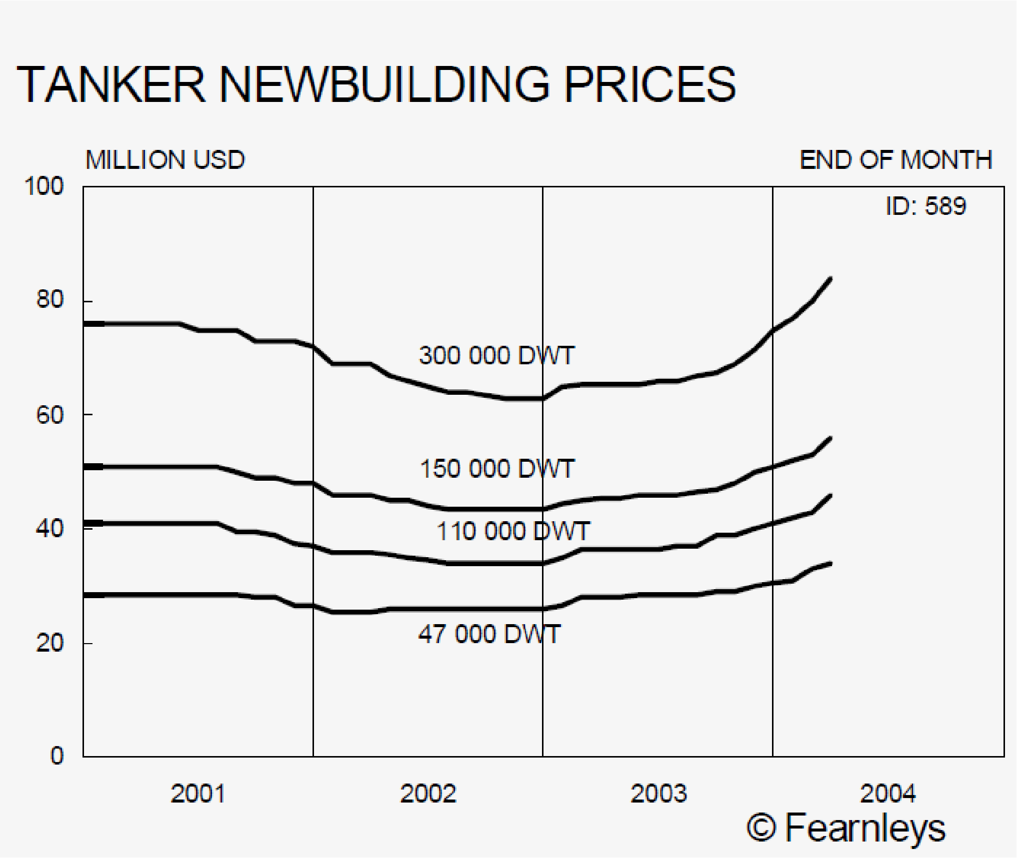

Figure 17 Tanker Newbuilding Prices (source [15])

Having in mind the results from the LCA and the super cycle of 60 years, that concluded with a lifecycle of 30 years for the simplified structure and 20 years for the original, leads to the fact that the ship with the simplified steel structure is about 30 percent cheaper. The reason is that the original ship needs three ships for a 60 year lifecycle, while the modified hull needs to ships. As mentioned before shipping is a multi-cyclical industry and ship owners are rarely as long-term as 60 years. A ship is in the reality for sale as soon as it is procured, the economical benefit of a simplified steel structure with a added life length and lower steel renewal cost is not as easy to calculate and depends mainly on the economical market.

Further work

The fact that the added life length of the ships was the leading factor in this LCA and maybe one of the most unsecure assumptions would lead to the most important chose of further work, and that is to establish more secure assumptions when it comes to corrosion resistance and economical life length. LCA-data should be gathered from experience from real life shipping, or based upon calculations from experts in corrosion.

Few sources of LCA- data in both building and operation phase can give a faulty LCA, to make the LCA more trustworthy more sources of LCA-data should be brought into the thesis so that they could be compared and brought together to make a new and better LCA-database.

In this thesis only one sample ship with a simplified structure was chosen, to evaluate a simplified ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle, several other types of product improving measures should be tested in a LCA. Most important would be to find a case that has similar data about the production phase like the rapport in source [2]. One example could be Ullstein groups X-bow. It is stated from source [16] that *"The X-bow offers significantly higher transit speed in adverse weather conditions, as well as enhanced fuel economics. The bow shape ensures soft entry into waves, thus reducing speed loss, pitch and heave accelerations, as well as eliminating slamming and vibration problems associated with conventional bow flare."* The question for further work could be; what are the differences in total CO2 between the original bow and the X-bow during a lifetime? Since the X-bow design has bigger differences in both building phase and operation phase versus the original bow shape, could the result be different than in the Ek-River case. The difference between the two bow shapes are shown in figure 18 underneath.

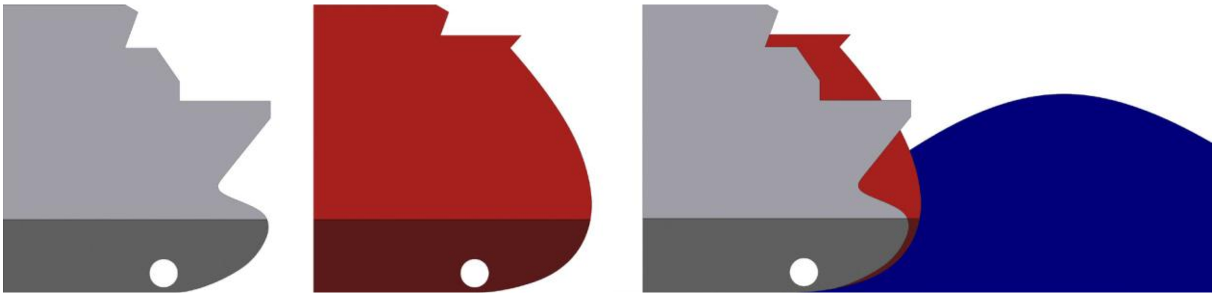

Figure 18 Ulstein X-bow, difference between a classic bow shape and X-bow

Conclusion

This master thesis looks into the consequences of designing a simplified (efficient to produce) ship structure and the effect this has on the total amount of CO2 emissions trough the ships lifecycle. An LCA (Life-Cycle Analysis) approach is to be used to analyze the effects and the relative impact of changes. A sample ship (e.g. ”EK River”) has been used as a basic case and results have been generalized to fit different ship sizes.

Results from the LCA with the assumptions made in the thesis gives the following results:

- Emissions from the building phase alone is about the same, only about 0,5 percent raise mainly due to higher lightship weight. The saved emissions due to less welding, burning and edge trimming are not enough to actually bring some difference to the total emissions.
- The added steel weight is too little to give added emissions in the operation phase alone.
- The difference between the two ship structures are mainly the operation profile and the added life length of the ship.
- With the assumption of a added life length from 20 to 30 years the factor(g CO2 / Ton Freighted x Nm) have improved from 1,5 to 4 percent depending on the ship size, the reason is added lifetime and less steel replacement. Results show that the ships with higher Dwt/lightship factor trends to have higher environmental effects of a simplified steel structure.

At the economical point of view, a ship with a simplified steel structure seems to cost about the same as a conventional design to build. With the assumption of an added life length of 10 years is the new design about 30 percent cheaper. The reason is that the original ship needs three ships for a 60 year lifecycle, while the modified hull only need to ships during the 60 year life cycle. The result concludes that it is both economical and environmental profitable to build a ship that have higher corrosion standards.

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Appendix

Information about the sample ship M/T EK-River

Built: 1994 by Sterkoder AS at Kristiansund, Norway
Flag: NIS
Signal letter: LAIN 7
Class no: 17997
LR/IMO no: 9056868
Trading area: Ocean Trade

CLASS:

DnV + 1A1, Tanker for Oil Products EO, Ice 1A, W1-OC.
(Finnish/Swedish ICE 1A)

Double Skin

DIMENSIONS:

Length over all:	144.90 m
Length between p.p	133.80 m
Breadth mld.	22.00 m
Depth upper deck	12.80 m
Draft summer load	9.8 m
Draft ballast Abt	Fore 4.70m Aft 6.70m
Gross tonnage	10.802 ton
Net tonnage	5.602 ton
Reduced Gross	8.968 ton

CAPACITIES:

Deadweight, summer:	17.259 MT
Deadweight, winter:	16.739 MT
Cargo, 98% volume:	18.910 m^3
Service slop tanks:	198 m^3
H.F.O tanks, 98%:	640 m^3
D.O. tanks:	120 m^3
Fresh water tanks:	150 m^3
W.B. tanks:	6.295,2 m^3

MACHINERY:
Main engine, MCR: 1 x 6.600 kW, 425 RPM
Propeller, CP Stainless steel: Diam. 5,5 m/90 RPM
Auxiliary gen.sets: 4X505 kW, 1.200 RPM 60 Hz
Boilers, thermal boil: 2 X 2.907 kW

Exhaust boiler: 1050 kW
Bowthruster,azimuth: 800 kW
Shaftgenerator: 1200 kW

SPEED AND CONSUMPTION:

Service speed loaded 14,8 knots

Service speed ballast: 16,6 knots
Consumption, service 85% MCR: Abt.23 t/day HFO
Consumption, discharge: Abt.7,5 t/day GO

Loading: Abt.2,0 t/day GO

Source [ektank.se]